

Coursework and practical assessment in senior secondary science: the perspective from international jurisdictions

Summary paper

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1. Introduction

In reviewing the subject specifications for Leaving Certificate biology, chemistry and physics, the National Council for Curriculum and Assessment (NCCA) is considering how practical assessment might be incorporated.

The NCCA's work in this area has been informed by research¹ that has identified some challenges to the introduction of a practical science examination in the Leaving Certificate. To further inform its review, the NCCA commissioned a short investigation of upper secondary (senior cycle) practical science assessment arrangements in international jurisdictions. The desk study investigation aimed to provide an insight into the role of practical assessment or coursework components in the assessment arrangements in place for biology, chemistry and physics in these jurisdictions.

This paper summarises the findings from the desk study examination of senior secondary practical science assessment arrangements in England, Hong Kong, Scotland and Singapore. It is also informed by the practical science assessment arrangements in the *International Baccalaureate Diploma Programme*, and by a top-level analysis of senior secondary science assessment arrangements in top-performing PISA jurisdictions².

The study examined publicly available documents from international organisations (e.g. the IBO and OECD), and from national education ministries and curriculum and qualification agencies, to provide information covering:

- how biology, chemistry and physics are assessed, and the range of assessment modes and methods used
- where coursework forms part of the assessment, how this is organised; the topics and skills that it assesses; how it is marked and moderated; and its contribution towards the final examination grade
- where there is a practical examination or practical activity/investigation component to assessment, how this is organised; the topics and skills that it assesses; how is it marked and moderated; and its contribution towards the final examination grade
- how achievement in practical science is recorded and reported
- the focus of any recent reforms in practical science assessment.

Detailed tables for England, Hong Kong, Scotland, Singapore, the *International Baccalaureate Diploma Programme*, and the top-performing PISA science jurisdictions form the basis for, and the Appendix to, this summary report. These tables include direct access (via url links) to all the documents used in the desk research.

¹ State Examinations Commission (2018). *Report on the Trialling of the Assessment of Practical Work in Leaving Certificate Biology, Chemistry and Physics* [online]. Available: <https://www.examinations.ie/misc-doc/EN-AU-52990956.pdf> [24 July, 2019].

² Based on OECD (2018). *PISA 2015: PISA Results in Focus* [online]. Available: <https://www.oecd.org/pisa/pisa-2015-results-in-focus.pdf> [24 July, 2019] (page 5).

2. Models of assessment in international jurisdictions

In the four international jurisdictions and the *International Baccalaureate Diploma Programme* which are the focus of this study, practical assessment in senior cycle biology, chemistry and physics includes:

- internally assessed practical activities/school-based assessments
- coursework assignments/individual investigations
- external practical examinations.

Table 1 summarises the models in place.

Table 1: Practical science assessment models in international jurisdictions

<p>England</p>	<p>Practical skills in <i>A Level</i> biology, chemistry and physics are assessed:</p> <ul style="list-style-type: none"> • indirectly, through questions in the written examinations which relate to the theory and application of practical skills • directly through internal practical science activities/assessments based on teachers' observation of students' competency in a range of skills. <p>It is intended that at least 15% of the marks available for the assessments by written examination in biology, chemistry and physics should come from questions or tasks which indirectly assess a learner's practical skills.</p> <p>For direct assessment, there are a minimum of 12 practical activities/assessments during the two-year course.</p>
<p>Hong Kong</p>	<p>Assessment arrangements for the <i>Hong Kong Diploma of Secondary Education</i> (HKDSE) examinations in biology, chemistry and physics include:</p> <ul style="list-style-type: none"> • a written examination component which assesses students' knowledge and skills and their ability to apply this knowledge • school-based assessment (SBA), administered by students' own teachers. <p>SBA in the science subjects aims to enhance the validity of the assessment by assessing students' practical and generic skills. It looks to make assessment more comprehensive by assessing the skills that can't be assessed by conventional written examinations.</p>
<p>Scotland</p>	<p>Assessment for the <i>Higher</i> qualifications in biology, human biology, chemistry and physics includes:</p> <ul style="list-style-type: none"> • two written question papers (examinations) • a coursework assignment which assesses the application of skills of scientific enquiry and knowledge and understanding. <p>The coursework assignment aims to allow the assessment of skills that can't be assessed by a written question paper, such as handling and processing data gathered through experimental work and research skills.</p> <p style="text-align: right;">./.</p>

./.	Table 1: Practical science assessment models in international jurisdictions
Singapore	<p>Assessment for the <i>Higher 2 (Singapore Cambridge) GCE A Levels</i> in biology, chemistry and physics includes:</p> <ul style="list-style-type: none"> • three written examinations, plus • a practical examination (paper 4)³. <p>The practical examination is designed to assess students' competence in those practical skills which can realistically be assessed within the context of a practical assessment.</p>
International Baccalaureate (IB) Diploma Programme	<p>In biology, chemistry and physics, <i>IB Diploma Programme</i> courses include:</p> <ul style="list-style-type: none"> • written examinations • in-school assessment in the form of a student-initiated individual investigation/research project. <p>The individual investigation in biology, chemistry and physics is intended to allow students to provide evidence of achievement against objectives that do not lend themselves to external examination. It aims to be flexible in the choice of topic so that it offers a valuable addition to students' education. It also looks to improve the validity of the assessment process and learning experience as a whole.</p>

Including a practical element to improve the validity of the assessment process in senior secondary science appears to be a common theme.

