Proceedings Paper:

Rossiter, J.A. (2022) Take home laboratories enhancing a threshold approach to assessment. In: Guzman, J.L., (ed.) IFAC-PapersOnLine. 13th IFAC Symposium on Advances in Control Education ACE 2022, 24-27 Jul 2022, Hamburg, Germany. Elsevier, on behalf of the International Federation of Automatic Control (IFAC), pp. 224-229. ISSN: 2405-8963. EISSN: 2405-8963.

https://doi.org/10.1016/j.ifacol.2022.09.283

Available online at www.sciencedirect.com

ScienceDirect

IFAC PapersOnLine 55-17 (2022) 224–229

Take home laboratories enhancing a threshold approach to assessment

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Abstract: This paper has a dual focus of threshold assessment (Rossiter, 2020) and take home laboratories (Taylor, Jones and Eastwood, 2013). One could argue that it is clear that take home laboratories are a good idea, but this paper focuses on effective integration into module delivery and assessment in order to maximise the value to the students. It is shown how using in a threshold assessment strategy can significantly enhance the efficacy of the take home laboratory usage.

Keywords: Interaction within a lecture, laboratories, quality assurance, efficient assessment, independent learning, student stress.

1. INTRODUCTION

The recent international pandemic created a number of pressures for higher education due to the requirement for teaching the majority of students on-line. In the main, universities have developed their pedagogies and delivery around face to face delivery and thus were not well placed for effective on-line delivery, although of course most managed well enough.

There are two areas, discussed here, where practice and pedagogy had already begun to develop and for which the pandemic accelerated the evidence of their potential. These are:

(1) The use of take home laboratories (Taylor, Jones and Eastwood, 2013).
(2) Concepts of threshold assessment (Rossiter, 2020).

These developments had been happening in parallel.

1.1 Accreditation and threshold assessment

Accreditation is an essential component of a university engineering education (ABET, 2019; ENAEE, 2019; UK-SPEC, 2019). It is important that potential employers have confidence in the skills, knowledge and attitudes students have developed. Consequently, there has been a developing focus on universities needing to prove that their graduates are suitably skilled. In simple terms, the graduating bodies have set out a number of statements on generic skills or holistic development (Rossiter and Gray, 2010) and the Universities need to demonstrate clearly that their graduates have acquired all these skills.

What is changing is the level of evidence that is being requested. Certainly within the UK, the rules are to be tightened from 2022 and one challenging requirement where the evidence requirement is becoming more stringent is that there needs to be: *a clear mapping of accreditation requirements into module/course learning outcomes (LO). Where a LO is essential to accreditation, proof is needed that the student has met this LO.*

In the simplest terms, this means that students must pass every module/course on their programme (exceptions being somewhat difficult to manage). Certainly in the author's institution, as common the the UK, this differs from previous practice where students could still graduate, notwithstanding a small number of soft module failures, as long as their overall performance was satisfactory.

This subtle change of emphasis is perhaps more seismic than is immediate apparent to the readers. In the UK, around 10% failure rate on a module is expected. Nevertheless one would also expect the majority of students to graduate because a different 10% fail each module so that most graduating students may have 1 or 2 module failures out of say 20 modules. With the new rules, any student carrying any module failure may not be able to graduate; this could affect around 50% of the graduating class if applied retrospectively.

In consequence, there is a need to change the approach to assessment to reduce the typical module failure rate. The potential role and pedagogy of threshold assessment Rossiter (2020) in this is introduced in section 2.

1.2 Take home laboratories

Clearly student access to expensive University laboratory facilities has been severely limited in the past year, and while some on-line alternatives can been offered (Egerstedt, 2016), the experience clearly is not as good. Virtual laboratories are becoming more popular and integrated into learning, but no matter how comprehensive (Cameron, 2009; Goodwin et al., 2011; de la Torre et al., 2013; Rossiter, 2017) are never as good as the real thing. Remote laboratories are also relatively widespread, (Fabregas et al., 2011; Vargas et al., 2011), but these suffer from high initial cost, challenging maintenance and

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2022.09.283

only one user at a time, as well of course any internet connectivity issues (Rossiter et al., 2018).

