AC 2007-925: USING TECHNOLOGY TO SUPPORT ENGINEERING LABORATORY STUDIES

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Mark Russell's teaching and learning interests are varied, and include exploring the effective use of technologies to support in-class activities, developing collaborative learning opportunities and developing innovative tools for electronic-assessment. Marks current interests lie in the area of Just-In-Time teaching and using the students' own understandings to help guide the lecture experience. In addition to winning the UK e-tutor of the year (2003) Mark was awarded a UK National Teaching Fellowship (2005).

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Using technology to support engineering laboratory studies

Abstract

Learning requires *activities* that facilitate exploration, personal (first-hand) experience as well as provide opportunities for students to develop and re-conceptualise their growing knowledge. Laboratory studies present an ideal opportunity for such personal action and reflection whilst also bringing some of the classroom activity to life. Although carefully considered laboratory studies have the potential to be highly educationally effective, issues arise with the associated burden these studies place on teachers. This is particularly evident in the United Kingdom with growing student numbers and an often associated reduction in teacher-student contact time. In the extreme, concerns over the low resource efficiency may dominate such that some laboratory studies may be withdrawn from the curriculum.

The approach demonstrated in this paper seeks to redress that issue and utilises computing technology and students themselves to increase the resource efficiency and enhance the educationally effectiveness experience.

Introduction

Learning is not a spectator sport – it requires *activities* that facilitate exploration, personal experience as well as provide opportunities for students to develop and re-conceptualise their growing knowledge. Such principles are articulated in instruments suggesting how we might think about learning, see for example Kolb's experiential learning cycle[1], as well as in suggested principles for good practice in undergraduate education[2].

Learning is also enhanced when it is a *situated* activity such that it presents an opportunity for the students to see, explore, and gain *first-hand* experiences. Far too often, however, didactic teaching *transmits* to the learners a second-hand view of knowledge. A view that is held by the teachers or conventional wisdom. Whilst the transmission of knowledge may be highly efficient the views are often too abstract and have limited relevance to the learners' current conceptions or knowledge base.

Laboratory studies, however, present an ideal opportunity for personal action and reflection. By definition, they also provide an opportunity for students to gain the much sought after first-hand experience whilst also bringing some of the classroom knowledge to life.

Whilst carefully considered laboratory studies have the potential to be highly educationally effective issues arise with the associated burden these studies place on teachers. This is particularly evident in the United Kingdom with growing student numbers and an often attendant reduction in teacher-student contact time. For cases where laboratory studies are unfortunately seen as a value-added activity, rather than an integral part of engineering curricula, concerns over the low resource efficiency often dominate such that some laboratory studies are withdrawn from the teaching plan. Such decisions, it is argued, will be detrimental to the undergraduates learning experience.

This paper demonstrates two approaches to redress the issue. In the first example technology is developed to better support the resource efficiency whereas in the second example technology and students are used to better support the development of the educational effectiveness of the laboratory experience.

Example 1. Using technology to enhance the resource efficiency

The need for change

Reorganisation of our degree programmes led to an increase from around 150 to 300 students studying a first year Materials Science module. With the lower number of students, one of the assessment tasks was a tensile test. This involved stretching to destruction a set of small samples and establishing their mechanical properties. The tensile test being undertaken by groups of around 4-6 students which gave them close and first hand experience in tensile testing. The culmination of the assessment task was the requirement to produce a formal laboratory report.

Although it is recognised that assessment is important in driving student activity[3] it is the feedback that helps the assessment activity become learning oriented. Feedback should reinforce what is known, correct what is misunderstood and give guidance for future work. The doubling in student numbers and the associated increase in administering, marking and providing appropriate feedback suggested the activity was in danger of being dropped; this was disappointing. And so drawing on, and re-purposing, technologies developed to support a technology-rich assessment regime used elsewhere[4] meant that the tensile test could remain.

The *technology rich* intervention

The need to establish an intervention forced a rethink of what was assessed and how the laboratory study was to be supported. In lieu of the previously used formal laboratory report the resulting assessment comprised three separate yet integrative tasks. Each task was aimed at different aspects of the laboratory study and tested their resulting gain in knowledge.

