Endorsing the practical endorsement? OCR's approach to practical assessment in science A-levels

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ABSTRACT This article summarises the practical requirements for new science A-levels in biology, chemistry and physics for first teaching from September 2015. It discusses the background to how the new approach was reached and how OCR has seen this taking shape in our assessment models. The opportunities presented by this new approach to practical assessment could, we feel, add value to practical teaching and learning within schools and colleges compared with current controlled assessment regimes. The importance and central nature of practical work is undisputed; this article focuses on the potential opportunities of a more holistic, teacher-led approach to development of essential practical skills during A-level science courses.

Perceived failings of the current system – could do better?

The topic of practical activities in science is a constant theme and quite rightly so. In considering the position of practical work, the recent question by Tim Oates, Cambridge Assessment's Group Director of Assessment Research and Development, at a Cambridge Assessment* seminar and at the Association for Science Education (ASE) annual conference (Holman, 2014; Oates, 2014) is often overlooked in the practical debate, that is, why are we doing practical work in the first place? Interestingly, although this question was asked at the start of that seminar and at the ASE conference, it was not fully answered. The debate instead centred on how practical work should be assessed. It may seem odd for an assessment organisation such as OCR to take a position outside of assessment but, especially for practical work in science, we believe a good, rich practical experience is about so much more than can ever be assessed by an awarding organisation.

Assessment is part of the practical equation but as part of a bigger picture, setting up the whole course of study for a young scientist. Any proposal for practical work that misses this point is, we feel, missing a key pillar of practical endeavour; that is, what is most important is how you apply a framework for meaningful skills development. That framework includes assessment, teaching and learning. In this article we aim to show how we have embedded our practical endorsement in teaching and learning.

The concerns of the science community with regard to practical endorsement are well documented (Miller, 2014). At OCR, during the course of our development work, we have spoken to hundreds of teachers and what has surprised us is the under-reported and often very positive response from teachers (and students) about the opportunities potentially provided by the endorsement (Shaha, 2014; Osborne, 2014; OCR *et al*., 2015). We have also found a very positive response from higher education (SCORE, 2014; OCR *et al*. 2015) to the benefits potentially presented by the new practical endorsement approach, for example (Evans, 2014):

> *. . . there has been a drift away from investigative practical work towards shorter experiments with already defined outcomes, because those are required by the current controlled assessment . . . Over the last six years at the University we've seen a noticeable decline in students' practical skills when they arrive to start their degree course. But if you're writing research papers at*

*OCR is part of the Cambridge Assessment Group, Europe's largest assessment agency and a department of the University of Cambridge. Cambridge Assessment develops and delivers assessments throughout the world, operating in over 150 countries.

university the traditional approach (apparatus, method, results, discussion, conclusion) is still the standard format, and for that, you need to have experience of doing practical experiments at A Level. (David Read, Principal Teaching Fellow at the University of Southampton)

If the experiment is not assessed then the student doesn't have to 'prove' anything and can explore and investigate, which is much more fulfilling. The idea that the results of experiments should always be pre-determined is crazy – it misrepresents the very essence of what science is about. (Harriet Jones, Senior Lecturer in the School of Biological Sciences at the University of East Anglia)

What all groups involved with science education and assessment are agreed upon is that current practical assessment does not allow for a rich practical experience for young people and is not even genuinely testing development of practical skills in many instances. Quoting from the Ofqual consultation that closed on 17 January 2014 (Ofqual, 2014):

… the data that we collect from exam boards as part of our review of standards programme shows that current practical skills assessments do not discriminate well between students… Teachers may focus on the skills that are typically required for the assessments at the expense of developing a wider range of skills. The types of assessment task set may not vary greatly year on year, because the exam boards set assessment tasks that can be undertaken in a fixed period of time and use equipment available in sufficient quantity to all students. Teachers can therefore predict the skills their students will be required to demonstrate and can choose to teach accordingly…

In short, Ofqual's key concerns regarding current practical assessment are that it:

- does not discriminate effectively;
- does not often assess skills that could not be better assessed in examinations;
- is open to malpractice;
- constrains teaching, leading to practical work being of limited real value for centres or students.

Ofqual's solution to the noted issues is to propose that practical assessment is covered within a practical endorsement that does not count towards the A-level but is reported separately to avoid pressures on teacher marking to drive malpractice and 'teaching to the test' approaches. Is such a proposal the death of practical work as some have said (Miller, 2014) or the birth of a new period where teachers are liberated from the formulaic approach of controlled assessment to help students develop key practical skills through a two-year A-level course?