In England and Hong Kong, guidance documents emphasise that the 12 practical science activities/assessments in England and the SBA in Hong Kong should not take the form of examinations/mini examinations, nor should they be an 'add-on' element in the curriculum. They state that SBA (Hong Kong) should be:

'an integral part of the learning and teaching process, with curriculum time allocated for key activities [...] within the regular school day', and integrated 'with [...] internal assessment practices so that SBA forms a natural part of [...] daily work and replaces some [...] existing assessment practices' (HKEAA, 2018a, p.3).

In England similarly, the practical science activities are intended to be part of the teaching and learning of the whole subject, with 'the assessment designed to assess students demonstrating the skills over a period, not just as a one-off (Ofqual, 2015, p.3).

The curriculum and assessment guides for HKDSE biology, chemistry and physics in Hong Kong also state that, in addition to enhancing the validity of assessment (Table 1), SBA:

- reduces dependence on the results of external, written public examinations, which may not always provide the most reliable indication of the actual abilities of candidates

³ There are also Higher 1 and Higher 3 GCE A Level examinations. These do not include a practical examination.

- enables assessment based on student performance over an extended period of time and developed by those who know the students best – their subject teachers – and so provides a more reliable assessment of each student
- promotes a positive ‘backwash effect’ on students, teachers and school staff by, for example, serving to motivate students by requiring them to engage in meaningful activities, and by encouraging teachers to reinforce curriculum aims and good teaching practice, and to provide structure and significance to an activity they are involved in on a daily basis, i.e. assessing their own students.

2.1 Internal practical assessments in England and Hong Kong

The study has highlighted that practical assessment in senior secondary science in England and Hong Kong is school-based, and intended to form an integral part of day-to-day teaching and learning activity. Table 2 below summarises the other key features of this school-based assessment in the two jurisdictions.

Table 2: Key features of school-based assessment in England and Hong Kong

<p>England</p>	<ul style="list-style-type: none"> • A minimum of 12 practical activities are completed throughout the two-year <i>A Level</i> courses in biology, chemistry and physics. These activities are assessed and observed by the student’s teacher(s). • At the end of the course, the student’s lead teacher assesses the practical activities as ‘pass’ or ‘unclassified’ (fail); there is no (granulated) grading. The pass or unclassified judgement is based on the record of the ongoing judgements made by teachers against the assessment criteria for the 12 practical activities. • The criteria for a pass are the same for all three subjects and include: follows written procedures; applies investigative approaches and methods when using instruments and equipment; safely uses a range of practical equipment and materials; makes and records observations; and researches, references and reports. • The assessments do not contribute to the final <i>A Level</i> grade, but a ‘practical endorsement’ (pass or unclassified) is reported alongside the student’s <i>A Level</i> grade for the written examinations. • Although the practical assessment does not contribute towards the final <i>A Level</i> grade, the majority of universities will ask for a pass in the practical science endorsement when making their offers to students seeking to begin a higher education science course. • The assessment arrangements are intended to promote frequent practical work that is closely integrated with subject content and covers a breadth of skills. • To monitor the delivery and marking of practical assessments, the external awarding organisations (exam body) for the qualifications must complete monitoring visits to schools (examination centres) at least every two years.
<p>./.</p>	<p>Table 2: Key features of school-based assessment in England and Hong Kong</p>

<p>Hong Kong</p>	<ul style="list-style-type: none"> • School-based assessment (SBA) for the <i>Hong Kong Diploma of Secondary Education</i> (HKDSE) examinations in biology, chemistry and physics involves assessment of student performance in practical work/practical-related tasks at different times during the final two years of the HKDSE course. • Teachers set and mark SBA tasks and are expected to devise them so that students are exposed to a variety of experiences covering different topics of the curriculum. In setting the tasks, they are also expected to bear in mind the workload of students and to avoid asking them to do a lot of work outside class time. Teachers are also recommended to complete most tasks, other than fieldwork or research, within school hours. • SBA tasks are intended to: help students to develop science process skills and other generic skills outlined in the curriculum; enable them to achieve a balanced integration between theory and practice; be appropriate to the topic taught, and suit the strength and ability of the students; and enable differentiation of students in their demonstration of the ability assessed. Teachers can design their own tasks or use or modify sample tasks provided by the Hong Kong Examinations and Assessment Authority (HKEAA). • To ensure that teachers arrange a reasonable range of practical activities for students, a minimum number of eight practical-related tasks are stipulated throughout the two years and, when submitting their assessment marks to the HKEAA for moderation, teachers are required to submit a list of assessment tasks completed over the two years, showing coverage of different types of work. • The HKEAA uses a statistical moderation method to moderate the SBA scores submitted by schools. This involves adjusting the average and spread of the SBA scores of students in a given school with reference to the written examination scores of the same group of students, supplemented with review of samples of students' work.
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2.2 Coursework assignments in Scotland and individual investigations in the *IB Diploma Programme*

Coursework assignments in Scotland and *IB Diploma Programme* individual investigations are research projects for which the topic is selected by students, with the support and guidance of their teachers. Table 3 summarises the key features of these assignments/investigations.