Concepts of a take home laboratory (Stark et al., 2013; Taylor, Jones and Eastwood, 2013) have only become achieveable on a broad scale in recent years due to the miniaturisation of computing with items such as the raspberry PI and arduino boards (Hedengren, 2019). The core point is to give students 24/7 access to an authentic engineering hardware experience, albeit on a relatively simplistic hardware. Some facilitating definitions could be useful:

(1) Take home means: portable, low cost, low weight, easy to deploy on a student laptop and in large numbers (available to the entire cohort to take home for an extended period).
(2) It is implicit that the required software (labview, matlab, python, ...) is provided by the institution license or free and the kit connects to the laptop through a USB or similar easy connection.
(3) The associated risk assessment (mandatory) must be very low risk.

This paper uses the take home kit described in Hedengren (2019); Rossiter et al. (2019) and a brief summary is provided within section 3.

1.3 Paper contribution

This paper shows how the confluence of changes to accreditation requirements and the adoption of take home laboratories produced a very effective pedagogy. Hence, after giving a little more detail on the threshold assessment and the assignment design incorporating take home laboratories in sections 2 and 3, section 4 describes how bringing these together was very effective for student learning and experience, especially in the context of a first course in control (Rossiter et al., 2020).

2. THRESHOLD ASSESSMENT

The author's early thoughts and trials on threshold assessment were reported in Rossiter (2020). In terms of core concepts, not much has changed so here we give a brief summary and some more up to date reflections based on the past year's usage.

2.1 Background

The most stressful part of a student journey is the assessment; marks can have a critical impact on both self-confidence and future careers. Ironically, many students do not focus enough on their study skills and preparedness for assessment and one role of staff is to help them prepare and develop as well as possible.

One well publicised and effective tool is to give students regular small summative tests (Croft et al, 2001; Rossiter etal., 2008; Stark et al., 2013); the word summative is core as without the associated weighting, the students who need these most often do not engage. In the author's experience formative assessment, while ideal in theory, does not work in practice because students prioritise the activities with marks associated.

However, conversely giving some weight to weekly tests (even 1-2% of a module) creates stress as students then worry about whether they scored 70 or 80 and quibble over marking, even when in reality they are arguing over perhaps 0.1% of a module mark. Hence, we need a model which encourages engagement and provides opportunities for giving feedback, but without being too pedantic about the associated mark.

Threshold assessment provides just a pass or fail judgement; a student who passes is given 100% for that component of the module and thus this reduces student stress and moaning significantly. In Sheffield we largely adopt 70% as the pass mark on threshold tests, so students who make the odd typo or silly mistake can still demonstrate sufficient competence to pass and no longer quibble over trivia. Moreover, we allow multiple attempts as this encourages learning, feedback opportunities and practice until good enough.

2.2 Threshold assessment and accreditation

A core point about threshold testing is that the focus is on: **what is enough to demonstrate the core learning outcomes of this module?** Students who pass all the threshold components are awarded 40%; not a mark to be proud of but enough to prove to the accreditors that students have passed. This is another reason we are relaxed at offering multiple attempts as the important question is whether students have mastered the basics.

When it comes to accreditation and demonstrating students have met the LO, threshold assessment should focus solely on the base level LO, those that students must pass. By avoiding the more challenging assessment questions and allowing repeated attempts as well as transparency of student progress, students are empowered and encouraged to pass. This means that, even before the end of year grading exam, fail rates should be far below the historical 10% target.

2.3 Threshold and grading assessment

A core component of the overall assessment regime is that we still need to grade the students overall performance on a 100 point scale and thus to distinguish between excellent, very good and so forth. With a threshold and grading approach there is a small but important difference compared to historical practice.

Historical examinations were designed to offer grades over the entire 100 point scale and thus had elementary (say recall) components and simple computations for students to demonstrate a pass. Questions then had aspects covering more challenging aspects such as analysis, evaluation, application and design. Actually designing several 20-30 minute questions covering this wide range of scores is nigh on impossible in practice so one could question whether historical examinations scores were really that reliable.