This article does not seek to provide a justification for the endorsement approach defined by Ofqual. What it does is start from the position of acknowledging that current practical assessment does not deliver for young people as well as it should. In such a scenario, what could the benefits be for the endorsement if all key stakeholders supported it and embraced the possibilities for rich practical skills development unencumbered by the hoop-jumping world of controlled assessment?

Introducing DAPS (direct assessment of practical skills) and IAPS (indirect assessment of practical skills)

The origins of the Ofqual proposal may be found in the work of Reiss, Abrahams and Sharpe (2012), who proposed that the assessment of practical science could be separated into two categories. It had previously been suggested that practical work could be adequately assessed indirectly, linking the assumption that if such work were adequately recorded then it could be implied that the student had demonstrated practical competence (Welford, Harlen and Schofield, 1985). This approach underpins the notion of indirectly assessing practical work; however, the conclusion reached by Reiss, Abrahams and Sharpe (2013) is that, while a conceptual understanding of the topology of knots might well be assessed by a written task, the most effective means of assessing whether a student is competent in tying their shoe laces is to watch them as they attempt to tie them.

The challenge is to create a scenario in which the teacher can directly assess students carrying out practical tasks that demonstrate competences in skills and techniques. These directly assessed practical skills can be defined and incorporated in a specification. More challenging still is creating the system of assessment for such observation of skills. Classic examples quoted for DAPS are the driving test or taking grades for playing a musical instrument. In such instances, the candidate and assessor are in a one-to-one relationship for a short period of time. Assessing DAPS in the science classroom is not one-to-one; however, the relationship between candidate and assessor, the teacher, is over a much longer term, allowing a more holistic judgement about ongoing competence to be made.

The indirectly assessed portion of the work can be considered in two ways (Table 1). Firstly, questions can be set under examination conditions to demonstrate planning, data manipulation, analysis and evaluation. Secondly, the written reports of practical work carried out can be used to support the teachers' judgements as a means of monitoring the satisfactory completion of practical work within a centre.

What does the new practical endorsement look like?

What is the practical endorsement at A-level? In essence, the practical endorsement:

- requires a defined list of skills and techniques to be assessed during the A-level (see Tables 2 and 3);
- requires a minimum of 12 practical activities (defined by each awarding organisation) to be carried out over the two-year A-level course, covering a common core list of apparatus and technique usage;
- requires each student to keep an appropriate record of their assessed practical activities (for instance, through a lab book);
- requires teacher assessment using Common Practical Assessment Criteria (CPAC), to define a 'Pass' (see Table 4);
- is reported separately from the A-level, as Pass/Fail;
- only applies to A-level (the AS has no practical endorsement).

Ofqual's proposal is clearly heavily influenced by the work on DAPS and IAPS discussed earlier. Ofqual has separated A-level practical assessment into:

- what can be assessed in written examinations; assessment of practical questions counts for a minimum of 15% of the marks available in the examination (IAPS, OCR has included this as a discrete module within our A-level specifications, see Table 2);
- what can only be assessed by teachers seeing practical work being done (the practical endorsement, broadly DAPS, see Table 3).

The practical endorsement is focused around encouraging a wide range of practical activity in centres and developing skills in practical work. It is intended that, by carrying out a set minimum number of practical activities, students acquire a level of competence in practical work that is rewarded within the practical endorsement while aspects of their understanding of practicals are assessed within written papers. Essentially, this requires students to think more about the

Table 1 A comparison of the direct assessment of practical skills (DAPS) and the indirect assessment of practical skills (IAPS); reproduced from Reiss, Abrahams and Sharpe (2012)

	DAPS	IAPS
What is the principle of the assessment?	A student's competency at the manipulation of real objects is *directly* determined as they manifest a particular skill	A student's competency at the manipulation of real objects is *inferred* from their data and/or reports of the practical work they undertook
How is the assessment undertaken?	Observations of students as they undertake a piece of practical work	Marking of student reports written immediately after they undertook a piece of practical work *or* marking of a written examination paper subsequently taken by students
Advantages	• High validity • Encourages teachers to ensure that students gain expertise at the practical skills that will be assessed	• More straightforward for those who are undertaking the assessment
Disadvantages	• More costly • Requires teachers or others to be trained to undertake the assessment • Has greater moderation requirements	• Lower validity • Less likely to raise students' level of practical skills

