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Blended Learning in Control Engineering Teaching; an Example of Good Practice

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Abstract: This paper focuses on good practice in terms of pedagogies rather than technical content, but with reference to a control engineering curriculum. A new lecturer will need to ask questions not only about the content of a course but also, how should that content be delivered? The paper presents arguments for a holistic or blended approach to student development and illustrates how that can be wrapped around technical learning outcomes. A core part of this approach is effective use of modern technologies (Rossiter, 2011). This paper provides a summary of good practice and an illustrative benchmark module.

Keywords: Interaction within a lecture, web-based laboratories, quality assurance, virtual learning environments, quizzes.

1. INTRODUCTION

A modern university education takes place in a challenging environment for academic staff due to new pressures on the design and delivery of courses. Increasingly, accreditation (ABET, 2019; ENAEE, 2019; UK-SPEC, 2019) bodies provide frameworks which mean the module design is only partially about technical content. In fact, the majority of the emphasis is on a holistic view of student development (Rossiter and Gray, 2010) which covers not only technical knowledge but also practical skills, problem solving, transferable skills such as writing and presentation, awareness of business culture and practice, independent learning, reflection and so forth. Each course leader must, to some extent, take responsibility for different aspects of this holistic vision.

A secondary issue which is increasingly becoming a challenge for staff is the changing expectations of modern students who have a much more customer focussed approach to education; they are the customer purchasing an education and see themselves as having significant rights and moreover, a belief that their opinions on how teaching should take place are important. This latter point can be especially problematic as it challenges the traditional teacher-student relationship whereby lecturers felt they should automatically be respected by students and listened to whereas this is often no longer the case. Students want a high quality delivery of their curriculum and also, want the lecturer to convince them, perhaps against their prior expectations of what good teaching looks like (Wilson and Maclaren, 2013), that the approach taken is appropriate.

This paper attempts to set up a framework for a modern course delivery and thus is based around:

(1) High quality resources (Rossiter et al., 2018).
(2) A clear recognition of accreditation requirements.
(3) A desire to help students develop their learning styles and expectations.

Each of the above items will be discussed in the following sections and is followed by a summary and a section illustrating an exemplar course.

2. HIGH QUALITY RESOURCES

Unsurprisingly, given the high cost of modern tertiary education and the technology solutions available to them in life, students might consider a lecturer who solely talks from the front, perhaps augmented by a few handouts, as being less than they have paid for (Laurillard, 2002). This is especially the case given our modern understanding of students having different learning styles and thus responding to different types of resource. This section gives a brief overview of the types of resources that students would expect on a modern engineering course, although of course this list is not comprehensive, it indicates that providing diverse modern high quality resources need not be either time consuming or expensive.

2.1 Web based resources

This section is here simply to recognise that modern students expect to be able to access their learning resources using mobile devices and computers. Staff need to engage with modern technology (Rossiter, 2011) and ask how this can enhance student accessibility and learning, but obviously in a cost effective fashion? It is perhaps dated by now to suggest that videos and podcasts (Fidler, Middelton and Nortcliffe, 2006; Middleton, 2013; Khan Academy, 2019; Rossiter et al., 2018; Rossiter, 2019) are almost a de facto minimum of extra resources which are both more accessible than traditional handouts and typically more engaging. In general terms, notes should be provided in soft copy form via the web but ideally would be supplemented by

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numerous other resources as discussed in the remainder of this section (Egerstedt, 2016).

2.2 Computer aided assessment

It is accepted that students need feedback on their learning, but involving staff in hand-marking of regular homeworks is inpractical in general, especially with large classes (100s of students). Moreover, hand-marking can still be slow and unwieldy to manage with 2-3 week turnaround times being commonplace, whereas feedback is most effective when it is returned immediately, or very close to submission. This best practice has long since been accepted in the community (Rossiter et al., 2004) but mechanisms are needed to support it.

One common and simple tool is a computer aided assessment tool. These tools can also be released to students as formative exercises with a prime role of providing feedback on progress and give instantaneous feedback on student responses. Typical quiz engines support a variety of question types such as multi-answer, yes/no, calculated, etc and thus have sufficient functionality for many basic learning outcomes, even if they are less easy to used for more involved learning outcomes and design. Students like the fact that they are in control of when they take these quizzes, being able to re-take them numerous times, rapid feedback, transparency of record keeping, and more.

It should be said that while a more substantial question database could be required for summative assessment and may take a long time to produce, nevertheless simple 5-10 question quizzes to assess student interim progress can be produced quite quickly and with minimal computing expertise. Some examples will be given in the last section.