Task 1 was oriented around the tensile test per se and included data collection, measurement and calculation of the samples physical and mechanical properties. e.g. sample diameter, percentage reduction in area, percentage elongation and tensile strength. *Task 2* comprised a set of multiple-choice questions that set out to establish if the student could abstract some of the knowledge gained from their tensile test results to give more generalised principles. Since the tensile test comprised two steel and two aluminium samples the questions also focused on their associated behavioural comparisons and contrasts. *Task 3* was a student unique sheet requiring calculation of mechanical properties for a specific sample. This also consolidated the knowledge gained from task 1.

The products developed to support to the tasks focused around the whole assessment and included -

i) Giving instruction in use
ii) Constructing student unique tasks
iii) Collecting student responses
iv) Marking and providing appropriate feedback

Instruction in use was created by authoring an audio-visual DVD. This included advice on running the test, data collection and associated health and safety information. This standalone facility allowed the students to review the introduction and the instructions at a time and pace that best suited them. The use of this technology also enabled them to revisit the DVD to confirm their actions or reaffirm any previously misunderstood information. Figure 1 provides two sample screen shots of the DVD.

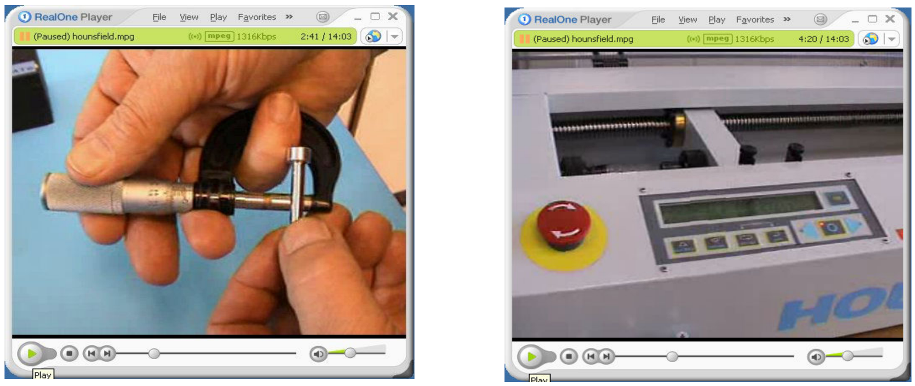

Figure 1. Example screen shots from the instruction in use DVD

Constructing student unique tasks was undertaken using mail-merge techniques. The mail merging constructed an identical task sheet but embedded student unique data. The benefit of this approach to assessment was that the student each tackled the same activity hence they could share thoughts on problem solving methodology but could not share answers. Given that each student had their own data set each student would also have a different set of results. Note: this activity was more supplementary to the laboratory study rather that at its core.

Collecting student responses

Having tasked the students the next requirement was to provide an appropriate facility to collect their responses. The intention being to reduce administrative time and collect the submissions in a format that better supports automated marking. In this instance the data collection was undertaken by a dedicated computer program; an *electronic post box* or *data gatherer*. The data gatherer has a range of functionalities including password protection, thereby enabling the correct association of student with their responses, checking for and stopping previous submissions and checking the submission for incorrect data-types. The program also advises the students if they have not responded to all the questions. At the end of the submission the computer program writes to the screen a student-unique data string. This can be thought of a digital receipt and is useful in resolving any issues where students claim to have submitted but were marked as if they did not. An example screen shot of the data gatherer is presented in figure 2.