Table 2 Practical skills required to be assessed in written examinations

Independent thinking	• solve problems set in practical contexts • apply scientific knowledge to practical contexts
Use and application of scientific methods and practices	• comment on experimental design and evaluate scientific methods • present data in appropriate ways • evaluate results and draw conclusions with reference to measurement uncertainties and errors • identify variables including those that must be controlled
Numeracy and the application of mathematical concepts in a practical context	• plot and interpret graphs • process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science • consider margins of error, accuracy and precision of data
Instruments and equipment	• know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification

practical activity and go beyond following instructions, but also requires teachers to provide exposure to a wide range of practical activity during the course.

It is very clear from the list in Table 3 that the endorsement will formally assess a much greater breadth of practical activity than has been done in any recent practical assessments in England.

It is important to highlight that the requirement is for a minimum number of practical activities, not a minimum number of specifically required, named (i.e. pre-identified), core practicals, e.g. dissection of a mammalian heart. Though interpreted widely as the latter, this would be incredibly limiting and is not an approach that OCR has taken. OCR has ensured in its development of the endorsement, detailed below, that we give the freedom for centres to choose the types of practical they could do to meet the requirements and better fit these practicals into their teaching. This approach also allows, for instance, for dissection to be carried out only on plant organs, if that is an issue for a centre or a student.

Teaching and learning

Science teaching and assessment relies very heavily on the use of language and demonstration of mathematical skills, but is also about the measurement, recording and analysis of data that make up the practical work which students have come to expect in GCSE and A-level science lessons. Good teaching effectively links such activities to the learning outcomes of the lesson in a way which can excite, motivate, illustrate and clarify (Wellington and Ireson, 2012).

The role of practical work in science teaching can thus be categorised in a number of ways (Main, 2014), alongside the use of practical equipment by the teacher:

- the introduction to scientific concepts;
- demonstration of physical phenomena;
- familiarisation with apparatus, skills and techniques;
- data gathering and analysis;
- an investigative approach to science;
- planning scientific investigation.

In addition to this, the teacher may use practical demonstration to illustrate concepts or to provide cognitive stimulus when considering complex ideas. This use is supported by Toplis (2012) who distinguishes between '*the cognitive argument*' for practical work in supporting explanation or stimulating discussion to help conceptual understanding and '*the skills argument*', that is, developing an understanding of skills and techniques, which, although they may not be specific to apparatus or techniques encountered in later life, provide a basis for recall and the easy adaptation to any new scientific laboratory environment. The notion of the cognitive argument identifies that the use of practical work is in no way limited to the teaching of practical skills but is essential in the teaching of scientific concepts.

It then becomes apparent that teaching the sciences without any recourse to practical

Table 3 Overview of practical endorsement requirements for skills and techniques, DAPS (see Department for Education (2014) for the detailed requirements listed in the A-level science criteria)

Subject	Use of apparatus and techniques included within the practical endorsement; overview of expectations common across all awarding organisations. Candidates must:
Biology	• use appropriate apparatus to record a range of quantitative measurements • use laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions • use a light microscope at high and low power • produce scientific drawings from observations • use qualitative reagents to identify biological molecules • separate biological compounds using thin-layer/paper chromatography/electrophoresis • safely and ethically use organisms to measure plant/animal responses and physiological functions • use microbiological aseptic techniques • safely use instruments for dissection of an animal/plant organ • use sampling techniques in fieldwork • use ICT such as computer modelling or a datalogger to collect data, or use software to process data
Chemistry	• use appropriate apparatus to record a range of measurements (mass, time, volume, temperature) • use a water bath/electric heater/sand bath for heating • measure pH • use laboratory apparatus for a variety of techniques including: titration, distillation, qualitative tests for ions and organic functional groups, filtration, recrystallisation • use melting point apparatus • use thin-layer or paper chromatography • set up electrochemical cells and measure voltages • safely and carefully handle solids and liquids • measure rates of reaction by at least two different methods
Physics	• use appropriate analogue and digital apparatus to record a range of measurements • use methods to increase accuracy of measurements • use stopwatch/light gates for timing • use of calipers and micrometers for small distances • design, construct and check circuits using dc power supplies, cells, and a range of circuit components • use a signal generator and oscilloscope • generate and measure waves • use a laser or light source to investigate characteristics of light, including interference and diffraction • use ICT such as computer modelling or a datalogger with a variety of sensors to collect data, or use software to process data • use ionising radiation, including detectors

demonstration or experience would be a one-dimensional exercise.

