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Submission to the Education and Innovation Committee: Inquiry into assessment methods in senior maths, chemistry and physics

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Executive Summary and recommendations to the enquiry

The effectiveness of extended research investigations in learning about and practising science in high schools and universities has a strong evidentiary base. Extended research investigations accordingly should be retained in line with current QSA practices.

Assessment strategies and assessment tasks should produce repeatable judgements on the quality of student work. Assessment should achieve transparent outcomes, guide student learning, measure valid learning outcomes, and provide repeatability of academic judgements on the quality of learning. Experts in assessment overwhelmingly support the use of standards-based, criterion-referenced assessment to achieve these outcomes.

Standards-based, criterion-referenced assessment provides greater repeatability in grading in isolation, and greater alignment when used with peer moderation. Standards-based, criterion-referenced assessment therefore should be retained in the physical and mathematical sciences. Using various learning taxonomies to guide the development of standards-based, criterion-referenced assessment can improve the quality of student learning and enrich approaches to completing assessment tasks.

For **teachers**, professional development to achieve consensus on the application of standards-based, criterion-referenced assessment will enhance the repeatability of judgements on the quality of student work. Programs to enhance the rubrics used in standards-based, criterion-referenced assessment should be implemented. For **students**, improved standards will enhance their approaches to learning and scaffold their cognitive development through the provision of more targeted feedback. For the **community**, implementing a public education program is likely to favour a wider understanding of the purposes and approaches to assessment adopted by the QSA.

An additional parliamentary enquiry into the ways in which we can more broadly integrate the teaching and immersion of students with studies of science from early childhood onwards would ensure Queensland maintained and improved our national and international standing as leaders in producing high school and university graduates capable of inventing the future prosperity and knowledge economy towards which Australia aspires.

The ability of assessment processes to support valid and reliable judgements with key stakeholders and relevant subject matter experts

Scholars now accept that practising the scientific method is the best way to learn about, and develop deep conceptual understandings in, the sciences. Extended investigations provide one mechanism through which students can learn about, engage with, practice, and receive feedback via assessment on the skills and cognitive approaches they will use as future scientists and valued members of society. The QSA's approach to using extended investigations remains well grounded in the education literature. Experts recognise the model adopted by the QSA as a best practice model. Further, there is broad acceptance that these approaches prepare students for future careers in the sciences, engineering, and associated disciplines critical to the wellbeing and economic abundance of the peoples of Queensland, Australia, and throughout the world.

At no time has such expertise been more desperately required. For example, the Australian Office of the Chief Scientist, and the Department of Climate Change and Energy Efficiency, estimate that Australia requires 88,000 new scientists and engineers by 2015. Australia will produce only thousands of graduates, rather than the tens of thousands of graduates required to meet domestic needs. Significant efforts are required to address this current and looming shortfall. This enquiry into the way we evidence excellence amongst our school students who aspire to careers in science, technology, engineering and mathematics (STEM) or any related field is accordingly both timely and appropriate.

The central discussion point for the Parliamentary enquiry focuses on the use of assessment as a tool to do more than rank students' performances. To this end, we provide an overarching distillation of the principles that underpin effective assessment in any discipline. We note that the current assessment practices of the QSA fulfil many of these principles and subordinate principles.

Well-reasoned principles should underpin assessment practices in all educational environments

To articulate the importance of assessment in guiding learners to deeper and richer understandings, we distil three principles that form the foundation of good assessment practice at all levels of learning and teaching endeavours.

Underpinning these principles is the recognition that assessment should be based on clearly articulated criteria, and that decisions about the grades awarded to students for assessment tasks based on the attainment (or otherwise) of those criteria at stated achievement standards. This assumes a system of grading student performance against a set of criteria (Standards-Based, Criteria-Referenced Assessment (CRA)) rather than against a group of peers (Normative Referenced Assessment - NRA).

Principle 1
Assessment should be seen as an integral part of the learning and teaching cycle.

Principle 2
Assessment has six key purposes that should be considered when developing assessment tasks and learning experiences for students in a unit of study. These purposes are to:

- guide students in the development of meaningful learning;
- inform learners of their progress;
- inform staff on the progress of students, and the effectiveness of their teaching;
- provide data for schools to arrive at final grades for students in a discipline;

- rank students for awards or progress to another level of study; and
- ensure academic quality and standards are maintained.

Principle 3
Assessment practices and processes must be transparent and fair.