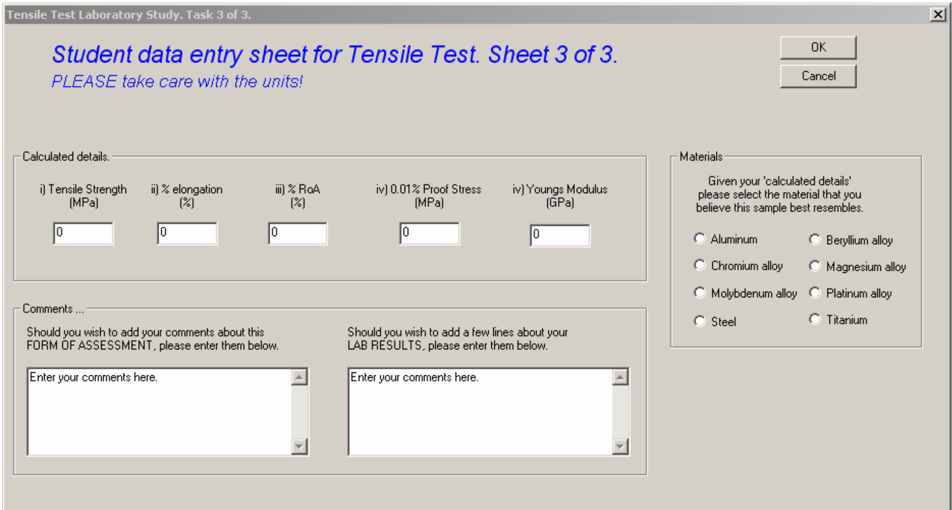

Figure 2. Example data entry screen for task 3

Marking and the provision of feedback is undertaken by a modified Microsoft Excel spreadsheet. A few VBA scripts have been embedded in the marking spreadsheet to allow it to :

- Read the students submissions (from the data file created by the data gatherer)
- Undertake the marking of the submissions – using marking rules and associated marking tolerances
- Collect appropriate feedback statements and
- Provide and deliver a student unique and personalised feedback e-mail. (see figure 3)

All of the which happens at the click of two buttons!

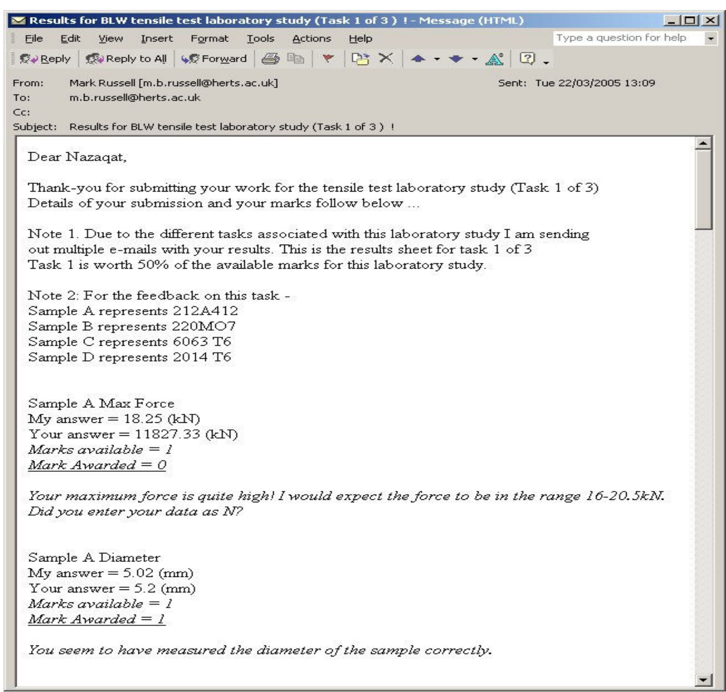

Figure 3. Example e-mail - constructed automatically within Microsoft Excel.

The results from the technology-rich intervention are very encouraging. The students' grades are well distributed and not clustered either at the top or the bottom of the grade structure. The fact that three assessment tasks were used enabled the teaching team to discriminate between the stronger and weaker students. In addition to the results, this approach has been extremely valuable in time saving terms too. No longer are the teachers involved in collecting or marking the work. That time was better invested, up-front, to develop the technology to undertake these tasks. That initial time investment is no longer needed and is likely to secure the future of the tensile testing laboratory study.

The voice of the student was also considered important such that when collecting the data the students were provided with an opportunity to share their thoughts on the study as well as provide a short narrative on their results. (See figure 2). Virtually all comments received were very positive. For example:

Student A " lab work was very enjoyable and the video gave all the information we as a group needed. As for the feedback, I thought they were very informative and showed me exactly where I went wrong. The fact they gave you the correct result and your result was brilliant as it shows how badly off I was on some of them! I did learn a fair bit from the lab, for one be sure to read what format the dimensions are to be given in. Lost out on about 20% because of my eagerness to get it done! Oh well, ce la vie!."

Student B. "Overall though I thought it was a great experience. The fact they leave it up to you to get the work done and don't spoon feed you everything you need to know."

Student C "I think this form of assessment is excellent!"

There were, of course, some contradictory responses from the students i.e.

Student D "I would rather hand it in to the hatch than electronically."

Student E "better than submitting work to d110."

In the above example the use of simple technologies has been to develop the resource efficiency of the tensile test rather than necessarily enhance its overall effectiveness. Both are important features of any assessment. As such these resources now allow the laboratory study to maintain its place within the Materials Science module. There is little doubt that with the growing student numbers this laboratory study would have otherwise been dropped.