In recent meetings with A-level science teachers it has been repeatedly confirmed that the vast majority in England continually integrate practical work and demonstration to make their lessons two-dimensional.

The addition of genuine context to the teaching and learning then provides the third dimension.

It is our intention to validate the existing use of practical work, integrated into the scheme of work, by using this as the vehicle for the assessment of practical skills and techniques, demonstrating each

Table 4 The summarised Common Practical Assessment Criteria (CPAC) used by all awarding organisations to define the Pass for the endorsement; the full version is available at www.ocr.org.uk/science

Competency	Assessment criteria
1 Follows written procedures	• Correctly follows instructions to carry out the experimental techniques or procedures.
2 Applies investigative approaches and methods when using instruments and equipment	• Correctly uses appropriate instrumentation, apparatus and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting. • Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and making adjustments when necessary. • Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled. • Selects appropriate equipment and measurement strategies in order to ensure suitably accurate results.
3 Safely uses a range of practical equipment and materials	• Identifies hazards and assesses risks associated with these hazards when carrying out experimental techniques and procedures in the lab or field. • Uses appropriate safety equipment and approaches to minimise risks with minimal prompting. • Identifies safety issues and makes adjustments when necessary.
4 Makes and records observations	• Makes accurate observations relevant to the experimental or investigative procedure. • Obtains accurate, precise and sufficient data for experimental and investigative procedures and records this methodically using appropriate units and conventions.
5 Researches, references and reports	• Uses appropriate software and/or tools to process data, carry out research and report findings. • Sources of information are cited demonstrating that research has taken place, supporting planning and conclusions.

student's practical competence. Having the tasks embedded in the teaching and learning adds validity to the assessment as a part of the entirety of the course, rather than a one-off event that is distinct from the students' ongoing learning (Stobart, 2008).

Because we are aware of the importance of matching the scheme of work to the learners, along with differing lesson patterns, technician resourcing and availability of equipment, we are not dictating specific required practicals; rather, we will provide a range of practical activities for each of our 12 practical activity groups (PAGs).

Teachers will also have different teaching approaches and may choose to use more open-ended tasks or to collect data to inform ongoing teaching and learning.

This validates the use by teachers who embed the practical work into their teaching to use more open-ended tasks. These may be at the outset of the teaching sequence for a topic, creating a stimulus for the subsequent learning yet still being able to credit students with the appropriate skills and techniques used.

Initially, the practical work is intended to be structured in such a way as to lead students through the process, allowing them to become familiar with the equipment or to observe anticipated outcomes (see Figure 1 later). As the students become more adept, the work set may become less structured, allowing the student to demonstrate planning and investigative skills, including problem solving.

Research suggests that it is a slow process to change teachers' practice and that it requires sustained support, including time to reflect and share experiences with other practitioners and trainers (Black, 2012).

OCR's approach

OCR's approach to practical assessment has started from the central principle of allowing a wide range of practical activities to be carried out rather than limiting the practical experience to a number of core practicals (Table 5). Our approach has also ensured that the requirement to develop investigative skills over the course (see

Table 5 A summary of the first six practical activity group (PAG) requirements for the OCR chemistry practical endorsement; full lists are available at www.ocr.org.uk/science

Practical activity group (PAG)	Techniques/skills covered (minimum)	Example of a suitable practical activity (a range of examples will be supplied by OCR website or centres can also devise their own activity)
1 Moles determination	• Measurement of mass • Measurement of volume of gas	Determination of the composition of copper(II) carbonate
2 Acid–base titration	• Measurement of volume of a liquid • Use of volumetric flask, including accurate technique for making up a standard solution • Titration, using burette and pipette • Use of acid–base indicators in titrations of weak/strong acids with weak/strong bases	Titration of sodium hydrogencarbonate against hydrochloric acid
3 Enthalpy determination	• Measurement of temperature	Determination of the enthalpy change of neutralisation
4 Qualitative analysis of ions	• Use of apparatus for qualitative tests for ions • Make and record qualitative observations	Identification of the anions and cations present in a mixture of Group 2 salts
5 Synthesis of an organic liquid	• Heating under reflux* • Purification using a separating funnel • Distillation • Risk assessment	Synthesis of a haloalkane
6 Synthesis of an organic solid	• Purification by recrystallisation • Use of melting point apparatus • Use of thin-layer or paper chromatography • Filtration • Heating under reflux* • Risk assessment	Synthesis of aspirin

* These techniques/skills may be covered in *either* of the groups indicated.