One should note that similar tools exist for assessing MATLAB code and are supported by Mathworks.

2.3 Laboratories

It is tacit in the engineering community that laboratory activity should be included into every degree and indeed should probably be in the majority of modules. Consequently, we take this part of good practice as a given.

Readers may be more interested in how to integrate laboratories? This paper takes the assumption that for a benchmark module, the lecturer is more interested in small scale activities to demonstrate the relevance of their topic and help students engage with practical aspects. Larger scale laboratory activities and assessment could be considered in dedicated modules focussed on practical skills or otherwise integrated into the overal programme curriculum design.

Here we summarise good practice using a number of exemplars of which each lecturer may choose one or more.

- Make use of Tri-lab concepts (Abdulwahed, 2010), that is where laboratories have pre- and post-activities based on remote access to the scenario (software or hardware). Pre-activities encourage proper preparation and engagement with the technical content and post-activities facilitate reflection and further experimentation.
- Make use of web-accessible activities such as virtual laboratories (Fabregas et al., 2011; Cameron, 2009; Goodwin et al., 2011; Guzman et al., 2006; Rossiter, 2017) or remote laboratories (de la Torre et al., 2013; Dormido et al, 2012; Vargas et al., 2011) so that students have access these 24/7 and thus are not subject to timetable/space constraints or tightly defined activities typical within a laboratory. These work well in a Tri-lab design.
- Provide take home laboratory kits so that students can play with these in their own time (Rossiter et al., 2018; Stark et al., 2013; Hedengren, 2019; Taylor, Jones and Eastwood, 2013).

A core point here is that it is now possible for every module to have some laboratory like content included as these can be provided in easy to access and time efficient ways.

2.4 Use of a VLE

Virtual learning environments (VLE) are now commonplace although surprisingly many staff are still somewhat reluctant to utilise them. Here we summarise some of the obvious functionalities which suggest that each module should be using these to some extent for the benefit of the students. While similar functionality maybe available with bespoke tools, it is easier for students to have a one-stop shop, that is, one place to go for everything.

- These are invaluable for University quality assurance mechanisms as they provide explicit and back-up tracking of student activity.
- They embed efficient feedback mechanisms, including grading tools constructed based on marking criteria. This ensures students get good quality feedback at the same time, and in a transparent manner.
- Social media tools such as discussions board are linked to those on the module automatically so that staff members can monitor and support students engaging with these in an efficient manner.
- Often quiz engine tools are included and it is well publicised how useful quizzes can be for supporting formative and summative assessment.
- Some VLE include peer assessment and group assignment tools which make managing coursework far easier for staff and students.
- VLEs are an obvious repository for core module resources so students can assess anytime/anywhere (assuming internet access).

2.5 Authentic assessment

One difficulty staff face in exams is that they resort to simple low complexity examples so that students can manage the numerical computations on pen and paper. Consequently the questions can be somewhat predictable and straightforward, whereas more realistic questions would be both more interesting and challenging. The main obstacle to including more realistic scenarios is computation and thus one proposal in the literature is very simple, let students have access to approprate software during assessment (Lynch and Becerra, 2011). Hence, a suggestion in this paper is to design the assessment assuming students have access to the sorts of tools they would have

in the workplace rather than more artificial questions and restricting access to calculator only. The author has been doing this for many years by allowing access to MATLAB, especially in combination with computer quizzes and it allows more valid or authentic assessment of the students' ability to use appropriate tools for design and problem solving.

2.6 Summary

It would be reasonable for a benchmark course to make use of many of the tools now available and discussed in this section. However we should emphasise that not every course needs to include every resource as this has a danger of overload. Moreover, it is recognised that many students are driven primarily by marks and may not engage with resources, not matter how high quality or useful, if there is not a direct link to a module mark. Consequently, sometimes inducements are needed to encourage engagement or, in the worst case, ensure that use of the resources is embeded into the module summative assessments.

One might also comment that many textbook publishers have recognised the themes in this section and now provide their textbooks in online form, supplemented by many addtional resources such as quizzes, videos, interactive parts and so forth. For some staff where this is possible, mandating students to purchase a specified text book may be a good solution.

3. ACCREDITATION

This section is deliberately brief as, while accreditation forms a context for most engineering programmes, there is not much interesting to say and most of this is outside the remit of this paper. For a degree to be accredited a number of criteria must be satisfied of which the following is a simplistic overview for brevity.

(1) The collection of all modules taken together must demonstrate a holistic student development.
   - Evidence of a suitable range of technical learning outcomes and design.
   - Evidence of the development of wider professional skills such as presentation, writing, time management, independent learning skills and so forth.
   - Evidence of business awareness, finance and similar issues.

