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8 May 2013

Education and Innovation Committee
Queensland Parliament
Parliament House
George Street
Brisbane QLD 4000

Re: Submission to Education and Innovation Committee into Assessment of senior maths, chemistry and physics in Queensland schools

Dear Committee Members,
I am the Head of Physics at the School of Engineering and Physical Sciences at James Cook University, Townsville. I write this in my capacity as a university academic but am not claiming to represent an official view of JCU. My response to the inquiry Terms of Reference is that the Queensland Studies Authority's policy for assessment of senior maths, chemistry and physics should be rejected as soon as possible. Assessment under this policy is demonstrably invalid, unreliable, sexist and of little value in determining tertiary success.

In my enclosed submission to the inquiry, I provide evidence that the QSA's complex assessment policy for these subjects is seriously invalid and unreliable in that it –

- assesses many irrelevant skills towards subject grades;
- uses non-numerical marking linked to invalid criteria and does not require upfront assessment combinations;
- includes lengthy written assignments, which cannot reliably be authenticated as the student's work.

I will be travelling to the United Kingdom until mid June; however, if it would assist the committee in any way, I am able to give evidence by telephone or video conferencing facilities during that period.

Yours sincerely

Professor Peter Ridd
Head of Physics
School of Engineering and Physical Sciences
James Cook University

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APPENDICES

1. My Background

Professor Peter V. Ridd. BSc, Dip. Ed., PhD

Head of Physics, School of Engineering and Physical Sciences, James Cook University

Work Experience

School Teacher 1982-3. Blackheath and Thornburgh Colleges, Charters Towers.

Experimental and Research Scientist 1984-88, 1991-2. Australian Institute of Marine Science.

University Academic: 1989-91, 1992- present

Research Interests: Environmental Physics, Electromagnetics, Geophysics. 60 publications in international journals including one book.

Engineering and Science Consulting: University Environmental Physics Consulting Unit. Grossed over $4M in the last 5 years.

Education experience: Registered School Teacher. University lecturer specialising in electromagnetics, oceanography, geophysics and the teaching of physics to students with substandard mathematics backgrounds.

Personal background influence: All of my secondary education was in Queensland (Innisfail SHS). The standards and rigour of maths and numerical science was very high. It is painful to see how far down our school system has dropped; according to a recent report, in the ‘70’s we were the best State in Australia, now we are the worst. I have also had to watch my children and their friends suffer under the appalling assessment regime mandated by the QSA.

Although I have seen first-hand the adverse affect of QSA assessment on my own children and many of their friends, the experience of students at high school is of great interest to those of us teaching science and engineering at university. I thus write this submission as a university academic.

2. Summary of the Problems

Queensland has a unique and highly radical system of assessment. It is a system that has been contrived by university education theorists and represents an uncontrolled experiment on our children. Worse still, the Queensland Studies Authority (QSA), which is responsible for our assessment system, has not properly evaluated the results of this experiment. They should have undertaken studies to compare Queensland's performance with other states and nations.

What information that is available indicates that Queensland has fallen behind other states and is drastically behind its own performance in the 1960s and 1970s.[1] [2]The QSA continuously claims to be a world leader in education and especially assessment. It is however notable that other jurisdictions around Australia and the world are not rushing to adopt its methodologies.

Compare Queensland assessment with other States in **Appendix A (Inter-state comparison of senior school assessment methods)**. It is the only state not to use a State-wide exam and to mandate for all assessment a non numerical system for determining the final grade (i.e marks cannot be used).

The QSA's assessment policy for Mathematics, Chemistry and Physics has resulted in the overuse of long written assessment instead of short numerical problems using mathematics. In some schools, EEIs and other assignments are grossly overused; the write-ups often exceed 5000 or even 10000 words, turning these subjects into *de facto* English classes. Any motivational experience of doing some cool Physics or Chemistry in the EEI is destroyed by the long write-up. This is a major disincentive for many students who are genuinely talented in these subjects. This over-emphasis on written tasks is likely to be the reason that the OP scores awarded to boys are 2 positions lower than **equally talented** girls (as measured by the QCS test.[3] [4] [5] (see section 4.1(a))

The long written assignments which are usually done at home mean that cheating is rampant because parents and tutors can give considerable help to a large fraction of the students assessment. This is likely to severely discriminate against students from lower socio-economic groups or those with little written English help at home. (see section 4.1(a))

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[1] ACER Masters G (2009) *A Shared Challenge. DETE; Australian Council of Educational Research*. p vi. Accessed April 2013. http://education.qld.gov.au/mastersreview/pdfs/final-report-masters.pdf

[2] Queensland students lag behind nation, Daniel Hurst, 9 September 2011, http://www.brisbanetimes.com.au/queensland/queensland-students-lag-behind-nation-20110909-1k0w8.html

[3] Ridd J (2013) Educational Sexism in Queensland. ON LINE Opinion. Accessed April 2013 http://www.onlineopinion.com.au/view.asp?article=14942&page=0
Quote: "Both of these results suggest that the system is discriminatory against males by about 2 OP rungs.... I conclude that presently we have statewide systematic sex discrimination on a huge scale."

[4] Dr Rowe K, Principal Research Fellow, ACER, Transcript of Evidence, p. 117. (2002) Boys: Getting it Right. Report on the inquiry into the education of boys, page 51Quote: "As for specialist maths or four-unit mathematics at year 12, a content analysis has demonstrated that on average the level of the nomenclature and sophisticated verbal reasoning skills that are required—to even understand what the problem is—is on average four times greater than what is required in Australian history and English literature... "

[5] House of Representatives Standing Committee on Education and Training (2002) Boys: Getting it Right. Report on the inquiry into the education of boys. Commonwealth of Australia, Canberra, page 51- 52. Accessed April 2013 http://trove.nla.gov.au/work/16822281

In Queensland, teachers are effectively forbidden to use marks (numbers) and add them up to give a final result. Almost no other state or country uses this non marks based system. The system is opaque and is extremely time consuming for teachers to implement. Queensland teachers must base their final result on a matrix of perhaps 30 individual letter grades. They must make an "holistic judgement", which is a fancy word for a guess. It is also very difficult to determine the rank order of students, which is crucial in the calculation of the students OP score. Because numbers cannot be used, students have no idea of the "worth" of an assessment item (or of specific questions within each item) and cannot apportion time appropriately. (see section 4.1(b))

The QSA does not require schools to provide students with 'upfront assessment combinations' (or compositions) which show the percentage worth of each planned assessment task counting towards the final grade. So the standard practice of saying that in a given year students will, for example, face an the assignment worth 10% and tests worth 20%, 30% and 40% respectively, is not allowed in Queensland. Instead teachers must 'cherry-pick' students' results. See section 4.1(c) and Appendix F.

An interesting area of disagreement emerged at the Education and Innovation Committee forum on 1 May 2013 where the education academics and the QSA stated that they did not regard Mathematics B, Mathematics C , Physics or Chemistry as primarily subjects designed for university entry. My view in contrast is that these subjects are primarily designed to provide background knowledge and skills for university subjects and that most students who take these subject will at least be considering going to university. The education academics and the QSA viewed them as general subjects designed to make students more rounded and knowledgeable citizens. Because of this fundamentally different perspective, the education academics and the QSA attached less importance to the mathematical aspects or the content in the subjects.