Table 4 and Figure 1) is embedded in the design of the PAG requirements. The 12 PAGs (Table 5) together cover all the skills and techniques that must be covered during the two-year A-level course (Tables 2 and 3) and also embed a logical progression from the start to the end of the course (as required by all awarding organisations to cover Competency 2; see Table 4, 'investigative nature'). We have deliberately not created 12 'core practicals' as this would be limiting for assessment, place undue logistical pressures on centres and be uninspiring for teachers and students alike.

We have focused on the practical skills being developed. For instance, in biology our PAG 2, dissection (see Figure 1), allows teachers to carry out a dissection experiment appropriate to the resources available in their centre. This is rather than one specific and limiting specified dissection, for example of an insect.

We define the types of skills that should be covered within the dissection activity rather than the specific dissection that must be carried out, the latter being best left to the teacher's judgement. Teachers are given a scaffold of the requirements for each PAG (see Table 5) and can either devise their own practical activity (with support from OCR) or follow one of the selection of practical activities supplied by OCR. Student progress can be tracked using teacher-created documents or with OCR's *Progress Tracker* (Figure 2).

What next for the endorsement?

Between September and December 2014 there was a trial across the awarding organisations (OCR *et al.*, 2014) of the CPAC (Table 4). The trial supported many of the pertinent points detailed in this article. Twenty-two centres, including comprehensive schools, academies, independent schools, sixth-form colleges and colleges of further education,