The second example demonstrates the use of students and technology to improve the resource efficiency and also develop the students laboratory report writing skills.

Example 2 – Using technology and peer assessment to enhance the students' laboratory reports

The need for change

Engineering undergraduates need not only to be able to conduct experiments but also to communicate their findings in a way that is effective, persuasive and consistent with that of a laboratory report. Laboratory reports will clearly differ in style from an essay or dissertation.

Problems arise here since no matter how much guidance appears to be given to students many demonstrate a consistent desire to ignore it. This second intervention uses students themselves and technology to help overcome that issue.

For completeness the intervention described below has been used in three modules. Unless otherwise stated the results presented arise from a first year Fluid Mechanics and Thermodynamics module.

The intervention

The intervention described here centred in bringing students closer to the assessment criteria. Assessment should not be seen as a game where indicators of success are hidden but rather where expectations are transparent and well articulated. During the module the students undertook two laboratory studies, one on flow measurement and one on the first law of thermodynamics. In both cases they worked in groups of around 4-6. At the end of the session the students were instructed to produce a formal laboratory report which should follow the set of previously issued guidance notes. '*An introduction to writing laboratory reports'*.

Collection of the laboratory reports was undertaken as normal but, at a pre-defined lecture, were handed back out along with a marking grid. The students were now tasked with assessing, using appropriate grading criteria, one of their peers' submissions. The motivation being to

i) situate the students closer to the assessment criteria,
ii) develop in the students an ability to act as a critical reviewer and
iii) provide the students with an opportunity to see how other students respond to the same task.

The assessment marking grid comprised around 50 questions of which some focused on content whereas others focused on formatting and style.

The assessment marking grid essentially followed the guidance notes and helped reinforce the importance of following such guidance. It was compartmentalise such that it asked questions about each expected section of the report. i.e. abstract, introduction, method, results, discussion and conclusions.

Using the marking grid the students were required to complete an optical marking sheet. This was subsequently processed by the optical marking reader and the resulting raw CSV file was read into a pre-prepared spreadsheet for further post processing and marking. It was important not simply to pass back final-grades but provide feedback statements generated within the spreadsheet and selected as a consequence of the peer marking. Naturally the marking spreadsheet not only drew on appropriate feedback statements but also collected them to produce and deliver a personalised feed-back e-mail. Much of this functionality is as described previously.

In addition to marking the students were also asked if they learnt anything from the process. The results are very encouraging and are presented in table 1

	++	+	0	-	--
M1	35	60	16	1	4
M2	15	29	16	7	9
M3	5	31	21	8	6
$\sum$	55	120	53	16	19

Table 1. Student Responses to *'I have learnt A lot from This Exercise'*

Legend for table 1
M1 = Fluid Mechanics and Thermodynamics.
A laboratory study investigating the first law of thermodynamics applied to a control volume
M2 = Simulation and Analysis Techniques.
A laboratory study investigating the pressure distribution around an aircraft wing.
M3 = Aero-thermodynamics and Design.
A laboratory study investigating the aerodynamic behaviours of an aircraft.

++ = strongly agree
\+ = agree
0 = neither agree nor disagree
\- = disagree
-- = strongly disagree

A summation of the positive responses, i.e. ++ or + shows that 175 students from the 297 total (~59%) thought this was a worthwhile exercise. This compares with only 69/297 (~23%) that did not. The rest, 53/297 (~18%) indicated a neutral response.

Conclusion

Laboratory studies should be considered an integral component of any engineering curricula. They offer significant value in that they allow the students to gain both first hand and situated knowledge of the subject domain. Two issues however are found to exist – both of which can be countered by judicious use of technology.

First the additional resource demands of laboratory studies and the attendant assessment demand can be offset using technology to help set, collect, mark and provide feedback. Second, the desire for students to disregard advice on how to write laboratory reports can be countered by using the learners as assessors. Peer assessment has been shown here to bring them closer to the assessment criteria, allow them to see how others tackle the same task and hence it becomes extremely educationally effective. Resource efficiency gains can be established using technologies to collect the students peer markings and convert them into feedback statements that are meaningful and individualised.

Both interventions rely on simple desktop technologies and have been extremely well received by the students.

References

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