A key decision of the committee will be to decide if these subjects are to be focused on university entry or not. If the decision is that they are primarily about preparation for university, then they must be changed to reflect that role. If the role is not for university entry, then the Queensland school system is largely irrelevant to the universities and the universities will ultimately be forced to institute entrance examinations in order to force schools to teach appropriately for those students who are likely to proceed to university.

The QSA has consistently refused to listen to criticism and is unlikely to change its philosophical approach to education. It is highly autocratic and [redacted] Widespread fear exists amongst teachers, and especially parents, will be a major barrier to the Inquiry's ability to ascertain levels of support/opposition.

3. Recommendations

3.1 **A numerical marks based assessment** system should be introduced at the start of 2014 for senior Maths, Physics and Chemistry (for subject grades and specific assessment tasks), modelled on systems used in other Australian States or leading overseas systems.

Numerical marking should also be mandated from January 2014 for other Senior subjects and for Prep to Year 10 to replace QSA's non-marks system implemented in 2012.

The urgent restoration of numerical marking will require the removal (possibly by legislation) by November 2013 of unnecessary and invalid syllabus marking requirements that fall outside the disciplines of maths, physics and chemistry.

3.2 **End of Year 12 State-wide Exams** should be introduced –

(a) by 2015 in Maths, Physics and Chemistry (worth around 30% of total senior assessment) and possibly with assistance from inter-State educational authorities; and

(b) for other pre-tertiary subjects (also worth around 30% of the total assessment), similar to States such as NSW and Victoria.

The State-wide exams for Maths, Physics and Chemistry must be set by experienced teachers with some guidance from university discipline experts in those disciplines in addition to those from associated disciplines such as Engineering and Medicine etc. Input from academics in the university education faculties (educational theorists) should only be used after careful selection and consideration.

3.3 Internal assessment to be **moderated with the assistance of statistical scaling from State-wide exam** results. A large fraction of the 4000 QSA moderators on internal assessment panels would not be required.[6]

3.4 Until the full implementation of the National Curriculum (or equivalent), **QSA syllabi in Maths, Physics and Chemistry need to be rewritten** with more detail about the content that is to be taught especially for the physics syllabus. This must be done under the guidance of university academics in the relevant disciplines (Physics, Chemistry, Maths, Engineering, Medicine etc. and industry), senior teachers and with input from industry representatives (e.g. Institute of Engineers). Academics in the university education faculties (educational theorists) should only be consulted after careful selection and consideration.

[6] ACER, Matters G (2008), *Realising and releasing potential 40 years on* indicated that social moderation is unreliable.

3.5 **Retain option for 100% end of Year 12 external exams,** for individual students or for schools such as Hubbard's School. Ensure numerical marks used and added to achieve the final result. Make students aware of this option.

3.6 **The OP score calculation is modified to follow the systems used in other states**, i.e it would be possible with the State-wide Exams to abolish the QCS test.

3.7 **Physics and Chemistry assignments** (EEIs, ERTs, other assignments or extended tasks) should be –

(a) non-compulsory;
(b) worth a maxiumum 10% of the final subject grade; and
(c) subject to a total 500 word cap, with penalties for exceeding it.[7] [8]

3.8 **Maths assignments** (including Extended Modelling and Problem Solving tasks) should be scrapped. In addition they should also be eliminated from the lower school. Modelling (i.e. applied mathematics) can be done as part of the day to day mathematics that is taught in class.

3.9 Schools should be required to provide students with **upfront 'assessment combinations'** specifying in advance the assessment tasks for the subject and their percentage value (if any) towards the final grade. For example:

Year 11 (2014)		2015 (2015)	
Sem 1	Sem 2 201	Sem 3	Sem 4
10% Test	15% Test	30% Test	30% State-wide exam
5% experimental writeup	5% Assignment	5% experiment writeup	

Upfront assessment combinations would replace QSA's policy of 'cherry-picking' exit grade assessment; see Part 4.1(c).

3.10 The primary focus of the subjects Maths B, Maths C, Physics and Chemistry should be explicitly declared to prepare students for university entry. Consideration could be given to introducing a new lower level subject that combines Chemistry and Physics and which would complement the present QSA subject Science21. This new subject could be presented in a non-mathematical way and be primarily designed to give students a working knowledge of Physics and Chemistry but NOT be intended as a useful prerequisite for advanced university study.

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[7] House of Representatives Standing Committee on Education and Training (2002) Boys: Getting it Right. Report on the inquiry into the education of boys. Commonwealth of Australia, Canberra, page 51- 52 Accessed April 2013 http://trove.nla.gov.au/work/16822281
Quote: "... assessment procedures for maths and sciences must, as a first requirement, provide information about students' knowledge, skills and achievement in the subject, and not be a de facto examination of students' English comprehension and expression."

[8] ACER, Matters G (2006) Assessment approaches in Queensland Senior science syllabuses: report to the Queensland Studies Authority.

3.11 Given the overwhelming evidence of the QSA failure properly to perform its assessment function or its related moderation function under the *Education (Queensland Studies Authority) Act 2002* **('the QSA Act')** consideration should be given to the future of the QSA and its board. I would recommend that the board members should be either removed by amending the QSA Act or by issuing all **QSA members with a notice to show cause why they should not be removed** from office forthwith. [9]

Even if these positions are terminated as permitted by law, the qualifications of members set out in s.25(2) of the QSA Act need to be urgently revised by passage of **legislation specifying different membership qualifications**, in particular, the requirement for tertiary discipline knowledge or industry experience rather than a pure educational background. The new QSA boards could implement the urgent short-term changes recommended here, such as numerical marking, and related syllabus rewrites to take effect from 2014.

3.12 With the introduction of the National Curriculum, QSA's role can be greatly reduced and considerable cost savings made. It is therefore recommended that the **QSA be replaced** by the end of 2014 with a smaller organisation whose primary purpose is to oversee assessment and the implementation of the national curriculum (or high quality equivalent e.g., the International Baccalaureate) in Queensland.

3.13 The QSA's replacement and other education organisations, such as the Queensland College of Teachers (QCT), need **more input from discipline experts** and less from education theorists.

3.14 The reformed, **valid and reliable assessment methods must continue to apply** in all Queensland schools after implementation of the National Curriculum or its equivalent.

3.15 I encourage the Committee to take a wide view of the issues and examine the low standards in Maths and the Numerical sciences over the whole of schooling, and to what extent fashionable syllabi and **pedagogy invented by the educational establishment are responsible for the low standards** throughout.

[9] See s.25 *Acts Interpretation Act (Qld) 1954* power to remove QSA members.

4. Term of Reference

4.1 QSA's invalid and unreliable assessment policies

(a) Overly long writing tasks in assessment:

See **Appendix B, which sets out key QSA syllabus provisions on assignments** for maths, physics and chemistry.

The QSA mandates the use of long written assessment (EEIs, extended experimental investigations, and ERTs, extended response tasks) in Physics and Chemistry, and assignments in Mathematics despite these subjects being fundamentally about calculations rather than writing. It was Sir Isaac Newton's great achievement to show that Physics is, and must be mathematically based. In that light QSA/education theorists ideas of science are hundreds of years out of date. In many schools these assignments are between 5000 and 10000 words long (10 to 20 pages). The following points should be considered.