With threshold and grading, examinations do not need to assess base level LO as students already have the marks for that. Hence other assessments focus solely on *how well have you passed?* By removing the elementary components, the assessment has more space to distinguish

Table 1. Example of a graded assessment scale for end of year assessment worth 60% of module mark.

Student mark	Quality of work
0/60	poor
0-10/60	satisfactory
10-20/60	good
20-30/60	v.good
30-40/60	v.v.good
40-60/60	excellent

between different levels of performance. Nevertheless it is paramount that staff understand that it is not a problem if many students score close to zero on the end of year assessment; these are the students who merit a bare pass only. Hence marking scales need to be clear. An example marking scheme is shown in Table 1 which clearly is somewhat different from a traditional one and focuses very much on some quality judgements.

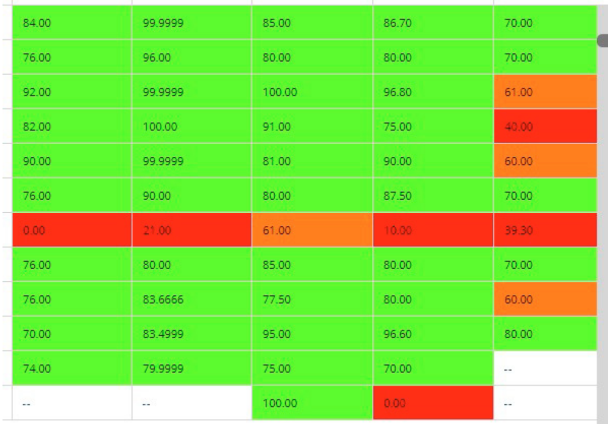
2.4 Notes on implementation

A core part of a threshold and grading implementation is that one needs to avoid overloading students with assessment and staff with marking. As the threshold parts are assessing base level competence only, questions can be simple (often single step computations) and thus assessed in many low cost and low time alternatives.

A tool that author makes large use of is computer aided assessment (CAA) (Rossiter et al., 2018; Stark et al., 2013; Croft et al, 2001); students can manage this in their own time, including repeat assessment and get immediate feedback on their progress. Largely students enjoy this type of assessment as they are in control and marks are transparent. It can take a while to develop a suitably large database of questions, but this approach has the advantage of re-useability for many years and, once the database is set up, involves staff in minimal ongoing effort. The author uses randomised number generation and question sets to reduce the potential for collusion, that is, students get different questions and numbers every time they take a quiz. Ideal quizzes should only take 15-20 minutes for students who have mastered the topic, albeit they will take longer while students are still learning. Remember, questions are only assessing base level competence so are largely straightforward.

Remark 1. Over nearly 20 years of using quizzes and the associated databases, the author has seen little evidence that a particularly large database is needed as students have too many other tasks to spend time trying to find all the questions and answers. It is more efficient for them just to answer the questions they get individually. Typically the author's database is about 5 times as large as the number of questions a student answers, but also, many questions have random number generation, so appear different each time.

In-class tests can also be easily used for threshold testing - students need to be alerted well in advance to ensure attendance. These are good for encouraging the development of exam writing skills and some peer assessment/reflection (Crouch and Mazur, 2001). The author will usually set a time limit of 35 min, then get students to swap scripts



84.00	99.9999	85.00	86.70	70.00
76.00	96.00	80.00	80.00	70.00
92.00	99.9999	100.00	96.80	61.00
82.00	100.00	91.00	75.00	40.00
90.00	99.9999	81.00	90.00	60.00
76.00	90.00	80.00	87.50	70.00
0.00	21.00	61.00	10.00	39.30
76.00	80.00	85.00	80.00	70.00
76.00	83.6666	77.50	80.00	60.00
70.00	83.4999	95.00	96.60	80.00
74.00	79.9999	75.00	70.00	--
--	--	100.00	0.00	--

Fig. 1. Example of gradebook (green=pass, orange = close to pass, red = fail.

for marking and spend 10 min going through the solutions and mark scheme. The last 5 min is used for students to show their marked script to the lecturer as they leave so pass/fail can be recorded. Students who fail have one week to bring in perfect, and neat, work for the test.