(2) The department must demonstrate good quality assurance and quality enhancement processes.
(3) The department must demonstrate suitable organisational structures and give evidence of appropriate actions to any issues that have arisen.
(4) The department must demonstrate how it supports and encourages wider student development, that is beyond the technical aspects of the programme.

This paper focuses mainly on point (1) above as this is more easily given to module leaders in terms of specific requirements they can fulfil in their teaching and assessment designs.

4. LEARNING STYLES

From anecdotal evidence available to most academic staff, it is clear that many students are motivated by marks rather than learning in itself. They see a degree certificate as the end point which opens the door to a good career rather than the personal development and learning along the way as the core facilitator. Consequently, lecturers need to design their course delivery to ensure adequate development and learning is automatic rather than a chance outcome. For instance, many students do not use learning resources because they are well designed or easy to learn from and rather they are focussed on assessments and will engage when they feel the resources are an efficient manner to passing an upcoming assessment (e.g. Rossiter et al. (2004, 2005)). High quality learning resources designed to help student development, but which are not directly tied to an assessment (Rossiter, 2011), maybe woefully under used.

4.1 The role of the lecture and lecture flipping

Concepts of learning theory (e.g. Kolb's model is popular) are commonly known and appreciated and a core message is that students learn more affectively by being active rather than passive. However, the conventional didactic lecture still seems to be the most common method of delivery even though this encourages passivity. One popular alternative is the the so-called flipped teaching approach (Crouch and Mazur, 2001; Hill, 2015; Lancaster and Read, 2013) which requires students to engage with learning resources ahead of staff contact time and then the contact time is used for more interactive activities which facilitate deeper understanding with the material. Of course, the negative side of a flipped approach is that it may be less effective with weaker and less disciplined students who do not engage sufficiently with the preparation material and then stop attending contact sessions because these are now too advanced for them.

In practice a middle ground is often required for typical cohorts, that is, a balance between didactic components to enthuse students and introduce basic concepts, student independent study to cover things not presented in a didactic mode, but leaving sufficient contact time for meaningful interactive activities that encourage deeper learning. Readers will notice that central to this philosophy is still the availability of high quality resources which support independent learning.

4.2 Supporting interactivity in lectures

Typical learning taxonomies emphasise that students must be active in oder to learn more effectively and thus the over use of didactic delivery mechanisms (Crouch and Mazur, 2001) is discouraged. However, simply placing an activity within a lecture may not work. For example, when students are given 5 minutes to solve a problem independently before the lecturer goes through this in more detail, many students make no effort and just chat, waiting for the answer so they can copy it down. Of course, a few such students will never engage, but there are some methodologes that can encourage engagement by a larger percentage of the class.

Lecture flipping is known to be quite successful for smaller class sizes, although even that is not well received by all students. A half-way house which is more practical with

very large classes (100s of students) is lecture response systems (Rossiter, 2014). This is technology which allows students to answer a question via a hand held device with all the student answers being collated instantaneously and presented through the data projector, for example as a bar chart. These days such systems are web based and largely operate through an app on students' phones or laptops and thus do not require additional hardware.

The advantage of such systems is the visibility and transparency of whole class responses, while retaining the anonymity of individual students; this seems to encourage more engagement. Students like to see whether they are correct or not and also, how they are faring compared to others. The bar charts are enlightening for staff and students as they expose areas where there is widespread student confusion and thus which need more lecture time, and also areas where most students are confident.

4.3 Supporting independent learning

A core skill for graduate engineers is the ability to learn independently and be confident in one's learning. Consequently, a core part of any University curriculum should be based on an expectation of significant independent learning. Of course this needs to be scaffolded so that students are gradually exposed to more challenging expectations.

One example of a good tool for supporting independent learning skills is the use of MATLAB (or equivalent software):

(1) MATLAB is best learnt independently, with some structured resources to faciliate this. Students can be exposed to the software early in year 1 and gradually expected to increase their skills by independent study throughout their programme. Numerous online resources are available to support this learning.
(2) MATLAB is also an excellent tool for students to evaluate their progress in many engineering topics and thus supports independent learning of other topics. Some easy examples are determinant calculations, closed-loop transfer functions and poles, gain/phase margins. Students can use MATLAB to test their hand working and thus to develop their skills in identifying and correcting errors in their learning.

5. SUMMARY

A benchmark control course should aim to contain a number of core components.