- Some students have 6 major assignments running at the same time.
- The pressure on students is crushing. Figures of 70+ hours per week are quoted to me by parents.
- Unfortunately, the time spent does not develop the skills appropriate for the subject, and needed for university engineering, maths and physics. These university disciplines do not value this long written assessment (first year university experimental write ups are relatively small, and students are penalised if they exceed the prescribed number of words). It would be far better if school students worked on numerical problem solving plus short experimental write-ups in the normal (concise) scientific style (NOT long essays).
- The criteria and instruction sheets for these assignments are often up to 10 pages long. These criteria and instruction sheets are often so long and confusing that students do not know what they are supposed to do and are left with a feeling of desperation. It is interesting to note that the QSA presented a sanitised criterion sheet presented to the committee during proceeding of the committee on 2^{0th} March which was only 2 pages long. This is the shortest that I have seen.
- The QSA has been totally inconsistent about the length of these EEIs etc. The syllabus says 1500 words, but the exemplars on the QSA web sites have been up to 6000 words (until they took them down after this was pointed out last year). Teachers frequently report that it is impossible to cover all the necessary criteria in the official word limit, so it is necessary to break the QSA rules in order to get a good mark.). It is notable that even the QSA example of an A+ assignment write-up presented to the Inquiry on 20th March, appears to be at least 50% longer than the stated word limit. Despite going considerably over-length, this assignment is the shortest I have seen at senior level under the present system, so I do not consider it to representative of common practice in the schools. There is no doubt that the QSA has not been enforcing its own rules on word length, a point that they fail to admit.
- The time spent on assignments, EEIs and ERTs, often leaves insufficient time to master the fundamental knowledge of the discipline (required for university).
- Assignments are now routinely given in Maths. They sometimes take weeks or months to complete. Meanwhile, little actual teaching occurs, and the students may do no practice questions at home. Assignments in Maths are now being done

in lower secondary schooling as well and will further reduce standards to Year 10 exit.

- Some EEIs in some schools are ludicrously ambitious, requiring 3rd year university knowledge o do them properly. Consequently, little is actually learnt except how to copy from Google.
- Cheating for EEIs and ERTs etc. is rampant. How can the teacher determine if the student, his/her parents, or a tutor did the write-up? In response, QSA suggests students do even more writing by producing log books or journals as well as the long assignments. However, this still does not solve the problem of authenticity.
- Overuse of assignments means that students from comfortable middle class backgrounds with well-educated parents, and a working computer at home, have an unassailable advantage over students from poorer backgrounds. This is due to the extra assistance that can be given for the assignments which have become the dominant form of assessment. Also if a teacher knows a student got some help from another person, does the teacher give the student zero or reduce the grade, and if so by how much? How does the teacher measure the degree of cheating?
- The original idea of the EEIs was a motivational tool, i.e. do some cool physics, chemistry or maths. However, due to the extreme write-up requirements, the EEIs are often hated. They actively disengage and victimise students who might be very talented at quantitative science or maths, but are ordinary at writing. Many great scientists have not been strong writers. For example the Nobel Prize winner, Neils Bohr, had considerable trouble writing. Three days to produce a 700 word paper was, for Neils Bohr, great haste. But he was one of the greatest ever theoretical physicists. He would have failed lamentably in QSA's Queensland.
- EEIs, ERTs and assignments are largely *de facto* English writing tests. If we want to know a student's ability at writing, we should look primarily at their results in English classes. Of course this presumes that the subject called English is focusing on appropriate material – but that could be a matter for a future Inquiry.

- The present Qld school assessment discriminates against boys. The OP scores awarded to boys are 2 positions lower than equally talented girls as measured by the QCS test (see submission by Dr J.C. Ridd or http://www.onlineopinion.com.au/view.asp?article=14942). This analysis should be considered very seriously by the committee as it demonstrates that the present system does exactly as one would expect, i.e by over-emphasising writing, which is traditionally weak in young males who are talented in quantitative subjects, boys are disadvantaged. Boys have been systematically disadvantaged by many facets of modern education theory. Indeed it is only slightly unkind to state that the conventional wisdom in the education establishment is that if boys are doing better than girls then we must change the subject, but if girls do better than boys, then boys must become like the girls, i.e in this case they must miraculously change the wiring of their adolescent brains and become better at writing. Of course many girls are disadvantaged by the overuse of long written tasks if they are naturally good at quantitative subjects but poor at writing. It is a shame that the only thing that they could do well is taken away from them by over-emphasising writing.

- It has been pointed out that even scientists must ultimately learn to write. I have authored over 60 publications, and helped all of my 20-odd PhD and MSc students to learn to write so I most certainly agree. However for many students the writing ability will come gradually with time and must not be over-stressed too early and certainly not in year 11 and 12 when the primary focus should be on the *quantitative* aspects of Mathematics, Physics and Chemistry. In year 11 and 12 we

should focus on trying to train the students to write very short reports and get the basics such as being able to write a respectable paragraph. Longer reports can come later in tertiary studies,

- Queensland should adopt the 2006 recommendation by ACER in a QSA-commissioned review that task-based assessment not be mandated because feasibility, reliability and validity have not been demonstrated.[10]
- On 20th March, the presenter who talked about the Physics EEI was clearly an excellent Physics teacher. I want to make it clear that if we had more teachers like him, irrespective of the system of assessment, we would have a terrific education system. But I would disagree with some aspects of his presentation. Firstly he claimed that with modern technology much more time is available and this is one motivation for introducing the extended experimental investigations. I cannot agree that technology has this affect. It certainly means that some far more interesting experiments can be done in the same time as was previously used to do more mundane experiments. But equally certainly we do not have weeks and months of spare time to do multiple EEI's where very little physics is actually learnt. He also was over-critical of the more traditional ("cookbook") style of experiment where students are given a list of instructions to perform in the experiment and given explicit instructions of how to analyse the data. These experiments teach the basic physics concepts far more efficiently than the EEI where students must discover the physics themselves. They also teach important concepts about measurement and error analysis. This does not mean that I think all experiments should be done in the traditional style. I highly value the concept of the EEI to allow the student to investigate something for themselves, but I strongly oppose the idea that ALL experiments should be EEI's as happens in most Qld schools today, or that the write-up should be excessively long.

(b) Non-numerical marking

QSA's marking policy

Queensland has an almost unique and highly radical assessment system that does not use marks. Instead, individual questions in exams, and different components of assignments are given a letter grade. An holistic judgement is supposed to be used to get the final grade (see table 1).[11]

When all the assessment outcomes are known there has to be some method of reaching a final subject 'result'. However the teacher/school has no numbers, only letters. Consequently:

- This system of determining the final grade is unreliable because it is not and cannot be properly defined.
- The "holistic judgment" is highly subjective. Different teachers will get a different result, especially if there is a wide divergence of letters in the matrix.
- The QSA has failed to demonstrate that its methods are more accurate than the more conventional method of adding marks.

[10] ACER, Matters G (2006) Assessment approaches in Queensland senior science syllabuses, p.36.