In general terms the author believes in a tri-lab concept for laboratory provision (Abdulwahed, 2010), using virtual and remote laboratories for deeper reflection and or preparation. A core component of this delivery and assessment plan can be threshold.

(1) Pre-activities to encourage reflection on the core learning in the lab and required computations are mandatory and marked as pass/fail. Those who fail are refused access and score zero.
(2) Performance during the laboratory is assessed as pass/fail by the demonstrator and this mark is given immediately.
(3) Students who pass 1-2 above, receive the threshold mark for the activity.

Where desirable, post laboratory activities, reflections and report writing would form the grading part of the marks available.

The author makes extensive use of virtual learning environments (VLE) which are now commonplace. These are good portals for transparency of student progress with respect to threshold assessments as the students can see clearly what they have passed, and what still needs doing. The author tends to colour code the grade book (see figure 1) as this means he is able to identify quickly students who need chasing.

3. GRADING ASSESSMENT AND TAKE HOME LABORATORIES

3.1 Background on end of year examinations

Grading assessment allows staff to remove simple questions from examinations/assignments and focus on more interesting problem solving and design, but it does not remove the challenges of computation. Too many examinations use elementary examples which lend themselves to multiplication and addition that can be done in an examination scenario with a hand calculator. In the author's view this does students a disservice. Modern computing tools are so easily available these days that (Lynch and Becerra, 2011; Rossiter etal., 2008) we should just give students access to these tools during the examination and focus on the problem solving and application of learning, not the number crunching. The author has been allowing access to MATLAB during examinations for years (Rossiter et al., 2018) and there is no evidence that this is artificially increasing marks or performance as long as the questions are suitable.

However, the focus of this paper is on take home laboratories. In a similar vein, the author was frustrated that end of year examinations are ultimately very limited in what they assess and to be honest, quite boring! Once in the workplace students will not be asked to regurgitate their knowledge in 2 hours while sat at a desk and with no access to the web, books, colleagues, etc. Hence, assignments have the potential to be both more interesting and more authentic assessments.

3.2 Assignment design and control engineering

It is known form the recent survey (Rossiter et al., 2020) and first hand experience of many, that students often experience a controls course as mathematics. There are lots of formula, Laplace transforms, definitions and so forth, but many students leave the first course not really knowing what it was all about or why it is important? This experience is reinforced with a dull end of year examination.

We may include industrial case studies and the like in lectures to enthuse and motivate students, but if this is not on the exam, they may well just switch off; if it is not assessed many students do not want to know! So, if assessment is core to student engagement, then we need to make motivation and implementation issues a core part of the assessment and get them to take more active ownership (Rossiter and Gray, 2010; Rossiter et al., 2017). Take home laboratories provide an ideal environment to do this because the assessment criteria can be developed around implementation on hardware and demonstration of authentic issues (Hill, 2015). Using take home laboratories means students are not rushed, as in conventional laboratory access, but can repeat tests, modify and be creative in designing tests to demonstrate and illustrate core learning.

In terms of timing, the ideal scenario is to give the students the hardware early in term and have regular support sessions building up their skills and confidence in advance of using it specifically for the assignment brief.

3.3 Supporting independent learning

As an aside, a core skill for graduate engineers is the ability to learn independently and thus the design of any module should actively consider how student independent learning skills and ownership of their learning is enhanced. The author often uses development of MATLAB skills as an easy win in this arena, by transparently advertising to the students that this part of the course is deliberately set up as independent learning (supported of course by tutorials). Critically, if students choose not to engage in MATLAB, they are likely to fail the module. It should be reiterated that, given most students are taught MATLAB elsewhere, the additional skills required are not large so it is the principle that is being emphasised here and moreover good students quickly realise that it benefits their learning to engage actively.