Table 3: Key features of coursework/investigations in Scotland and the *IB Diploma Programme*

<p>Scotland</p>	<ul style="list-style-type: none"> • The coursework assignment has two formal assessment stages: <ul style="list-style-type: none"> ○ research - experimental work which, for example, allows measurements to be made and data to be gathered, and during which students must gather information from the internet, books or journals ○ report - students produce a report on their research. • Assignments are set by individual schools/colleges within guidelines published by the Scottish Qualifications Authority (SQA). They are an individually produced piece of work from each student, based on their chosen topic/research question, which is started at an appropriate point in the course and conducted under 'controlled conditions'. • Under these controlled conditions, the SQA recommends that no more than 8 hours is spent on the whole assignment. A maximum of 2 hours is allowed for the report stage. • Controlled conditions are designed to: ensure that all candidates spend approximately the same amount of time on their assignments; prevent third parties from providing inappropriate levels of guidance and input; mitigate concerns about plagiarism; and ensure reliability and validity, at the same time as allowing schools and colleges a reasonable degree of freedom and control, and allowing candidates to produce an original piece of work. • Students can carry out the assignment research individually or as part of a small group, e.g. where experimental work is labour- or time-intensive. The assignment report is an individual report, submitted to the SQA for external marking. • Coursework assignments aim to assess the application of skills of scientific enquiry and knowledge and understanding. They also look to offer challenge, by requiring students to apply skills, knowledge and understanding in a context that is one or more of unfamiliar; familiar but investigated in greater depth; or that integrates a number of familiar contexts.
<p><i>IB Diploma Programme</i></p>	<ul style="list-style-type: none"> • The individual investigation is an independent research project, which aims to show appreciation of the scientific context in addressing a purposeful research question incorporating a scientific rationale. The student comes up with the research question and methodology, while the teacher acts as a guide. • A wide range of investigations (laboratory/exploratory work) is permitted, including, for example, a hands-on approach, modelling and spreadsheet analysis, computer simulation analysis, online database analysis or a combination of these. • The investigation and write-up - in the form of a report of between 6 and 12 pages - is internally assessed by a student's own teacher(s) and externally moderated by the IB. • In addition to the individual investigation, students also take part in prescribed practical activities and a collaborative group project during the Diploma Programme course. The collaborative project aims to develop an understanding

	of the relationships between scientific disciplines and their influence on other areas of knowledge. Only the individual investigation, however, contributes towards the marks for the final <i>IB Diploma Programme</i> assessment.
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In producing their assignment/individual investigation reports, students are allowed some support from their teachers. In Scotland, for example, the term ‘reasonable assistance’ is used to describe the support that teachers may give to students before the formal two-hour report writing process takes place. Teachers must though not provide any form or feedback to the student on their report, nor must they allow them to redraft it. They must also not read it before submitting it to the SQA for marking. For the *IB Diploma Programme*, students generally submit a first draft individual investigation to their teacher(s), who will make general comments and annotations regarding its strengths and weaknesses, but these should not be corrections. Students then revise their report before final submission to their teacher(s) for internal marking (and IB moderation).

2.3 External practical examinations in Singapore

In Singapore, the practical examination evaluates students’ experimental and investigative skills. It is scheduled first in the examinations timetable and students are divided into three shifts to take the exams, which are administered and marked by the Singapore Examinations and Assessment Board (SEAB).

Practical papers last 2 hours 30 minutes and consist of a variable number of compulsory practical questions; students are expected to attempt them all. Questions assess the skills of: planning; manipulation, measurement and observation (MMO); presentation of data and observations (PDO); and analysis, conclusions and evaluation (ACE). Assessment of MMO, PDO and ACE usually requires access to apparatus, although the assessment of skill areas PDO and ACE may also include exam questions on data-analysis (data handling/interpretation) which do not require practical equipment and apparatus. In some practical examinations, candidates may have access to apparatus and materials for specific questions for a specified time. They may also be told which question(s) to attempt first.

The syllabus documents include lists of the apparatus and reagents that are expected to generally be available for examination purposes. Practical examinations may also require additional apparatus and materials; if this is the case, this is specified in the confidential instructions to teachers distributed with the examination. The apparatus and material requirements for the practical examination vary year on year.

Candidates are not allowed to refer to notebooks, textbooks or any other information in the practical examination, although, in the chemistry examination, qualitative analysis notes are included in the question paper for candidates’ use.

The models in place for the assessment of practical science in senior secondary education in England, Hong Kong, Scotland, Singapore and the *IB Diploma Programme* reflect those in place across the top-performing PISA jurisdictions in science, which include:

- internal, school-based assessment - which may be a school-set and marked examination; or the assessment of practical work such as scientific investigations, laboratory work or fieldwork throughout the course
- internal, school-based assessment - as above but externally moderated
- internally marked coursework/scientific research project
- internally marked coursework/scientific research project, externally moderated
- externally marked coursework
- external practical examinations.