A detailed discussion of these principles is not included here. However, these principles are best met through a criterion-referenced, standards-based assessment system. Important elements of the system are:

- ensuring a clear alignment between stated learning outcomes, the learning experiences provided for students, and the assessment tasks;
- addressing subject-specific criteria through assessment tasks;
- designing assessment tasks to require the analysis and synthesis of information and concepts rather than only recall of information previously presented;
- facilitating student understanding of the assessment process by clear explanations of the assessment tasks, how the assessment tasks relate to the learning outcomes, and the criteria and standards against which students will be assessed;
- developing assessment rubrics that are soundly based in learning taxonomies e.g. SOLO taxonomy of Biggs and Collis (1982)
- providing students with descriptions of their progress against stated learning outcomes, criteria and achievement standards; and
- integrating the assessment requirements of a component of the subject with the subject overall.

We note that the majority of current practices directed by the QSA meet these principles. To this end, we support current practices. As part of the ongoing improvement cycle, additional refinements could be made to the assessment *strategy*, rather than individual assessment tasks in the evaluation of senior secondary mathematics, physics, and chemistry.

Standards-based, criterion-referenced assessment provides valid, repeatable, authentic and transparent outcomes for students, teachers, and community

Students commonly assume that assessment involves a 'hidden curriculum'. Many students believe that our assessment tasks provide them with specific messages about the importance of particular topics. In addition, assessment directs and guides students' approaches to study, leading them to concentrate on those things that they believe we hold most important. Accordingly, assessment represents the single most powerful tool we possess to direct and guide students' approaches to learning. Through clearly articulating the learning outcomes that teachers design, we can more effectively guide students' thinking and their approaches to learning.

The use of percentages, implicit in the terms of reference for the enquiry, to make judgements on students' level of achievement requires scrutiny and rebuttal. The critical underlying and mistaken assumption is that teachers are able to reliably and repeatedly make precise judgements at the half or one percent level of certainty on the quality of students' work. The use of standards against which to evaluate student performance (associated with letter grades of achievement) provides opportunities for greater reliability in judgement with reasonable levels of precision and repeatability for the evaluation of student achievement. The research literature and focus on standards-based, criterion-referenced assessment is now well established and broadly accepted in, for example, the United States, Europe, and Finland.

Standards-based, criterion-referenced assessment policies implemented at the national level ensure we achieve a number of outcomes, including addressing students' concerns regarding our assessment practices. In addition, this approach ensures we achieve a range of benefits for students, teachers, and the community. These include:

- Evaluating students' performance against standards and criteria, in the absence of comparisons with other students, ensures we maintain standards within and between years
- Students earn grades for the quality of their work alone, without reference to the work of others (i.e. replacing normative referencing with standards-based, criteria-referencing) or students' past performances
- Clearly articulating the standards and criteria against which judgments will be made about the quality of students' work will guide and enhance their focus on the task of learning
- Providing detailed guidance on how and on what bases students will earn particular grades for their work
- Providing students with enhanced opportunities to accept increasing levels of responsibility for their learning
- Increasing transparency in assigning grades students earn for their work
- Improving students learning outcomes
- Enhanced alignment between the development of the skills and cognitive understandings that aspiring scientists and mathematicians require in their future careers

The benefits of standards-based, criteria-referenced assessment program occur at several levels, including those for students and staff.

Students

- Through clearly articulating our academic expectations, students will invest more time working towards achieving precisely the designed learning outcomes.
- Students will understand more clearly the things they need to do and the approaches they need to adopt in order to earn particular grades.
- Through enhancing feedback on formative and summative assessment tasks we ensure students' understanding aligns with expectations of the discipline.

Teaching staff

- Enhancing our focus on curriculum design will allow us to even more effectively guide learners and learning.
- Teachers will use their professional knowledge in grading work to guide students' learning through clearly articulating our expectations before students complete assessment tasks.
- In large classes and amongst multiple markers, using standards and criteria improves the consistency of allocating grades to students' work.

Standards-based, criterion-referenced assessment allows teachers to quantify the extent students have achieved the goals of a unit of study and a subject. This assessment is carried out against previously specified criteria and achievement standards. Where a grade is assigned, it is assigned on the basis of the standard the student has achieved on each of the criteria.

In summary, criterion-referenced assessment is the process of determining student achievement and assigning grades against a set of specified criteria and achievement standards. To recognise the importance of this issue requires some background in terminology and understandings of approaches to assessment.

Ensuring assessment processes are supported by teachers

The public enquiry and perceptions noted therein suggest some concerns exist regarding the effectiveness and engagement of teachers with the QSA and ACARA assessment strategies.

It is broadly acknowledged that assessment drives what students learn because it provides a tacit, or perceived hidden curriculum, that signifies to learners what is important and the ways in which students should approach and evidence their understandings. Failure in public trust on these issues strikes at the heart of the purposes of the assessment strategy in the secondary sector, or elsewhere. Any reasonable expectation of assessment would acknowledge that assessment strategies should be valid, transparent, reliable, repeatable, and authentic.