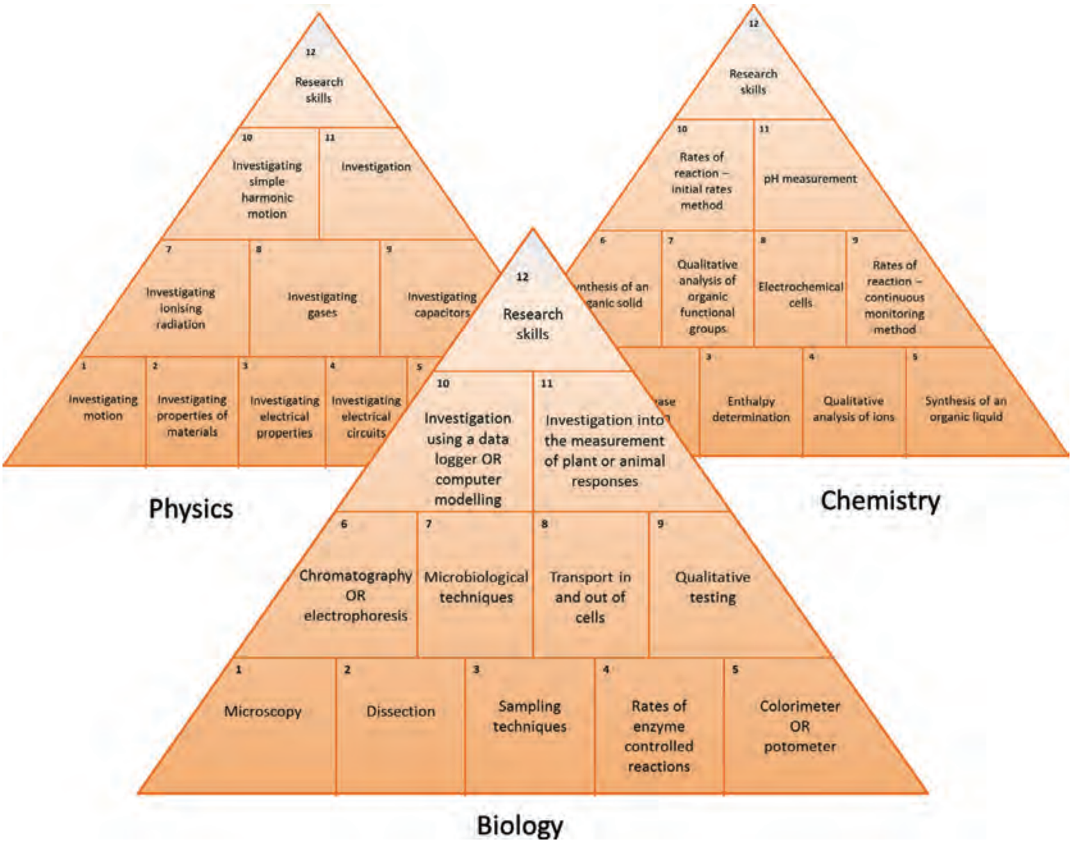

Figure 1 The OCR endorsement showing the 12 required practical activity groups (PAGs 1 to 12, ©OCR). The OCR endorsement is a common model across all three sciences with the CPAC requirement for development of investigative skills (Table 4) integrated into the model through the two-year course. Practical activities towards the top of the triangle are less scaffolded and more open-ended and would be anticipated for completion in the second half of the two-year course. Activities at the base of the triangle cover the more core techniques, include more guidance for students and would be intended for coverage earlier in the A-level course. OCR supplies example activities for each of PAGs 1 to 12 or centres can devise their own with support/guidance from OCR subject specialists if required.

volunteered and carried out practical activities that they judged against the CPAC requirements.

The key findings were that centres were able to successfully interpret the CPAC and monitors were able to substantiate their judgements. Comments made included (OCR *et al.*, 2014):

This is a great opportunity to make skills in the science for practical work play a larger role…

CPAC… relatively easy to judge, once I had decided my criteria for each lesson…

Most students felt the new system would be an improvement since it is not 'all or nothing' on one day.

The completion of trialling should lead to a finalisation, by Ofqual, of requirements for monitoring of the practical endorsement by Spring 2015. The process of development has been a long one but many teachers have been involved in shaping the assessment. The potential for the endorsement to genuinely allow students to develop practical skills in a much more meaningful way than has been done in recent assessments, with teachers empowered to use their expert judgement, is very attractive indeed.

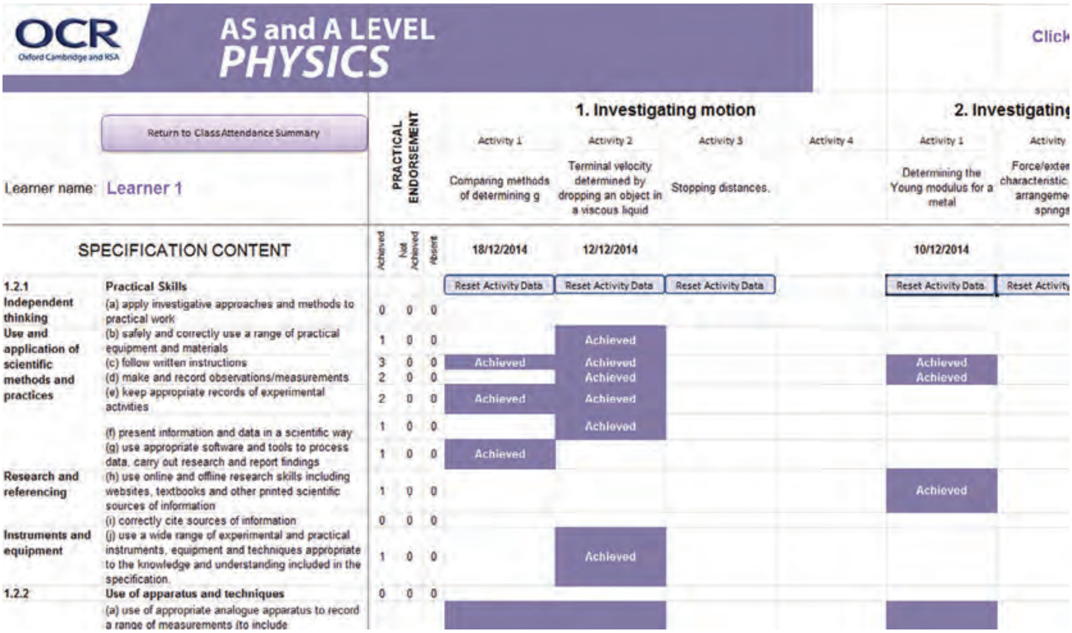

Figure 2 The optional PAG *Progress Tracker* (screenshot © OCR). All OCR PAGs are mapped against the endorsement requirements. Teachers completing an OCR PAG simply indicate the date and the file then autocompletes all information for the teacher. The tracker also allows both the class teacher and the centre coordinator to view ongoing progress of a class or cohort and to identify students who may need encouragement and support or are in danger of failing. For planning, it allows selection of the intended practical activities and opportunity to ensure all required outcomes are being met

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