In around a third of the PISA top-performing science jurisdictions reviewed for this study, there appears to be no form of practical assessment or coursework component in senior secondary science. In these jurisdictions, which include Japan, Finland and South Korea, written science examinations are the main form of assessment. As in England, however, these written examinations may aim to indirectly assess the theory and application of practical skills.

3. Skills assessed in practical science assessments

The science practical activities in England, school-based assessment in Hong Kong, the coursework assignment in Scotland, and individual investigations in the *IB Diploma Programme* all have as an aim that they allow the assessment of skills that don't lend themselves to external examination via a conventional, written question paper.

The practical examination in Singapore, on the other hand, is designed to assess students' competence in those practical skills which can realistically be assessed within the context of a practical assessment.

There are though similarities across the jurisdictions, and across the science subjects, regardless of the format or method of the practical assessments, in the skills these assessments look to assess. These are summarised, and the similarities colour-coded, in Table 4.

The weighting of the practical assessment component, in terms of the overall senior secondary science examination result, is also similar across subjects and jurisdictions. This is summarised in Section 4 on 'Recording and reporting'.

Table 4: Skills assessed in practical science assessment in international jurisdictions

England	<ul style="list-style-type: none"> • Independent thinking: apply investigative approaches and methods to practical work • Use and apply scientific methods and practices
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<p>There are four skills for direct assessment through practical activities in all three sciences:</p>	<ul style="list-style-type: none"> ● Research and referencing: use online and offline research skills and referencing ● Use a wide range of appropriate experimental and practical instruments, equipment and techniques
<p>Hong Kong SBA in HKDSE biology assesses:</p> <p>SBA in HKDSE chemistry assesses:</p> <p>SBA in HKDSE physics assesses:</p>	<ul style="list-style-type: none"> ● Organising and performing practical work, using suitable apparatus and equipment <ul style="list-style-type: none"> ● Making accurate observations and measurements ● Planning and reporting scientific investigation <ul style="list-style-type: none"> ● Volumetric analysis (VA) ● Qualitative analysis (QA) ● Experimental work (EXPT) (perform experiments and report on them) or investigative study (IS), which includes assessment of the ‘proposal’ (planning) and of the ‘process and report’ ● Experimental work (EXPT) (performing experiments and producing a detailed report) ● Investigative study (IS) (planning a study/experiment [design]; undertaking the experiment [process]; and reporting on it [report])
<p>Scotland The coursework assignment aims to give students the opportunity to demonstrate the skills, knowledge and understanding of:</p>	<ul style="list-style-type: none"> ● Applying subject knowledge to new situations, interpreting information and solving problems ● Planning, designing and safely carrying out experiments/ practical investigations to test given hypotheses or to illustrate particular effects ● Selecting information from a variety of sources ● Presenting information appropriately in a variety of forms ● Processing information (using calculations and units, where appropriate) ● Making predictions and generalisations based on evidence/information ● Drawing valid conclusions and giving explanations supported by evidence/justification ● Evaluating experiments/practical investigations and suggesting improvements ● Communicating findings/information effectively
<p>Singapore For all three sciences, the practical examination assesses the skill areas of:</p> <p>For biology, it specifically assesses:</p>	<ul style="list-style-type: none"> ● Planning <ul style="list-style-type: none"> ● Manipulation, measurement and observation (MMO) ● Presentation of data and observations (PDO) ● Analysis, conclusions and evaluation (ACE) <p>1. Following a detailed sequence of instructions or applying standard techniques</p>

For chemistry, it assesses:	<ol style="list-style-type: none"> 2. Devising and planning investigations which may include constructing and/or testing a hypothesis and selecting techniques, apparatus and material 3. Using techniques, apparatus and materials safely and effectively 4. Making and recording observations, measurements and estimates 5. Interpreting and evaluating observations and experimental data 6. Evaluating methods and techniques, and suggesting possible improvements
For physics, it assesses:	<ol style="list-style-type: none"> 1. Following a detailed set or sequence of instructions and using techniques, apparatus and materials safely and effectively 2. Making, recording and presenting observations and measurements with due regard for precision and accuracy 3. Interpreting and evaluating observations and experimental data 4. Identifying a problem, devising and planning investigations, selecting techniques, apparatus and materials 5. Evaluating methods and techniques, and suggesting possible improvements
IB Diploma Programme The individual investigation covers four assessment objectives	<ul style="list-style-type: none"> • Demonstrating knowledge and understanding • Applying knowledge and understanding • Formulating, analysing and evaluating • Demonstrating the appropriate research, experimental, and personal skills necessary to carry out insightful and ethical investigations

4. Recording and reporting

Practical assessment in biology, chemistry and physics commonly contributes 20% of the final mark for senior secondary qualifications (Table 5).

Table 5: The contribution of practical science assessment to final qualification grades

England	The 'pass' or 'unclassified' 'practical endorsement' does not contribute towards the final grade for <i>A Level</i> biology, chemistry or physics.
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Hong Kong	School-based assessment accounts for 20% of the final <i>Hong Kong Diploma of Secondary Education</i> (HKDSE) examination mark in biology, chemistry or physics.
Scotland	The coursework assignment for the <i>Higher</i> qualifications in biology, human biology, chemistry and physics accounts for 20% of the overall course mark.
Singapore	The paper 4 practical examination for the <i>Higher 2 (Singapore Cambridge) GCE A Levels</i> in biology, chemistry and physics accounts for 20% of the final mark.
IB Diploma Programme	The individual investigation for the Diploma Programme courses in biology, chemistry and physics accounts for 20% of the final grade.