[11] **QSA policy document 2010:** "An on-balance judgment can then be made in each criterion. It is not an appropriate practice to ''add-up" or aggregate grades to arrive at an overall judgment about a student's level of achievement within each criterion." http://www.platoqld.com/wp-content/uploads/2012/05/Media-3.pdf

- The non-numbers based system is enforced in all subjects and in all grades despite claims to the contrary.
- All games, be it League, AFL, Cricket or Billiards, have very precisely defined rules and scoring systems. All players, parents, administrators, spectators, commentators and backers know, for example, that a try in League is worth 4 points, but a field goal (which is precisely defined) is only worth one point. Students in Queensland are 'playing a game' of much more significance than that. There is no indication of the worth or value of anything, no clear method of reaching a set of results for any given piece of work, and absolutely nothing at all on how to get the final subject result over the two years.
- Inevitably, due to the hopelessly vague system, there are continuous arguments between teachers and the panels about how to apply the system. The syllabi have a dozen pages of detail explaining how they should be applied, but it is still unclear.
- The irony of the system is that once the teacher has determined the rank order of all the students without using marks or numbers, as instructed by the QSA, the QSA itself inevitably has to use a purely number and marks based system to calculate the OP. **Why do they force teachers not to use marks when they know that they themselves will use numbers to calculate the OP**?
- The non-numerical assessment system means that students cannot prioritise time, because the question "What is this EEI worth Miss?" has no meaning. A student cannot tell if the EEI is worth 5% or 50%, and thus cannot determine if more (or less) time should be spent on other assessment. A consequence is that students often labour away at pointless assignments, and totally fail to do the technical practicing that is essential for maths and numerical sciences.
- The QSA often claim that teachers can still use marks. This is deliberately duplicitous, and they have never explained how this can be done. They make these assertions because they can see that in the eyes of the public, numbers are a logical way of aggregating assessment. They can attempt to discredit opponents by falsely claiming that numbers can still be used. The QSA has even stated to this Inquiry (proceedings of 20th March) that numbers can be used if a teacher really wants to but then contradicted itself by stating that, for example, in order to get an A grade overall, a student MUST get either 3 A's or 2 A's and a B, i.e letters must be used. I am completely sure that marks cannot be used in the conventional sense, i.e they cannot be added to get the final overall grade, however it is possible that I am mistaken along with hundreds of teachers that I have communicated with. If that is the case, it is symptomatic of the QSA's incompetence that intelligent and conscientious teachers after years of implementation of the assessment methods have not been informed that marks are able to be used and given directions about the methodology. However, the reality is that marks are not able to be used to determine the final grade and the QSA is deceiving the committee, intentionally or otherwise.
- Many teachers break QSA rules to use conventional, reliable numerical marking, which students appreciate. Or they convert back an A to 5, B to 4, C to 3, D to 2 and E to 1. They then add up the numbers. However, teachers are bound by QSA policy against numerical marking,[12] which the QSA panels enforce.[13] Therefore

[12] **The QSA (March 2013)** ***State Review Panel Reports*** **states:** "They should not resemble a marking scheme nor should they contain descriptors that prescribe a "quantity" of some element" and "An on-balance judgment should be used to determine the standard awarded in each criterion" and "Where a mechanical or formulaic method was used to determine standards in a criterion, there was little alignment to the specific standard descriptors".
Accessed April 2013 http://www.qsa.qld.edu.au/downloads/senior/assess_snr_rpt_panel_2013.pdf

[13] **QSA policy document March 2010:** "Simply adding up marks to arrive at a level of achievement, does not allow for consideration of the standards achieved in each of the dimensions across the range of assessment

teachers who convert to marks have to be careful to make sure that the moderation panel does not know what was done.

- One major reason that teachers illicitly convert to marks is so that they can work out the student rank order, which is a primary input for the OP calculation. It is entirely possible for large classes that there could be 50 students all with, for example, a B grade for a particular subject. The teacher must now rank these 50 B grade students but all they have is the 50 matrices each with perhaps a couple of dozen letters. It becomes very difficult to objectively rank students without using a numerical scheme. See example in **Appendix C (Using QSA letters to determine a student's final grade and rank order**)..
- Whilst the QSA forbade the use of marks by schools, it ran its own external exam system (for certain schools) where marks were universally used. When the hypocrisy of this was pointed out to them, they decided to cancel the external exam option for the special schools (phasing out by 2015).
- Any examination of past first year university maths and science examinations shows a very large decline in standards. This has been compelled by the clear decline in knowledge on entry. In the case of JCU, in the last two decades, we have significantly reduced the content of the first year engineering maths subject on two occasions and are preparing to do this again as failure rates have risen again to around 50%. In addition we have introduced a very low level maths subject for those students with minimal mathematics from school. All other universities have similar problems.
- Research by Dr Shaun Belward of the JCU Mathematics Department (see submission by JCU faculty of Science and Engineering) demonstrates, in a rigorous analytical manner, that the standards of students on entry to university are feeble, especially in Arithmetic and Algebra **at the Year 10 level, i.e. students entering first year university with a sound achievement in year 12 maths B struggle with year 10 level mathematics. The QSA says these students are sound at Maths B but in reality they struggle even at Grade 10 level mathematics.** Belward has also shown that whether a student achieved a school ratings Sound (C) as opposed to High (B) had no significant affect on tertiary first semester results. This is likely because the QSA assessment values different skills to the university assessment, i.e university mathematics subjects value mathematical skills rather than writing and other largely irrelevant skills. Thus the QSA produces meaningless discrimination by levels of achievement in addition to poor standards. This research destroys absolutely any idea that the QSA system is **reliable**.
- Assessment drives what is taught in class. **Validity** is the measure of whether what is purported to be tested is actually tested. With senior student graduates struggling with even Year 10 mathematics, the QSA processes are evidently invalid because it is not scoring up what is right or wrong in the subject knowledge.

QSA evidence on its marking policy

The Inquiry proceedings of 20/3/2013 were an invitation by the committee for the QSA to explain how the Qld assessment system worked. The QSA chose to invite

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instruments" QSA policy March 2010 Policy.Using standards to make judgments about student achievement in Authority and Authority-registered subjects, top of page 4.
Accessed April 2013: http://www.qsa.qld.edu.au/downloads/approach/qsa_policy_standards.pdf This is a furphy, disproved in other states and highly successful countries. If the exam is designed well, it will test the required standards anyway and the differential weighting of the numerical marks tells students exactly how much they mastered those standards.

three teachers to make the majority of the presentation. In my view the details of the system were glossed over and the presentations turned into an exercise in promoting the present system rather than simply stating how the system worked. Despite some probing questions by the committee the QSA presentation was deficient in the following aspects.