The author also provides occasionally drop in support classes where students can get help with MATLAB and some focussed notes/resources. These sessions seem to help reducing collusion as all students are developing their own unique results in parallel, but are allowed to help each other with coding, direction and so forth.

3.4 Assignment criteria

This subsection gives an example of the sort of criteria that are easy to incorporate into an assessment that students really experience through hardware and thus understand. Clearly this list is not exhaustive, but they are applicable to a first course in control as long as students have the right support and hardware.

(1) Why is proportional control alone, or indeed integral control alone, ineffective?
(2) Demonstrate the efficacy of simple PI tuning rules.
(3) Modelling real processes through time constant, gain (and delay). Do parameterisation/modelling errors matter?
(4) What is the impact of discretisation and different sampling times on performance?
(5) What is a disturbance and why do these matter?
(6) What is the impact of sensor noise on behaviour?

The author asks students to create posters to encourage them to focus on core insights and illustrations and not to write too much low value text. The quality mark is based around the evidence/data provided and more importantly, presentation and interpretation of that evidence.

3.5 Description of take home equipment used

The authors department have acquired a number of the take home kits described in Hedengren (2019) to support a first course in control as these are cheap enough to be purchased in large quantities. We have other equipment for more advanced courses (Rossiter et al., 2019; Taylor, Jones and Eastwood, 2013).

In superficial terms, the equipment (Figure 2) comprises two heating elements and heat loss is largely to the surroundings. Consequently the dynamics of each heater can largely be captured by a first order model with a small delay:

$$G(s) = e^{-s\tau}\frac{K}{Ts+1} \tag{1}$$

The heaters are close together so there is some interaction which can act as a disturbance input.

The equipment plugs into a laptop USB and can be run using MATLAB or python, assuming the suitable free arduino toolbox is available. Simple code is provided which illustrates tasks from simple step tests up to advanced control and identification (Figure 3); for a first control course the step tests and PI implementations are sufficient and

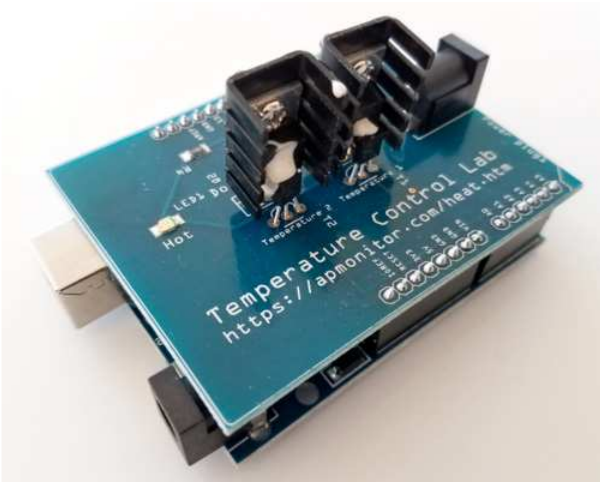


Fig. 2. Heating kit.

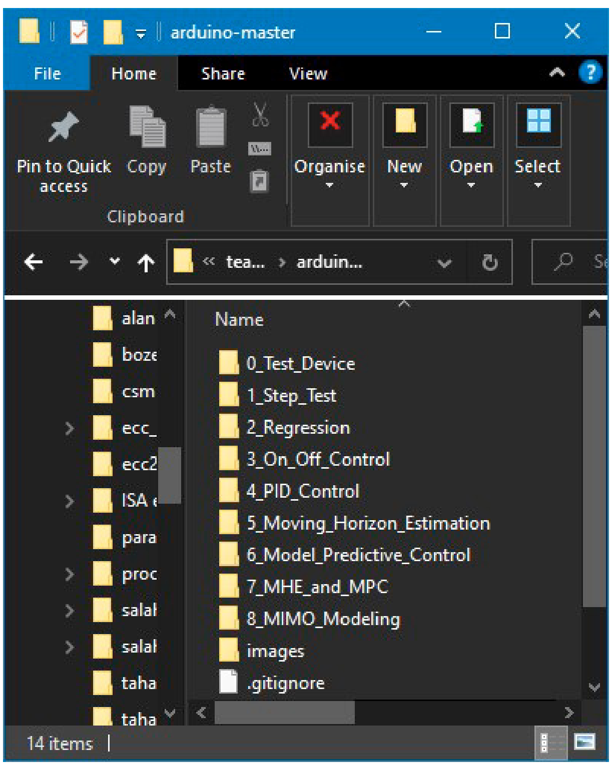


Fig. 3. Range of pre-provided code.