Looking at the brief analysis of the PISA top-performers in science completed to support this desk study, only in Queensland does practical assessment appear to contribute more towards the final mark. The credit-based Queensland Certificate of Education (QCE) is assessed via internal and external assessment. Internal assessment for students studying QCE biology, chemistry and physics includes a data test, a student experiment, and a research investigation which account for 50% of the total marks; the remaining 50% come from an external examination.

Where teachers mark assessments which are then externally moderated (e.g. in SBA in Hong Kong and for the individual investigation in the *IB Diploma Programme*), assessment criteria/an assessment framework and a marking scale are provided by central authorities. In the Diploma Programme, for example, 25% of the available marks are awarded for each of exploration, analysis, and evaluation, while the remaining marks are awarded for personal engagement (8%) and communication (17%). In HKDSE biology, the 20% of the final qualification marks from SBA come from a student's best two SBAs of practical activities (8%), and from his/or her best two SBAs for planning and reporting of scientific investigation (12%). In chemistry, this 20% comes from one SBA over the two years in each of volumetric analysis (VA) and qualitative analysis (QA) (5%) each, and from two assessments of experimental work or investigative study (IS) (5% each). In physics, the 20% comes from a student's best three SBA results: 6% each from two experiments/experimental work assessments, and 8% from an experiment with a detailed report, or an investigative study (IS).

In Scotland, where the coursework assignment report is marked externally, the marking scale allocates 1 of the 20 available marks to the coursework aim; 4 to underlying biology; 5 to data collection and handling; 4 to graphical presentation; 1 to analysis; 1 to the conclusion; 3 to the evaluation of the investigation; and 1 to structure. In Singapore, equal weighting is given in the marking of the practical examinations to the skills of manipulation, measurement and observation (MMO); presentation of data and observations (PDO); and analysis, conclusions and evaluation (ACE). Lesser weighting is accorded to the skill of planning.

4.1 Guarding against malpractice

To ensure validity of the results of practical assessments and/or respond to concerns of malpractice, jurisdictions commonly provide detailed guidance for teachers. They may also:

- provide common practical assessment criteria (England, Hong Kong, *IB Diploma Programme*)
- provide specific guidance for those instances where students are permitted to take part in group work as part of practical science assessment (England, Hong Kong, Scotland)
- require teachers to confirm that the work they present for external moderation is the student's own work (Hong Kong)
- require schools to confirm that school-based assessment has been conducted in accordance with requirements (England, Hong Kong)
- use external statistical moderation of teacher assessment results (Hong Kong, *IB Diploma Programme*)
- conduct monitoring visits (England, Hong Kong)
- require students to sign a declaration form regarding proper conduct (Hong Kong)
- provide teachers with specific guidance on the level of assistance they can provide to students (Hong Kong, Scotland, *IB Diploma Programme*)
- produce an annual malpractice report (Scotland).

The statistical moderation method used by the Hong Kong Examinations and Assessment Authority (HKEAA) to moderate the SBA scores submitted by schools involves adjusting the average and spread of the SBA scores of students in a given school with reference to the written examination scores of the same group of students. This is supplemented by a review of samples of students' work (HKEAA, 2018b). For the individual investigations in the *IB Diploma programme*, the IB selects a sample for external moderation and every school has a sample of their marking re-marked by a moderator. Statistical comparisons and linear regression techniques are used to determine the degree to which the original teacher's marks may need adjusting to bring them in line with set standards.

The annual malpractice report produced by the Scottish Qualifications Authority (SQA) highlights the number of instances of malpractice reported each year; the principal types of malpractice identified; and the measures taken as a result to safeguard the integrity of qualifications. Concerns of malpractice can come from individual teachers, schools or colleges, or from parents, but, in the majority, concerns are identified by the SQA during the course of marking and quality assurance processes. The malpractice report for 2018 (SQA, 2019) identified 'not applying the assessment conditions' as the most prevalent instance of malpractice. This included instances where group-work approaches were used in instances where candidate evidence must be generated independently; access to more than the permitted resources; and assessments completed in more than the permitted number of sittings. The level of direction provided for assessments also featured in the malpractice report. A finding of malpractice may lead to the provision of specialist support to ensure compliance; a requirement for increased quality assurance monitoring; the withdrawal of approval to a school or college to offer specific qualifications; or to adjustments to candidate marks. The latter may, in turn, affect students' certificated award.

5. Recent reforms

Table 6 summarises recent changes that have taken place in the assessment of practical science in the international jurisdictions that are the subject of this study. It is followed by a short commentary on the impetus for and impact of these changes.

