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A new approach to assessing the experimental work of science students

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Introduction

Effective Higher Education must equip students with transferable skills for the workplace and the benefit of wider society (Keniston, 1960; Knight and York, 2003; Quality Assurance Agency for Higher Education, 2006; Schwartz, 2003; Maharasoa and Hay, 2001; UK Government Department for Business Innovation and Skills, 2009). Students must therefore develop transferable skills as part of their studies. Employers should be convinced that a student in possession of a science degree has a certain level of competence in the laboratory, can carry out simple experiments unaided and can appropriately analyse data thereby generated. At present, the methodology by which we assess the laboratory work of science students in UK universities falls short of meeting this goal.

Problem-based learning

Undergraduate science student practical work is an example of problem-based learning (PBL). Savin-Baden (2000) has identified five types of PBL:

1. Epistemological competence: wherein a student is required to apply knowledge in the solution of a set of problems, the answers to which are known by staff.

2. Professional action: students become competent to practise a certain set of skills, developing critical abilities for the workplace.

3. Interdisciplinary understanding: the gleaning of skills which can be applied across the boundaries of the academic context into the working environment. Students learn both factual knowledge, and methods by which this might be applied.

4. Trans-disciplinary learning: students independently decide how they will learn, and think critically outside discipline-specific silos. This model fosters deep learning and understanding, and students develop a critical and autonomous position towards knowledge, the actions of their peers, and themselves.

5. *Critical contestability:* this model seeks to drive students to examine critically proposals put to them, and to respond constructively to challenges made by others. It encourages students to become critical and challenging as practitioners of a discipline.

Laboratory practical work can best be placed under categories two and three. An assessment allowing a student to demonstrate skills under these categories is depicted in Table 1below.

Table 1: Assessment of the professional action and interdisciplinary learning facets of Savin-Baden's description of PBL. (Adapted from Savin-Baden, 2000).

	Professional action	**Interdisciplinary learning**
Learning	Development of knowledge for use in the work place	Gain knowledge/skills across disciplinary boundaries
Problem scenario	A life-like problem that has a practical solution(s)	Develop knowledge to be able to deliver
Facilitator	Demonstrates skills; provides guidance on best practice	Organises knowledge and skill development
Assessment	Tests skills and competence for the workplace, allows the student to demonstrate their body of knowledge	Tests skills and knowledge in a context that may be different to that where they were learnt

Assessment of practical work: current practice

At present, a student is first required to do some pre-lab reading before undertaking an experiment under close staff supervision. The experiment will generally require the students to synthesise a product. Once the experiment is completed, a small amount of characterising data is recorded to verify that the product is as expected. The entire assessment turns on a report the student subsequently writes on their experimental work (see Figure 1): beyond a statutory attendance requirement, no assessment is made of how competent the student was in the lab, or of how much initiative and effort they exhibited. The more desirable scientist is the one who can confront an unexpected result or problem with their experiment and resolve it, but this type of crucial skill is not currently assessed.

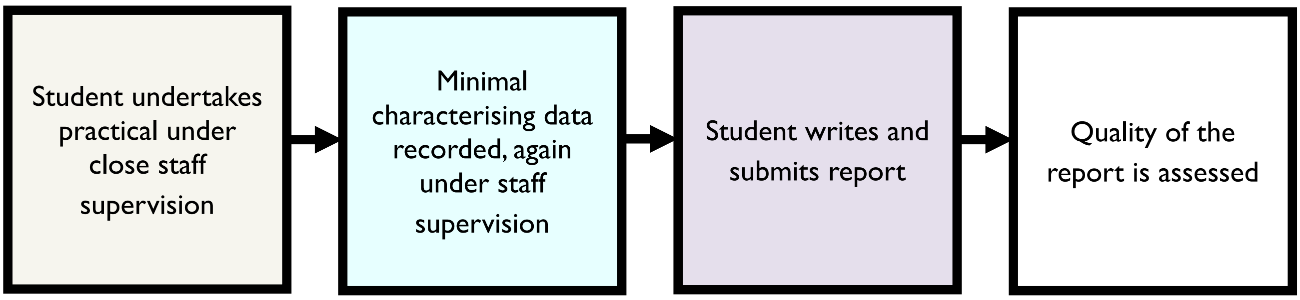

Figure 1: Current practice in assessing laboratory work.