(1) Laboratory activities: hardware if possible but definitely virtual and/or remote laboratories and/or take home kit that can be accessed 24/7 to reinforce and support learning. These should be embedded into assessment to encourage engagement.

    This paper has shown that such a design need no longer be onerous for staff as many of these resources are readily available and often free at the point of use. Interactive laboratories are now widespread and free to use, and creating your own can also be relatively quick and simple with software tools such as MATLAB and Easy Java. Finally, take home kits are more prevalent and can be cheap to purchase.
(2) Self-assessment resources such as computer based quizzes which students can use independently to assess their progress. These should be embedded into assessment to encourage engagement.

    Quiz environments are increasingly available and relatively straightforward to code so that staff can produce short quizzes quite quickly, albeit more comprehensive data bases would take longer. Also, for those who can insist on student access to given textbooks, many online text books now include multiple online quizzes with mechansims for staff to record student performance efficiently.
(3) Appropriate learning tools provided on modern VLEs to support engagement with staff and peers.

    Examples of typical web-based tools that are now readily available and easy to use include discussions and other social media board, feedback mechanisms linked to marking criteria for assignments, soft copy submission of work, etc.
(4) Learning outcomes for accreditation which go beyond technical learning. For example presentation skills, problem solving, independent learning and so forth. Allow use of authentic software during assessment so that the assessment matches a realistic scenario.

6. EXAMPLE OF A BENCHMARK COURSE

An introductory modelling, behaviour and control course (200 hours including student private study) in the author's department is made up with the following design. In general terms the course receives excellent feedback and in particular the quality of the resources which enables the students to learn independently is often commented on (see last subsection for some student quotes).

6.1 Course summary

(1) Two 50min interactive lectures per week. These are mostly a mix of didactic content/demonstration, students engaged in problem solving (e.g. Figure 1), peer discussion and large group feedback. There are ample independent learning resources provided so not all material is covered in a didactic fashion and students are required to learn some topics independently to develop this skill.
(2) Weekly drop-in tutorials where students can ask any questions they want and get one-to-one assistance.
(3) Fortnightly short computer quizzes (e.g. Figure 2) on the foundational learning elements are available via the web for students to self-assess their progress. Multiple attempts are allowed and very small marks are available for these to encouragement engagement (repeated use to master skills) and good study skills.
(4) Active use of a VLE. The VLE stores all data automatically and in a form that allows rapid identification of absent or low performing students (Figure 3). Discussions board to field regular student queries (Figure 4). Use of rubrics for assisting in feedback generation and marking of assignments (Figure 5).
(5) Three hardware laboratories to apply learning. These require preparation and students not doing the preparation adequately are refused entry. The in-laboratory activities are assessed face to face at the time to minimise marking time for staff and unnecessary writing

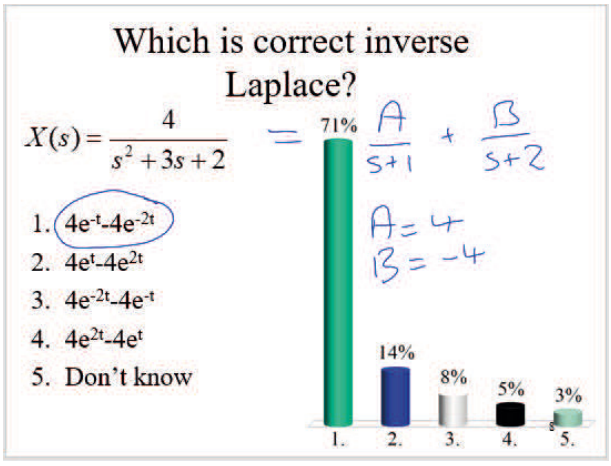

Fig. 1. Example of simple quiz questions with a lecture response system.

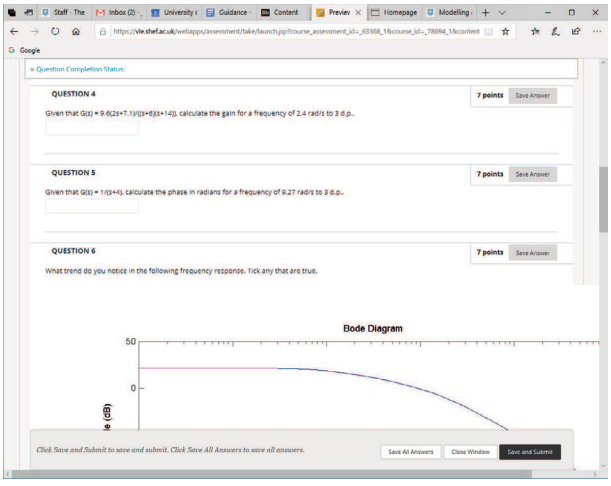

Fig. 2. Example of simple computer quiz environment.

for the students. [Report writing skills are assessed elsewhere in the curriculum.]