Table 6: Changes in practical science assessment in the international jurisdictions

England	Moved from a system:	Moved to a system:
	<ul style="list-style-type: none"> • of modular (unit) assessment • where all assessment of work in practical science contributed to the overall <i>A Level</i> grade • where practical work was assessed through tasks set either by the exam board or by teachers, that were marked either by the teacher or by the exam board • that also included individual investigative projects, which were written up as a coursework component that could be marked by teachers or sent to the exam board for marking 	<ul style="list-style-type: none"> • where assessment is linear, through end-of-course written examinations • where other types of assessment, such as practical science assessment, are used only where needed to test specific skills • where practical science assessment is reported alongside the <i>A Level</i> grade (for the written examination component) but does not contribute towards the overall grade
Hong Kong	<ul style="list-style-type: none"> • of two sets of external secondary examinations (the Hong Kong Certificate of Education Examination, HKCEE and the Hong Kong Advanced Level Examination, HKALE) 	<ul style="list-style-type: none"> • of one set of examinations - the <i>Hong Kong Diploma of Secondary Education</i> (HKDSE) examinations, which include a school-based assessment (SBA) component for the science examinations
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	Moved from a system:	Moved to a system:
Scotland	<ul style="list-style-type: none"> • with a unit structure, in which students had to pass mandatory <i>Higher</i> qualification ‘unit assessments’ as they progressed through the course. These unit assessments were in addition to course assessment (written examinations and coursework assignments) 	<ul style="list-style-type: none"> • of course assessment (written examinations and coursework assignments) only

Singapore	<ul style="list-style-type: none"> of internal School-based Practical Assessment (SPA), which involved teachers administering a series of three practical assessments over the course 	<ul style="list-style-type: none"> of external assessment via a practical examination
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The **impetus** for change in England was linked, to a degree, to the potential for malpractice in the previous system of assessing practical work in science. There were also concerns regarding the limited ability to validate results across the various exam boards for biology, chemistry and physics *A Levels*; and concerns that many students were achieving similar grades for practical work. These were often 'bunched' at the high end of the mark range, and so did not discriminate effectively. At the same time, higher education institutions expressed some concerns about the level of practical skills of students entering their courses.

In Hong Kong, the introduction of the HKDSE aimed to create more space and time in the curriculum (by replacing two examinations with one) and so enrich students' learning experience and enhance the effectiveness of learning. It aimed also, through the more diverse HKDSE curriculum to cater to the needs of students with different aptitudes, needs and abilities. The specific introduction of the SBA in practical science aimed primarily to enhance the validity of the assessment; reduce dependence on the results of external, written public examinations, which may not always provide the most reliable indication of the actual abilities of students; and to have a positive 'backwash effect' by requiring students to engage in meaningful activities, and encouraging teachers to reinforce curriculum aims and good teaching practice.

In Scotland, the mandatory unit assessments previously required to achieve *Higher* qualifications were removed in the 2018/19 school year. Course assessment for science *Highers* now includes examinations and coursework assignments only. The intention of the changes is to reduce the amount of assessment experienced by young people; reduce teacher workload created as a result of administering the units; and help assessment approaches to benefit teachers and learners by focusing on skills and their application, along with knowledge and understanding, and by supporting learning and teaching, rather than driving them.

In Singapore also there had been concerns that the previous system of ongoing internal School-based Practical Assessment (SPA) for science subjects (like the unit assessments for *Highers* in Scotland) had been driving teachers to focus their practical work on drilling students for the SPA. Some of the lower secondary science examinations had previously included terminal, externally assessed practical examinations, and the Ministry of Education judged that practical experiences for students were not so narrow when this approach was used.

There have been some concerns about the potential **impact** of the change to the assessment of practical science activities in England, which do not contribute towards the final *A Level* grade. In particular, it

was felt that the changed system would result in schools treating practical science as less of a priority and that, as a result, students' practical skills would decline. Ofqual research (Ofqual, 2019) has, however, concluded that, across the three science subjects, there is no evidence to suggest that practical skills have declined as a result of the changes.

In Scotland, the removal of the mandatory unit assessments for science *Highers* has resulted in changes to the requirements for the examination and coursework parts of the assessments. To ensure that students are still assessed on the full content of the course, and to protect the integrity of courses so that they maintain their value on the Scottish Credit and Qualifications Framework, some science examination question papers have been extended to cover more content. This has usually meant extending the amount of time allowed for a question paper, and has resulted in some papers being separated into two. In all science subjects, the weighting of the coursework assignment contribution to the final mark for the qualification has been increased to the current 20%.

6. Concluding remarks

This summary paper has highlighted the forms of practical science assessment in place in international jurisdictions, the aims for and organisation of this practical assessment, and the types of skills assessed. It has also examined some of the measures taken to ensure the validity, reliability and robustness of practical assessments, along with some of the challenges experienced in international jurisdictions in implementing practical science assessment in senior secondary education.

In summarising the key factual information from the detailed tables provided as an Appendix to this report⁴, the report has briefly examined how international jurisdictions look to:

- ensure that practical science assessments do not unduly increase the workload of both teachers and students, e.g. by requiring schools to integrate practical science assessment into day-to-day teaching, learning and assessment (England and Hong Kong), or by limiting the time allowed for the coursework assignment (e.g. through controlled conditions, Scotland)
- ensure the validity, reliability, robustness and comparability of the assessments across awarding organisations/exam bodies, schools and science subjects, e.g. through monitoring visits, external moderation, controlled conditions, and common practical science assessment criteria and mark schemes
- enable the assessments to take account of the full range of student ability and support differentiation, so that assessment judgements discriminate effectively, e.g. by making practical science assessment for external qualifications part of everyday teaching and learning, supported by moderation of, monitoring of, or the external marking of school-based assessment

⁴ The tables provide further information on the conduct of practical assessment in senior secondary science in England, Hong Kong, Scotland, Singapore and the *International Baccalaureate Diploma Programme*.