This is analogous to teaching someone to cook a simple meal. Prior to the meal, one would expect the student to have studied the recipe and to have some comprehension of the process they were about to undertake. The student would be offered support while they cooked the meal, perhaps with regard to mixing times, *etc.* This is similar to faculty staff assisting students undertaking a practical. Once the food is cooked, we might "characterise" it by looking at the colour, considering the smell, or tasting it. The current characterisation performed by students in practicals is akin to looking at the food to check its colour, but not smelling the food and ignoring its taste. This allows a minimum standard to be confirmed – for instance that the student has cooked a roast chicken rather than a cake. However, it does not evaluate the quality of the output: a delicious cake may be a preferred output to a burnt chicken. One would expect the assessment process to allow the student to demonstrate their ability to follow a recipe, flair in the kitchen, and adaptation to overcome adverse circumstances. The quality of the meal produced would be a profound consideration, and taste, followed by smell, would be most important in determining this. Our current methodology for assessing science students' practical work is akin to assessing the culinary student solely based on how good his report of the cooking experience was. It provides no insight into culinary skill, nor into how good the meal produced was.

Considering this in the light of the Savin-Baden model (Table 1), it is clear we do not test the skills and competence required for the workplace; although students can demonstrate their knowledge through the report, they have no opportunity to show this experimentally. Hence, we fail to deliver the assessment required for the professional action facet of PBL. While students can show skills/knowledge across contexts through their report, they cannot demonstrate an ability to draw skills from one context and apply them in another during practical work. Therefore, the current assessment model at best partially meets the requirements of an interdisciplinary learning PBL model.

The work of Rhodes and Tallantyre (2003) also reveals the current assessment methodology to be sub-optimal in that it fails to provide students with an opportunity to demonstrate transferable skills. While writing a report does allow them to demonstrate some written communications and ICT skills, it permits no consideration of organisational, oral communication, and teamworking skills. A report also does not allow measurement of a student's effectiveness.

Furthermore, a crucial facet of being a successful practitioner is the ability to engage in critical reflection and to constantly evaluate one's performance (Kolb, 1984; Schön, 1983 and 1987). Students at present have no opportunity to do this in their practical work, yet it is a core skill likely to be much in demand from employers.

The Association of the British Pharmaceutical Industry states that "the main skills gap in candidates is their lack of basic lab skills" and that "it would help if [...] graduates had more opportunities to work with high level analytical equipment" (ABPI, 2008). The Confederation of British Industry (CBI) reports that "51% of employers are concerned they will not be able to fill posts requiring the right graduate level [...] skills in the coming years" (CBI, 2010). This problem is so acute that there exists a programme called "Science Graduates for Work", which aims to help unemployed scientists find work by enhancing their basic laboratory skills (Skills Development Scotland, 2010). These students have not been able to demonstrate the required skills from their degree study.

An alternative model

Giving students the opportunity to develop higher-level analytical skills in the laboratory is unfortunately precluded by cost: the state of the art equipment required is unaffordable in the current economic climate. Therefore, I propose the alternative assessment model given in Figure 2.