- They failed to demonstrate exactly how the final grade was determined by the matrix of letters. They should have presented multiple student letter matrices (such as shown in **Appendix C**) and showed exactly how they derived the result. They also should have presented multiple student matrices which all got the same grade (perhaps a B) and demonstrated exactly how they determined the rank order of those students (see appendix C). This is crucial as it is a primary determinant of the OP
- The QSA director was asked about the precise way that the OP score was calculated but she gave almost no useful detail. In particular it was not explained why the OP score calculation uses numbers throughout to calculate the final result whereas the QSA forbids the use of numbers in the calculation of the school grade. Perhaps the QSA director skipped over the mathematical aspect of the OP calculation because it would have highlighted QSA hypocrisy on this matter.
- Despite a specific question by a committee member who pointed out that many of the criteria are very similar, varying often by only one word, it was not explained how a teacher was supposed to interpret the criteria. This is a continual problem faced by teachers. In the example presented to the committee, the A criteria is "*data and ideas have been selected with discrimination to make meaning clear"*. The C grade required that " *data and ideas have been selected to convey meaning*". The committee member who asked this question pointed out that there was not much difference between these criteria but was assured by the teacher presenter that to an experienced teacher this was very clear. I disagree strenuously and suggest that most teachers struggle with this subtle distinction.

Compare QSA marking policy with simple NSW marking guide

The QSA's invalid and unreliable non-numerical marking is also extremely time-consuming. To help the Committee contrast the Queensland system with New South Wales compare them –

- A 72-page workshop manual on Queensland's assessment **–** see **Appendix D (Mathematics ABC Assessement Workshop 2009)**; and
- A simple, short New South Wales marking guide for a Higher School Certificate external maths exam – see **Appendix E (Mathematics marking guide NSW)**.

Not only is the New South Wales system (and marking guide) simple to administer, unlike the QSA method, it is both valid and reliable.

(c) Invalid 'Cherry-picking' student results

The QSA syllabuses for maths/science impose a policy of continuous assessment of assessment tasks (such as tests and assignments) without a requirement for teachers to inform students which tasks will count towards their exit grade.

Teachers are permitted after assessment has been completed to effectively 'cherry-pick' particular class or student results that count towards each student's assessment. See **Appendix F (QSA syllabuses on 'cherry-picking' student results)**.

4.2 Many teachers reject QSA's assessment processes

The comments earlier about the absolute power of QSA and the widespread fear that exists amongst teachers and especially parents is a major barrier to the inquiry's ability to get a good information about the level of support/opposition throughout the community. Parents are very frightened in case their children are victimised, teachers have to 'keep their noses clean' to protect their professional prospects. There is strong evidence that many teachers reject QSA assessment processes-

- In an informal survey that I conducted of over 400 maths and science teachers, the overwhelming majority (90%) found that the non-marks based system was difficult and frustrating to implement and was extremely time consuming. Many teachers have reported that their marking load has become crippling, and this takes away from time that can be devoted to being a good teacher.
- A survey done by the QIEU published on 5th March 2013 found that less than half of maths and science teachers were confident that the QSA process delivers accurate results. Less than 30% said they had enough time to implement the system. Notably, the QIEU survey also failed to ask the obvious question about whether teachers would prefer to use masks instead of the present system. Instead it asked a few questions which carefully skirted around the issue.
- It is disappointing to note that the effect on teacher workloads has, until recently, been ignored by the teachers unions. The Queensland Teachers Union (QTU), with ties to the QSA board, has defended the QSA approach although it has documented teacher dissatisfaction and student equity problems with this system in its submission to this inquiry.[14] The QTU has in the past ignored the pleas of its members to investigate this issue. Union leaders have, on occasions, attacked the messengers. I note that the QTU submission to the Inquiry now accepts that there are some significant issues with our present system.

It is evident that because the QSA system has now been in operation for a considerable time, many young teachers do not know any other system and have no idea that they are being required to operate a highly time consuming and problematic system, and that a better alternative is used in every other state.

4.3 Student participation levels

Participation levels (and success and standards) are not determined in Years 11/12. The decisions to take/not take a subject are made in Year 10. Although early secondary and primary stages are outside the ambit of this inquiry, the significance and importance of earlier years cannot be ignored.

[14] Queensland Teachers' Union Submission 26, to this inquiry.
http://www.parliament.qld.gov.au/documents/committees/EIC/2013/QldAssessment/submissions/026.pdf

It is therefore relevant to see why students are electing before their senior years not to do these subjects.

QSA's poor quality senior assessment lowers standards in earlier grades

The previous government, seeing the poor NAPLAN results as a 'wake-up call', employed ACER, the highest and most authoritative education research organisation in Australia, to do a study on Primary and also early Secondary education. It is called *A shared Challenge* (ACER 2009). A summary of the situation in Maths in Queensland is: "the absolute decline in lower secondary school mathematics achievement appears to have been greater than in any other State, and have been the **equivalent of about two years learning".**

Axiomatically, that appalling decline has a massive effect on standards in Year11. It should be noted that a decline in standards in year 10 may not result in a reduction in participation in year 11 especially if the standards are also reduced in the year 11 and 12 maths subjects.

5. Why QSA has failed.

5.1 QSA is incompetent and intolerant of criticism

- The QSA has completely bungled the introduction of the present Physics, Chemistry and Maths Syllabuses. There have been continuous modifications, changes, clarifications, re-clarifications and reversals. District panels struggle to implement the system because the rules are unclear and varying. Advice from the QSA will sometimes have a disclaimer attached stating that the advice might not be right. At least they get that bit correct. An example of such a disclaimer is in a document attempting to clarify some technical terms of the syllabus (the words "complex" and "challenging"). It states "*This clarification is not meant to offer a binding definition, nor does it provide the only possible interpretation. It does however offer teachers one definition, around which there has been discussion and consensus among practising teachers (i.e. state review chairs and panellists and district review panel chairs*)." It demonstrates the vagueness of the system when the QSA itself cannot define its own terms.
- The syllabi are supposed to provide guidance on what is to be taught. However, the physics syllabus in particular contains almost no guidance on content. Unlike previous syllabi and those in other states, there is no list of content or the mathematical detail to which content must be taught. The only potential useful list of content in the physics syllabus carries a disclaimer that the list is neither exhaustive nor even compulsory, i.e. it is a pointless list. Consequently, different schools can do almost anything they wish. The QSA director at the forum on 1 May stated that the physics syllabus contained many pages of content that needed to be taught but in fact these pages are largely meaningless and unhelpful - like most of the Physics syllabus document.

- The QSA has never provided evidence that the present system performs better than the system it replaced. Much of it was originally invented in the USA and was rejected after trials. Western Australia adopted a similar system, only to replace it with a more traditional approach three years ago after considerable public outrage and the resignation of the education Minister. (See submissions by Mr Pat Whalen and Professor Igor Bray).
- The QSA has been deliberately vague to this committee about how the present system works. It was asked by the committee to explain the system on 20/3/2013. In my view the details of the system were glossed over and the presentations turned into an exercise in promoting the present system rather than simply stating how the system worked.
- QSA has enormous power and they use it. Even now with the forthcoming parliamentary inquiry, many teachers will be very wary about making public comments. This fear is very real and will be a major obstacle for the inquiry. It will be even more difficult to get parents to speak against the system because they fear that it can be interpreted as a criticism of their child's school or teacher.
- The QSA system of social moderation has no ability to scale fairly between schools.[15] This prevents transparency, which could otherwise show up biases that some teachers and parents suspect but cannot confirm, while others have alluded to these in submissions to this Inquiry to date.
- A chronology of reform after questionable reform, demonstrates the constant and undoubtedly expensive changes for little demonstrable benefits, for which the QSA is at least in part responsibility.[16]

5.2 Ideology of Education Theorists

The problems in the QSA are symptomatic of wider deep-seated problem across all our organisations associated with school education. These include Education Queensland, the teachers unions and education faculties at universities. Note that it is likely that some of the official university submissions to this Inquiry will effectively come from education faculties, and that little consultation will have been done with lecturers who are responsible for teaching first year subjects in Science or Engineering etc. There is usually an ideological gulf between education faculties and the Science and Engineering faculties.