- ensure the important contribution of the development of practical skills to senior secondary science qualifications by including the results of practical science assessments in the final mark for the qualifications; practical science assessment commonly contributes 20% of the final mark
- confirm the important role of practical science activities by including a practical endorsement as part of final certification.

The paper has aimed to provide NCCA with further 'food for thought', as it considers the form of practical science assessment for Leaving Certificate biology, chemistry and physics that will ensure:

- the most valid and appropriate assessment of practical skills and knowledge
- that the right skills are being assessed
- effective discrimination between students
- manageability for teachers and students
- reliability and comparability, and
- avoidance of assessment 'drilling'/teaching to the test - whatever form that testing may take.

Glossary of key terms, abbreviations and acronyms

ACE	Singapore: analysis, conclusions and evaluation
<i>A Level(s)</i>	England: single-subject qualifications typically taken at age 18 after two years of full-time post-16 study. They are the main higher education entry qualification
CPAC	England: common practical assessment criteria
<i>Higher 2 GCE A Levels</i>	Singapore: single subject qualifications designed for students who wish to carry on further learning in the subject area
<i>Highers</i>	Scotland: single-subject National Qualifications and the main higher education entry qualification
HKALE	Hong Kong Advanced Level Examination
HKCEE	Hong Kong Certificate of Education Examination
HKEAA	Hong Kong Examinations and Assessment Authority
HKDSE	The <i>Hong Kong Diploma of Secondary Education</i> examinations, which are the main higher education entry qualification
IB/IBO	International Baccalaureate/International Baccalaureate Organization
<i>International Baccalaureate Diploma Programme/IB Diploma Programme</i>	An assessed programme for students aged 16-19, which is designed to equip students with the basic academic skills needed for university study, further education and their chosen profession
IS	Hong Kong: investigative study
MMO	Singapore: manipulation, measurement and observation
NCCA	National Council for Curriculum and Assessment
OECD	Organisation for Economic Co-operation and Development
PDO	Singapore: presentation of data and observations
QA	Singapore: qualitative analysis
SBA	Hong Kong: School-based assessment
SEAB	Singapore Examinations and Assessment Board
SPA	Singapore: School-based Practical Assessment
SQA	Scottish Qualifications Authority
VA	Singapore: volumetric analysis

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Appendix

See the separate tables for England, Hong Kong, Scotland, Singapore, the *International Baccalaureate Diploma Programme*, and the top-performing PISA jurisdictions.

Sharon O'Donnell, draft at 26 July 2019

The views expressed in this report are those of the author and do not necessarily reflect the views or policy of the National Council for Curriculum and Assessment

The place of coursework and/or practical assessment in senior secondary science assessment

The perspective from selected top-performing PISA jurisdictions: summary table

Draft: Sharon O'Donnell, August 2019, for

The place of coursework and/or practical assessment in senior secondary science assessment: the perspective from selected top-performing PISA jurisdictions⁵

Key

E = coursework or practical assessment component, externally assessed

I = coursework or practical assessment component, internally assessed

X = no coursework or practical assessment component

Jurisdiction	Coursework component	Practical assessment component	
Singapore	X	E	The table illustrates assessment for Higher 2 Singapore-Cambridge A Levels (the most common tertiary education entry qualification) in biology, chemistry and physics, which include practical assessment. There are 4 external examinations; paper 4 is a practical examination.
Japan	X	X	The table illustrates upper secondary assessment for university entry via the National Center for University Entrance Examinations. These are standardised written examinations - multiple-choice - which follow curriculum guidelines set by the Ministry of Education, Culture, Sports, Science and Technology and include tests in biology, chemistry and physics. Applicants take tests in the subjects required by their chosen university. (Individual schools also issue a Certificate of Upper Secondary Education which is based on teacher assessment and there is no external moderation.)
Estonia	I	X	To receive the upper secondary leaving certificate, students take (external) state examinations in Estonian, mathematics and a foreign language; must receive satisfactory marks for ongoing teacher assessment during upper secondary education; take an internal high school examination; and must complete a student research project or practical assignment during the course of upper secondary school studies.
Chinese Taipei	X	X	External, written examinations in biology, chemistry and physics form part of the General Scholastic Ability Test which is required for university entry.
Finland	X	X	Biology, chemistry and physics are included in the external tests for the Matriculation Examination .

⁵ Based on OECD (2015). *PISA 2015: PISA Results in Focus* (p.5) [online]. Available: <https://www.oecd.org/pisa/pisa-2015-results-in-focus.pdf> [25 July, 2019].