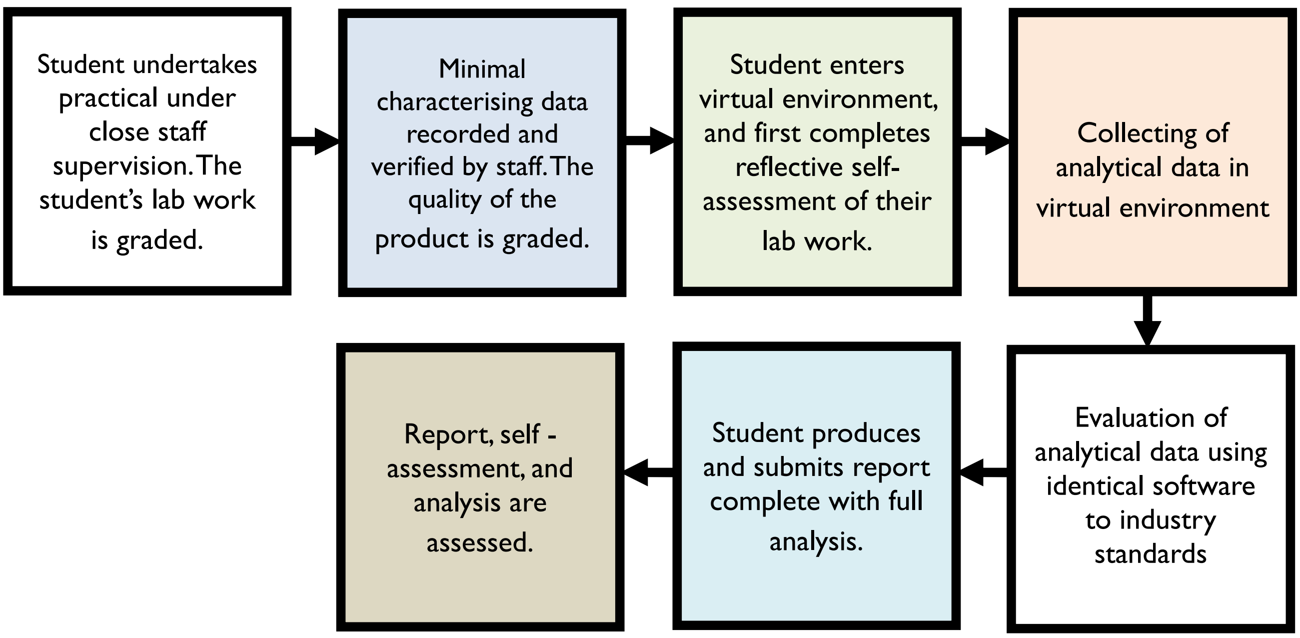

Figure 2: An alternative assessment model.

This model allows us to redress the key failings of the current assessment model. By recording only minimal characterising data in the lab (significantly less than at present), we free up significant time for basic skills development and will be able to reflect these in the assessment. Subsequent to laboratory work, the students will move into a 'virtual' environment. They will first reflect on their laboratory experience, consider their own performance together with that of their peers, and suggest possible improvements. Next, they will undertake the 'virtual' collection and analysis of detailed characterising data using software analogous to industry standards. This will mirror the process undergone when conducting analysis in industry. The virtual environment will be set up to provide assistance to students having difficulties and to record information on the steps they took along the analysis pathway. Tutorial sessions would be arranged to help the students overcome obstacles, in the same way that as employees they would seek advice from more experienced colleagues if encountering difficulty in the workplace.

The student will finally produce a report which will detail both what they did in the lab and the data analysis process. This will be considered in the assessment along with staff evaluations of the student's laboratory skills and the readout from the virtual environment on the steps taken in the analysis. Assessment criteria and feedback would be developed which place appropriate weighting on each part of the desired skill set: practical skills, initiative, analysis skills, and report writing.

This revised methodology would allow us to both test the skills and competence required for the workplace and enable students to demonstrate their knowledge (fulfilling the assessment criteria for the professional action facet of PBL). Students would be able to demonstrate skills/knowledge across contexts in the laboratory while monitored by staff, and could exemplify their transferable skills during the analysis process in the virtual environment. Therefore, the revised assessment model would also meet the requirements of an interdisciplinary learning PBL model.

The model also offers advantages over current practice in terms of formative assessment. By asking the students to reflect on their performance in the laboratory, they have the opportunity to consider where they might improve. The virtual environment could be configured to permit the students to work through a number of practice analysis exercises before they attempt the summative exercise and could also provide appropriate feedback as they did so. This offers a highly resource efficient method for bespoke formative assessment.

Possible problems with the alternative model

It is of course also instructive to consider possible disadvantages of the revised model. It could be argued that a virtual environment is insufficient and that students should gain experience of handling complex equipment to collect data. However, cost considerations preclude this. In my experience the physical manipulations required to record characterising data are anyway fairly simple, and the different software packages used by different firms are also reasonably consistent. It is the process of conducting the analysis, the general principles of software structure, and the thought process required to reach a satisfactory conclusion which are most challenging. Characterisation may be regarded as akin to the process of tasting and smelling some food. It is not hard to taste or smell something – the skill is in knowing what the food should taste like.

It could also be suggested that the virtual environment will be expensive to establish. While some resource would undoubtedly be required, the LondonMet CELTeLearn team (formerly the Teaching and Learning Technology Centre) together with Faculty of Life Sciences staff could put together a workable virtual environment using Weblearn. Some external assistance may be required to perfect the environment, but this would only require some simple Java programming and should be fairly inexpensive.

Therefore, while there are undoubtedly imperfections in the model, I believe that it provides a practicable solution allowing us to address the most pressing problems with the current methodology by which we assess the practical work of science students.

Conclusion

In this paper, I analyse the current method for assessing the laboratory work of science students. I show that it fails to meet the requirements for assessment in germane problem based learning models and does not allow graduates to demonstrate key attributes required by industry. I suggest a practicable alternative model and explain how this improves on the current situation.

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