only trivial editing is needed for students to personalise as required. In addition the author provides the students with simple code for a discrete implementation with PI compensation where the PI parameters and sampling time are transparent to edit. It is noteworthy that this kit easily meets the criteria in the previous subsection while requiring students to acquire relatively minimal MATLAB skills; we assume that students already know sufficient MATLAB for basic plotting and simple script files.

4. REFLECTIONS ON THRESHOLD AND GRADING WITH TAKE HOME HARDWARE

As noted earlier, both the author and the students found the end of year exam experience rather dull and uninspiring. A threshold and grading approach gave the opportunity to dispense with the foundational material in a straightforward manner and then focus the grading assessment on far more interesting activities. Hence the module design was updated as follows:

- Threshold tests covering basic analysis of systems dynamics and feedback loops. [40%]
- Access to and use of university laboratories [10%].
- Grading assessment using the take home kit [50%].

The most significant part is that the grading assessment has a rather open-ended remit along the lines of demonstrate why control is important, some common design methodologies and the issues you are likely to face in a practical scenario. Students were given more guidance on possible activities they could undertake in frequent workshop meetings and the page limit was deliberately low so students would focus on developing clear illustrations/figures rather than providing lots of text. There was little need to use space to demonstrate straightforward computations/analysis as MATLAB tools could be used and this would often come under the quality assessment of 'poor/satisfactory', so receive very few marks.

4.1 Quality of student work

On average the quality of the student worked submitted far exceeded what would be typical for an end of year examination. In terms of simple numbers, and despite very severe marking schemes, the average on the assignment suggested an average performance close to 10% above normal expectations. Of course this is not unusual with coursework assignments as students put in the extra effort to get those extra marks, but then one could argue therefore a core aim of encouraging student engagement and learning has been achieved.

Remark 2. It is interesting to note that a few students (typically weaker students) chose not to do the assignment. They were happy with a bare pass from the threshold components and wanted to spend their time ensuring they passed their other modules. Once could argue that this is a core benefit of the approach and such students are more likely to meet accreditation requirements now than under a previous scheme where no doubt they would have had multiple soft fails.

4.2 Staff reflections

Students were rather slow getting into the assignment, but once they started the on-line workshop meetings suggested the development of real insight and understanding of control. Several students commented explicitly how the assignment had been very valuable to them.

As a staff member, being able to exploit MATLAB tools and the hardware made it much more time efficient to expose students to important issues such as discretisation, disturbance rejection and model uncertainty; this would be very difficult in a more analytical/mathematical approach to module assessment.

One obvious downside is that marking assignments takes longer than marking exams but too some extent, that is what staff are paid to do so we should not resent it!

5. CONCLUSIONS

The author feels that, especially given the COVID scenario so that there was no human contact while the students were working on the equipment, the overall module design went very well.

- Generally, albeit with extensions, the vast majority of the students scored close to full marks on the threshold components which was a core aim of the redesign.
- The quality of insight and understanding demonstrated by students in the assignment was far deeper and more perceptive than is ever evidenced in a conventional end of year exam.

Anecdotal student comments from the regular weekly meetings suggest that, although they did find it hard, in the main students enjoyed the activity and appreciated the importance of the topic far more than previous exam assessed cohorts, even if it was not their favourite subject (civil and mechanical seem to be the more favoured future directions for general engineers). Indeed, the main complaint of students overlapped with the strength, that is, the need to engage with, understand and illustrate the importance of control through a real example; the complaining students wanted simple memorise and regurgitate problems rather than real understanding and appreciation.

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