The present system of assessment is supported by all the major organisations involved with education (EQ, unions etc) despite none of them surveying what parents, the general public or teachers (QIEU excepted) want. However none have benchmarked the Qld system against other systems elsewhere.

The strange assessment systems are by no means the only fashionable education trend that has been invented by Education Theorists. Others are (a) the notion that teachers are no longer teachers, but rather are "education facilitators" that help children discover their own truths from the vast array of information that is now available on the web, and (b) drilling of spelling, practice at multiplication tables, and doing large numbers of repetitious algebraic manipulations must be avoided. They will often describe practice to become technically competent as "tick and flick", a clever but unintelligent phrase.

Justine Ferrari, in The Australian newspaper of 10th July 2012, reported that the Australian University ' Deans of Science utterly rejected' *the published QSA view of science, and by*

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[15] ACER, Matters G (2008) pp 13-15. Quote: "…the rules of statistical combination require statistical moderation." See also Table 1: Purposes and forms of moderation, which concludes that social moderation (used by QSA) has **no** ability to perform scaling

[16] ACER Masters G (2009) A shared challenge. ACER pp 45-46
http://education.qld.gov.au/mastersreview/pdfs/final-report-masters.pdf

implication, the Queensland science syllabuses and assessment processes. In this report the Deans' view is that the QSA approach 'fundamentally misunderstands the nature of scientific inquiry'. This is an example of how the entire ideology of the educational theorists, in this case within the QSA, is out of step with the real world.

5.3 QSA's repeated failure to adopt evidence-based recommendations

The QSA has repeatedly failed to implement recommendations – even those in reviews the QSA has commissioned - to address the gross invalidity and unreliability of senior assessment of maths and science. The entire cast of staff, of whatever good intentions, has been unable to overcome an entrenched culture of clinging on to unscientific methods.

2006 ACER recommendations ignored

The QSA ignored comments about the reliability of assignments in the main recommendations of the 2006 QSA-commissioned ACER report[17] into the assessment of Senior science subjects *viz.*,

> ***Recommendation 2:*** *That the continued exploration and employment of task-based assessment be encouraged but "not mandated until its feasibility, reliability and validity have been demonstrated."*

This ACER report (page 5) also stated that

> *"... the Queensland system of criteria-based assessment developed, not so much underpinned by theory but more so as a theory-building exercise in itself"*

or to put this in plain English, **it is an experiment.**

2008 ACER recommendations ignored

The QSA also failed to reform its flawed assessment policies despite the findings of 2008 QSA-commissioned ACER report[18] into syllabuses and Senior assessment of all subjects that –

(a) **external exams** should be considered for Queensland senior subjects including as a way to moderate or 'anchor' internal assessment [19]; and

[17] ACER, Matters G (2006) Assessment approaches in Queensland Senior science syllabuses: report to the Queensland Studies Authority.

[18] ACER Matters G (2008) *Realising and releasing potential 40 years on*. Australian Council for Educational Research; Griffith University.

(b) the QSA's system of **social moderation** has no ability to scale fairly between schools; [20]
(c) Queensland should provide students with **upfront assessment composition rules**.[21] This contrasts with the current invalid and unreliable QSA policy that allows teachers to retrospectively 'cherry-pick' students' results towards the final grade.

Summary

The QSA has failed time and again to implement changes for valid and reliable assessment and continues in its self-delusional state that Queensland is leading the world in assessment.

6. What needs to be done?

I have made specific recommendations in section 3 of this document. As a final comment the role of the QSA board requires particular attention as it is in the final analysis responsible for the problems we face. It is useful to consider the Western Australian example. Until three years ago, WA had a similar system to Queensland. There was such a public outcry about the system that the WA minister of education was forced to resign. The following minister changed the system to a more traditional approach and effectively sacked the WA Curriculum Council (the QSA equivalent). Importantly, they have also reduced the power of educational theorists. I strongly recommend that the Education and Innovation Committee invite Prof Igor Bray, from the Physics Department at Curtin University, to describe the Western Australian experience.

It is interesting to note the QSA has stated to this Inquiry (7 March) that the Qld system "*bears no relationship to the system of outcomes based education recently discarded in Western Australia*". This is a completely erroneous statement (see submissions by Prof Igor Bray and Mr Pat Whalen). The WA system had (a) a similar non marks based assessment system, (b) comparison with standards, and (c) the over-use of long assignments. If anything, the discredited WA system was considerably less radical and extreme than the present system in Qld because WA at least had an external exam to standardise some of the results. Clearly the QSA wants to distance itself from the WA example because it provides an obvious precedent for what should be done in Qld, i.e reform of the assessment and reform or replacement of the QSA.

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[19] In this 2008 ACER report Professor Gabrielle Matters noted that "fusing internal assessment and standardised examinations should not be rejected out of hand".

[20] ACER, Matters G (2008) pp 13-15, "…the rules of statistical combination require statistical moderation." See also Table 1: Purposes and forms of moderation, which concludes that social moderation (used by QSA) has **no** ability to perform scaling

[21] ACER, Matters G (2008) p15, "A grading scheme that has become increasingly common throughout the world is to communicate to students at the beginning of a course what the criteria are for assessment (e.g., for exit assessment and task-specific assessment). Students are informed about what the assessment program will be, its components, and how results will be combined. In the case of overall or exit assessment, the composition rule, which is formulated by syllabus writers, states how the results are to be combined and grades assigned. The criteria, which sometimes incorporate mandatory minima on certain components, are the composition rules. Nominating the criteria does not tell students about standards."

The evidence in my submission and other submissions before this inquiry is that the QSA has failed over a period of years to provide valid or reliable assessment methods in senior maths, physics and chemistry.

There is overwhelming evidence that the QSA has failed to properly perform its assessment function or its related moderation function under the *Education (Queensland Studies Authority) Act 2002* **('the QSA Act')**. In my opinion, this failure and the surrounding circumstances constitute ample grounds for QSA members appointed under s25 to be issued with a notice to show cause why they should not be removed from office forthwith.

However, even if these positions are terminated as permitted by law[22], the qualifications of members set out in s.25(2) of the QSA Act need to be urgently revised by passage of legislation specifying different membership qualifications. In particular, the board should not be dominated by those who are part of the 'education establishment" who have caused so many of the problems. Instead I would value more highly the input from a group of sensible mums and dads, who have been successful in other walks of life, and industry representatives. They could take specialist advice when appropriate in much the same way as do Parliamentarians and Ministers. However, unlike many of those in the 'education establishment', their general outlook on education would better reflect community standards and values. In any case, the composition of the QSA board or its replacement needs to be carefully considered.