(6) Youtube videos for all the core material - supplementary so students can chose not to use these although those who do find them very useful (Rossiter, 2019).
(7) Virtual laboratories (e.g. Figure 6) based on authentic scenarios for reinforcing core concepts - again these are largely supplementary/motivational although use of a few appear in the fortnightly quizzes to encourage student engagement with them.
(8) End of year exam where MATLAB access is allowed for computations and plotting as this is a more authentic scenario in the workplace.
(9) If space allows, students often appreciate the inclusion of open-ended assignments which allow them the opportunity to explore and research specific areas in more detail and also to report the results in a format of their own choice (video, poster, website, etc.). Allowing such creativity seems to facilitate more enthusiasm for doing the research and really getting to grips with a topic (Rossiter et al., 2017).

QUIZ ON 1ST ORDER RESPONSES	QUIZ ON 2ND ORDER RESPONSES	QUIZ ON 2ND ORDER SYSTEMS	QUIZ ON LAPLACE AND MATLAB
84.00	55.40	50.00	70.00
69.00	53.00	20.00	65.00
92.00	100.00	40.00	56.80
67.60	48.00	50.00	0.00
98.00	67.06667	60.00	81.00
--	--	--	--
74.00	0.00	--	0.00
82.00	48.00	30.00	70.00
84.00	66.00	60.00	69.9999
92.00	56.40	80.00	63.30

Fig. 3. Example of marks automatically stored on a VLE.

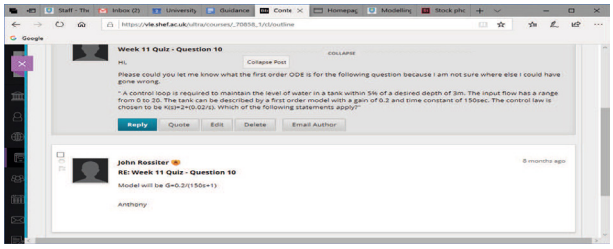

Fig. 4. Example of discussions board entry and answer.

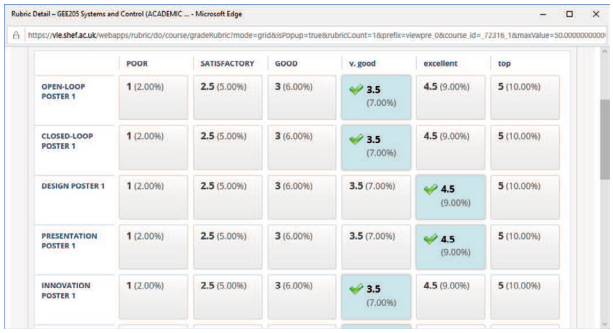

Fig. 5. Example of rubric to allow efficient generation of marks and automated student feedback.

6.2 Sample of student quotes

(1) Thoroughly enjoyed every lecture, feel like I am being taught how to think as an engineer and not just learning mathematical methods.
(2) Constant quizzes allows you to reinforce and check knowledge.
(3) Quizzes extremely helpful, all online resources very good, MATLAB GUIs help develop understanding.
(4) YouTube videos are great to get a quick understanding of the topic, and they were short too.
(5) I liked the use of the lecture response systems to aid interactivity in lectures.

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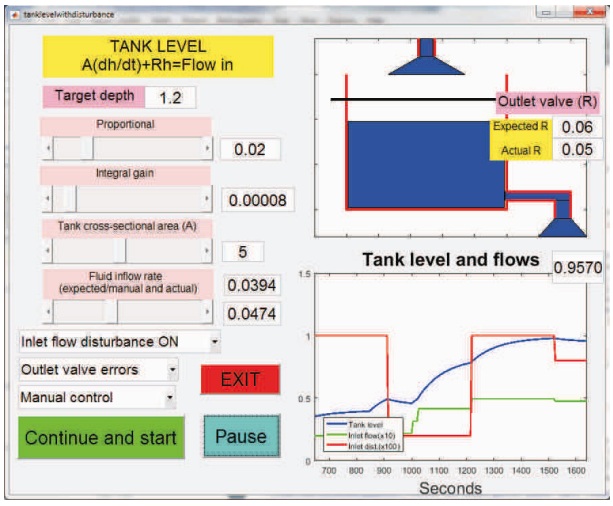

Fig. 6. GUI for tank level control.

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