The need for authentic learning experiences reinforces the consensus view among experts in education: that extended investigations provide an appropriate platform for students to learn about, practice, receive feedback, and assessment on their understandings in the practice of science. The use of criteria-referenced, standards-based assessment tasks provides greater repeatability and reliability in judgements than other methods of ascribing marks or percentages to students' work. To this end, the retention of standards-based, criteria referenced assessment should be retained.

The media release and terms of reference for the Parliamentary Enquiry suggest that the assessment strategy in senior mathematics, physics, and chemistry detrimentally impacts students' choices to enrol in these disciplines. This assumption requires examination, which we provide in the next section.

Additional factors potentially impacting the number of secondary school students studying mathematics, physics, and chemistry

Implicit in the terms of reference for the enquiry, is the assumption that assessment is impacting and driving the number of students studying mathematics, chemistry and physics. While assessment may have some bearing on the attractiveness of the physical sciences to potential students, other factors potentially influence student behaviour, subject selection, and career aspirations in the physical and mathematical sciences.

Judgements that single out assessment strategies as a leading driver influencing the number of students entering the hard sciences remain simplistic. The challenge comes much earlier, and requires an integrated approach to embedding the sciences, arts, and social studies across a broad educational experience for students. To meaningfully address these issues requires a concerted effort. Such efforts would focus in cumulatively building science into the curriculum, pedagogical, and assessment strategies from the early years as part of holistic education reforms. While outside the terms of reference for this enquiry, we provide limited comment on some of the other factors responsible for declines in the proportion of the population studying the physical and mathematical sciences in secondary schools. These factors include:

Diversification of the upper secondary school curriculum

The Queensland upper secondary school curriculum has become increasingly diverse in recent years. Although subject offerings in the sciences and mathematics have remained static in number, increases in the number of QSA authority subjects in other areas such as Business and Economics, Health and Physical Education, and IT and Design have resulted in mathematics and the sciences progressively declining from 26% to 20% to 17% of the total QSA authority subjects from 1992 to 2002 to 2012 respectively. The potential of other subjects to attract some students away from mathematics and the physical sciences, particularly when some students perceive these disciplines to be conceptually challenging, is reflected in the declining proportions of completions in the senior maths and sciences (illustrated by trends in graphical data trends since 1999 included within the Related Publications on the website for *Assessment Methods for Senior Maths, Chemistry and Physics*). Graphical data are shown for Biology, Chemistry, Physics, Mathematics B, and Mathematics C.

Unfortunately *comparable* data for Mathematics A are not included, however QSA subject enrolment data (at http://www.qsa.qld.edu.au/617.html) for Year 12 students indicate that Mathematics A, in contrast to Mathematics B, Chemistry and Physics, is increasingly attractive to students (with the proportion of the Year 12 cohort enrolled in Mathematics A increasing from about 58% in 1999 to about 76% in 2012). Therefore, in addition to the diversification of the curriculum, upper secondary school students are favouring Mathematics A in place of Mathematics B, perhaps due to the perception in the conceptual difficulty of Mathematics B.

Student and teacher attitudes to the physical and mathematical science disciplines

The approaches and preparedness of teachers from early childhood through to the final high school years and beyond have the capacity to profoundly influence student aspirations and decisions to pursue physical and mathematic sciences. It remains unclear to the extent that teacher attitudes and expertise in the sciences are encouraging or discouraging students' aspirations to pursue scientific careers.

Early learning experiences

Integration of science learning from the early years profoundly influences the aspirations of students to all of the sciences, and the physical and mathematical sciences in particular. A targeted program to embed science and related disciplines into the fabric of play-based activities from early childhood, and the formal learning and assessment activities in later years, warrants greater evaluation.

Students studying science, technology, engineering and mathematics (STEM)

DEEWR research undertaken by ACER noted in 2008 for OECD economies the declining percentage of students for the past 20 years studying science, technology, engineering and mathematics (STEM). The DEEWR report draws attention to a steady decline nationally in the percentage of Year 12 students participating in biology, chemistry and physics from 1976 to 2007. The report also notes a decline in participation in 'Advanced' and 'Intermediate' mathematics. Reviews commissioned by the Australian Council of Deans of Science (ACDS) (e.g. 1998; 2003; 2003) have raised similar concerns about participation in mathematics and the sciences at Year 12 and in Higher Education.

These factors are outside the purview of the stated terms of reference for the enquiry.

Summary

The authors of this submission support the current QSA assessment practices in the mathematical and physical sciences. Part of the ongoing refinement process could focus on enhancing the quality of learning outcomes for students. Ongoing professional development for teaches in understanding and enhancing their expertise in the use of standards-based, criteria-referenced assessment may improve the quality of students' learning and understanding.

A public awareness campaign to describe how professional teachers reach their academic judgements using standards-based, criteria-referenced assessment rubrics and strategies would serve to strengthen public confidence in what experts recognise as best practice.

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