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[22] See s.25 *Acts Interpretation Act (Qld) 1954.*

Appendix A:

Inter-state comparison of senior school assessment methods

Senior Maths Assessment – Qld vs. Other Australian States								
Subject	State	Qld maths equivalent (Syllabus link)	Who assesses & how much weight placed on subject external exam?		Marking exam questions: Individual questions = Total		Mandatory Assessment other than tests or exams?	
			External exam	Internal assessment	Numerical marks per Question added up to mark out of 100% Total Converted to A-E	A-E grading per criterion per item results in: Multiple A-E grades that must become a single grade from A-E	Yes / No	% of annual assessment
1	Qld	Mathematics B	Nil*	100%		All assessment items*	Yes (≥2)	Not fully specified
2	NSW	Mathematics	50%	50%	All assessment items		Yes (≥1)	25%
3	Vic	Mathematical Methods	66%	34%	All assessment items		Yes (≥ 2)	< 34%
4	WA	Mathematics	50%	50%	All assessment items		Yes	Not fully specified
5	SA	Mathematical Methods	30%	70%	External exam and Skills and Applications Tasks		Yes (≥ 2)	25 %
6	TAS	Mathematical Methods	5 ratings A to E	7 ratings A to E	External exam definitely		No	N/A

* Both these non-statistical anomalies are hoped to be amended by following findings from this inquiry

Appendix B:

QSA syllabuses on Assignments

Queensland Studies Authority's Policy on Assignments for Senior Maths, Chemistry & Physics (April 2013)						
Name of written assignment task	**Senior Assignment type required in QSA syllabus**	**Assignment details**	**No. of assignments**	**What % of overall assessment are assignments worth?**	**Can schools "cherry pick" which assignments count for assessment?**	**QSA's upper word limit?**
EMPS tasks (Extended Modelling and Problem Solving)	Mathematics A Syllabus (2008)[23] Mathematics B Syllabus (2008)[24] Mathematics C Syllabus (2008)[25]	An EMPS tasks is an "extended modelling and problem-solving task OR a report OR similar …. "	**2 per year** An EMPS task "must be included at least twice a year"	**No % ispecified by QSA.** EMPS tasks "should **contribute significantly** to the decision-making process in each of the three exit criteria [for the final subject grade]."	**Yes** Teachers have to "cherry pick" class and/or student results. (See details in "Cherry Picking" Appendix F)	**None** QSA appeared to contradict its 1000 word limit policy, and which is pointless anyway as it does not apply to methods, appendices, etc and the word cap is only recommended, it is not enforced, leading to an escalating arms race of bigger and more sophisticated assignments
EEI (Extended Experimental Investigation)	Chemistry [26]	See Section 7, Chemistry or physics syllabus				
	Physics [27]	See Section 7,Chemistry or physics syllabus				
ERT (Extended Response Task)	Chemistry	See Section 7 ,Chemistry or physics syllabus				
	Physics	See Section 7 ,Chemistry or physics syllabus				

[23] Qld's *Mathematics A Syllabus (2008)*, see Section 6. URLs in this document all accessed 24 April 2013 http://www.qsa.qld.edu.au/downloads/senior/snr_maths_a_08_syll.pdf

[24] Qld's *Mathematics B Syllabus (2008)*, see Section 6. http://www.qsa.qld.edu.au/downloads/senior/snr_maths_b_08_syll.pdf

[25] Qld's *Mathematics C Syllabus (2008)*, see Section 6. http://www.qsa.qld.edu.au/downloads/senior/snr_maths_c_08_syll.pdf

[26] Qld's Chemistry Syllabus, see section 7. http://www.qsa.qld.edu.au/1952.html

[27] Qld's Physics Syllabus, see section 7. http://www.qsa.qld.edu.au/1964.html

Appendix C:

Using QSA letters to determine a student's final grade and rank order

(An example of three students' result matrices or ‘profiles’)

One of the biggest problems with the non-marks based assessment system is determining the rank order of students. In the following three pages, I will present the results matrices of 3 different students to show how difficult this is. In addition, the conventional system of marks, which is used in almost every other state and country in the world is also presented.

The committee must ask themselves the question. If one uses the letter matrix,

(a) what is the final grade, and
(b) how can I determine the rank order of these students, i.e which of the students is best and which is worst?

Perhaps each committee member could fill in the space for the final grade (the space with two question marks, ??) and compare results. You however must not cheat and do it the simple way by looking at the marks table below the letter matrix.

P.T.O./...

Name: Student 1					
Black Stump Catholic Independent Girls State High School.					
Physics:					
Semester	**Assessment Task**		**Knowledge, Conceptual Understanding**	**Investigative Processes**	**Evaluating and Concluding**
1	F	Extended response task (ERT)	C+	C+	A
1	F	exam	D	C-	
1	F	exam	D+	C	C
2	F	Extended experimental investigation (EEI)	C+	C	B
2	F	exam	C	D	
2	F	exam	C	A	A-
	Monitoring (does not count)		**C**	**C**	**B**
3	S	Extended response task (ERT)	A	A	A
3	S	exam	D+	D	A
3	S	Exam	C+	A+	A-
3	S	Extended experimental investigation (EEI)	A	A+	A
4	S	Exam	B	C-	B-
	EXIT Grade		**??**	**??**	**??**
	FINAL OVERALL RESULT		**??**		
	Rank Order				

Table 1: QSA system of aggregating results:

Small Tests/ 20	14
Practicals/15	12
Assignments/5	4
Exams/ 60	45
Final Percentage	75%
Final Grade after consultation with district Panel	B

Table 2: System used in most of the rest of the world. Marks are added up and the final grade is judged by analysing the difficulty of the assessment. Rank order for OP calculation is a trivial task, i.e. just look at the final percentage.

Name: Student 2					
Black Stump Catholic Independent Girls State High School.					
Physics:					
Semester	**Assessment Task**		**Knowledge, Conceptual Understanding**	**Investigative Processes**	**Evaluating and Concluding**
1	F	Extended response task (ERT)	C+	C+	A
1	F	exam	D	C	
1	F	exam	D	C	C
2	F	Extended experimental investigation (EEI)	C+	C+	C+
2	F	exam	C	D	
2	F	exam	C	A	A-
	Monitoring (does not count)		**C**	**C**	**B**
3	S	Extended response task (ERT)	A	A-	A
3	S	exam	D	C-	A
3	S	Exam	C-	A+	A
3	S	Extended experimental investigation (EEI)	A+	A+	A
4	S	Exam	C+	C	B-
	EXIT Grade		**??**	**??**	**??**
	FINAL OVERALL RESULT		**??**		
	Rank Order		??		

Table 1: QSA system of aggregating results:

Small Tests/ 20	14
Practicals/15	12
Assignments/5	4
Exams/ 60	43
Final Percentage	73%
Final Grade after consultation with district Panel	B^-

Table 2: System used in most of the rest of the world. Marks are added up and the final grade is judged by analysing the difficulty of the assessment. Rank order for OP calculation is a trivial task, i.e. just look at the final percentage.