Jurisdiction	Coursework component	Practical assessment component	
Canada: Ontario	X	I	The entry is based on the Ontario Secondary School Diploma, which requires the achievement of 30 credits which are internally assessed. Internal assessment is based on evaluations conducted throughout the course, and on a final evaluation which may be an internal examination, performance, essay or other method of evaluation suitable to course content. The curriculum document for senior secondary science (page 23) defines assessment in science as the process of gathering information from a variety of sources (e.g. assignments, day-to-day observations, demonstrations, projects, performances, and tests) that accurately reflects how well a student is achieving the curriculum expectations. It confirms also (page 20) that students must be given opportunities to learn through investigation.
Vietnam	X	X	To graduate from high school students must pass a national exit examination - the Secondary School Leaving Examination . This includes five test subjects: three compulsory subjects (mathematics, Vietnamese language, foreign language); and two stream-specific subjects, which include biology, chemistry and physics. The exams are administered by the provincial Departments of Education, and involve multiple choice and essay questions. The Government intends to lessen the importance of examinations and has announced that national graduation exams will be abolished from 2020, at which point university admission will be based on overall student performance during senior high school.
Hong Kong	X	I	Assessment for the Hong Kong Diploma of Secondary Education (HKDSE) in biology, chemistry and physics (and in combined science and integrated science) includes a public examination written component and externally moderated school-based assessment of practical work e.g. scientific investigations, laboratory work, fieldwork or investigative study.
Korea	X	X	The College Scholastic Ability Test (CSAT) involves a written, external test in six main subject areas - Korean language; mathematics; English; Korean history; social studies, science, and vocational education; and a second foreign language. If students select science in the subject area 'social studies, science and vocational education', they are tested in two subject areas, which they select from physics I, physics II, chemistry I, chemistry II, biology I, biology II, earth science I, and earth science II. The test consists of 20 multiple-choice questions per subject and each subject test lasts 30 minutes (so 60 minutes in total).

Jurisdiction	Coursework component	Practical assessment component	
New Zealand	X	I	Assessment for the National Certificate of Educational Achievement (NCEA) Level 3 is credit-based and includes external assessment (exams) and school-based (internal) assessment. Completion of a practical investigation is a requirement for successful completion of the NCEA Level 3 credits for biology, chemistry and physics. This practical investigation is internally assessed.
Slovenia	I	I	The general Matura is a national, external senior secondary examination which students take in five subjects. Three subjects are compulsory - mother tongue, mathematics and a foreign language. Students select the remaining two subjects from the list of Matura subjects, which includes biology, chemistry and physics. External assessment (the written tests for the Matura) is complemented by internal assessment for biology, chemistry and physics. This accounts for 20% of the final mark and is a form of practical assessment. It can either be laboratory or field work, or a research project, which takes place during the school year under the guidance of the student's teacher. It is conducted in line with regulations determined by central Matura subject testing committees.
Australia: Queensland	I	I	The entry is based on the Queensland Certificate of Education (QCE) which is credit based. The QCE is assessed via internal and external assessment. Internal assessment for students studying QCE biology, chemistry and physics includes a data test, a student experiment and a research investigation (50% of total marks; the remaining 50% of marks come from an external examination).
United Kingdom: England	X	I	Pupils complete at least 12 practical activities for the A level in biology, chemistry or physics during the two-year course, which are internally assessed. A separate (pass or not classified) grade is reported for practical skills as demonstrated through these practical activities, but the result does not count towards the final A Level examination grade.
United Kingdom: Scotland	E	X	Course assessment for Higher qualifications in biology, human biology, chemistry and physics includes two (written) question papers and a coursework assignment. The report of the coursework assignment accounts for 20% of the final Higher grade. The assignment takes place in school but is marked externally by the Scottish Qualifications Authority.

Jurisdiction	Coursework component	Practical assessment component	
Germany	I	I	<p>Although practical assessment does not usually form part of external assessment/ the exams for the Abitur, teacher assessment of practical work can form an important, summative part of the final grade in the Abitur.</p> <p>The final Abitur grade usually reflects:</p> <ul style="list-style-type: none"> • student performance by way of teacher assessment of around 40 courses taken during the last two years of upper secondary education, which can comprise up to two thirds of the final grade; and • results from a series of external exams.
Netherlands	I	I	<p>The entry is based on the VWO pathway and exams for biology, chemistry and physics. The VWO is the general academic qualification for university entry. There are national exams and school exams for all three subjects. In the school exams for chemistry and physics, students complete 'research and design activities' in which they must demonstrate that they can design and complete experiments, and analyse and interpret the results. There appears to be no such requirement for the VWO biology exam.</p> <p>In addition, all students following VWO courses complete an 80- hour independent research project. Some will complete a practical science project for this component of the VWO.</p>
Denmark	E	E	<p>Pupils studying for the Studentereksamen (STX) - the general upper secondary examination, must take at least four subjects at A-level and normally three B-level and seven C-level subjects. As a rule, most students take biology, chemistry and physics at B-level.</p> <p>All students must submit a major written assignment or project, which forms part of the examination. This may be science-related.</p> <p>Examinations can be written or oral/practical, or they can be case studies or project-based tests, or a combination of these.</p>
Poland	X	X	<p>The maturity exams are central/external and set by the Central Examinations Board. Oral exams for languages are internal and assessed by the school; all other exams are written and external.</p>
Portugal	X	X	<p>To successfully complete upper secondary education, students must pass all subjects in their study programme and sit final exams in four subjects.</p>

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