Name: Student 3					
Black Stump Catholic Independent Girls State High School.					
Physics:					
Semester	**Assessment Task**		**Knowledge, Conceptual Understanding**	**Investigative Processes**	**Evaluating and Concluding**
1	F	Extended response task (ERT)	C+	C+	A
1	F	exam	D	C	
1	F	exam	D	C	C
2	F	Extended experimental investigation (EEI)	C+	C+	C
2	F	exam	C+	D	
2	F	exam	C	A-	A-
	Monitoring (does not count)		**C**	**C**	**B**
3	S	Extended response task (ERT)	A	B	A+
3	S	exam	D	C-	A
3	S	Exam	C-	A	A+
3	S	Extended experimental investigation (EEI)	A+	A+	A-
4	S	Exam	B	C-	B
	EXIT Grade		**??**	**??**	**??**
	FINAL OVERALL RESULT		**??**		
	Rank Order				

Table 1: QSA system of aggregating results:

Small Tests/ 20	12
Practicals/15	12
Assignments/5	4
Exams/ 60	43
Final Percentage	71%
Final Grade after consultation with district Panel	B^-

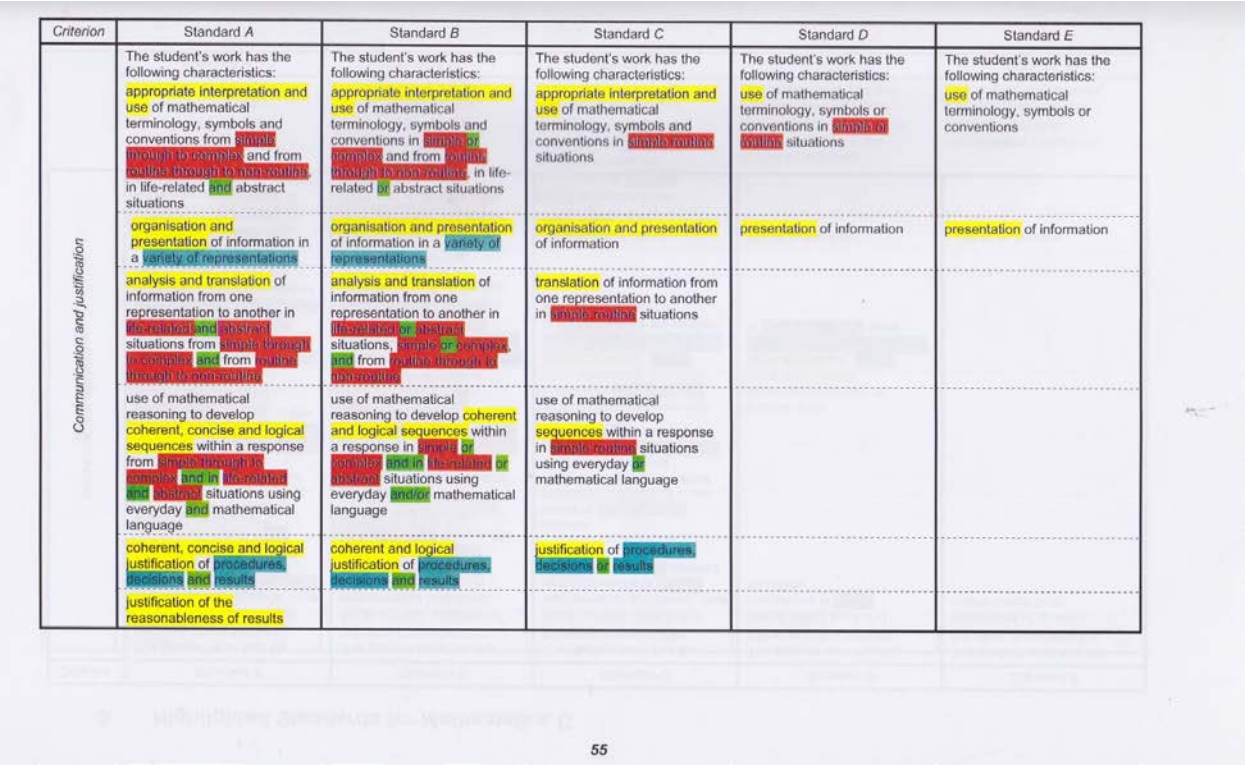
Table 2: System used in most of the rest of the world. Marks are added up and the final grade is judged by analysing the difficulty of the assessment. Rank order for OP calculation is a trivial task, i.e. just look at the final percentage.

Appendix D:

Excerpt from 72 page book “Mathematics ABC Assessment Workshop 2009” (QSA manual). Note, this book is generally not available to the public and can only be received by teachers upon paying the QSA to attend workshops on ‘how to mark’.

Below is just one page from the booklet. See attached pdf for full 72-page book on how to mark a question in Queensland tests and tasks.

Please compare with Appendix E: NSW marking guide



Criterion	Standard A	Standard B	Standard C	Standard D	Standard E
Communication and justification	The student's work has the following characteristics: appropriate interpretation and use of mathematical terminology, symbols and conventions from simple through to complex and from routine through to non-routine, in life-related and abstract situations	The student's work has the following characteristics: appropriate interpretation and use of mathematical terminology, symbols and conventions in simple or complex and from routine through to non-routine, in life-related or abstract situations	The student's work has the following characteristics: appropriate interpretation and use of mathematical terminology, symbols and conventions in simple routine situations	The student's work has the following characteristics: use of mathematical terminology, symbols or conventions in simple or routine situations	The student's work has the following characteristics: use of mathematical terminology, symbols or conventions
	organisation and presentation of information in a variety of representations	organisation and presentation of information in a variety of representations	organisation and presentation of information	presentation of information	presentation of information
	analysis and translation of information from one representation to another in life-related and abstract situations from simple through to complex and from routine through to non-routine	analysis and translation of information from one representation to another in life-related or abstract situations, simple or complex, and from routine through to non-routine	translation of information from one representation to another in simple routine situations		
	use of mathematical reasoning to develop coherent, concise and logical sequences within a response from simple through to complex and in life-related and abstract situations using everyday and mathematical language	use of mathematical reasoning to develop coherent and logical sequences within a response in simple or complex and in life-related or abstract situations using everyday and/or mathematical language	use of mathematical reasoning to develop sequences within a response in simple routine situations using everyday or mathematical language		
	coherent, concise and logical justification of procedures, decisions and results	coherent and logical justification of procedures, decisions and results	justification of procedures, decisions or results		
	justification of the reasonableness of results				

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Appendix E: also found at http://www.boardofstudies.nsw.edu.au/hsc_exams/hsc2011exams/

Mathematics marking guide (NSW external maths exam)

2011 HSC (NSW EXTERNAL EXAM: note guidelines so that markers also mark part-marks same)

General Mathematics

Marking Guidelines

Question 23 (a)

Criteria	Marks
• Correct calculation of the Medicare levy	3
• Correct calculation of taxable income OR significant progress towards an answer	2
• Correct calculation of total deductions OR progress towards an answer	1

Question 23 (b) (i)

Criteria	Marks
• Correct shape	1

Question 23 (b) (ii)

Criteria	Marks
• Correct answer or correct numerical expression	1

Question 23 (b) (iii)

Criteria	Marks
Correct answer including explanation and calculations Correct working and conclusion based on working in (b) (ii)	2
• Evidence of linking N and F correctly, eg $N = 3F + 2$, or in words OR • Correct conclusion from their working	1

Criteria	Marks
• Correct solution using value from table	2
• Correct value from table OR • Correct n, incorrect r, and multiplied by 5000 OR Correct r, incorrect n, and multiplied by 5000 Correct n and r	1

Appendix F:

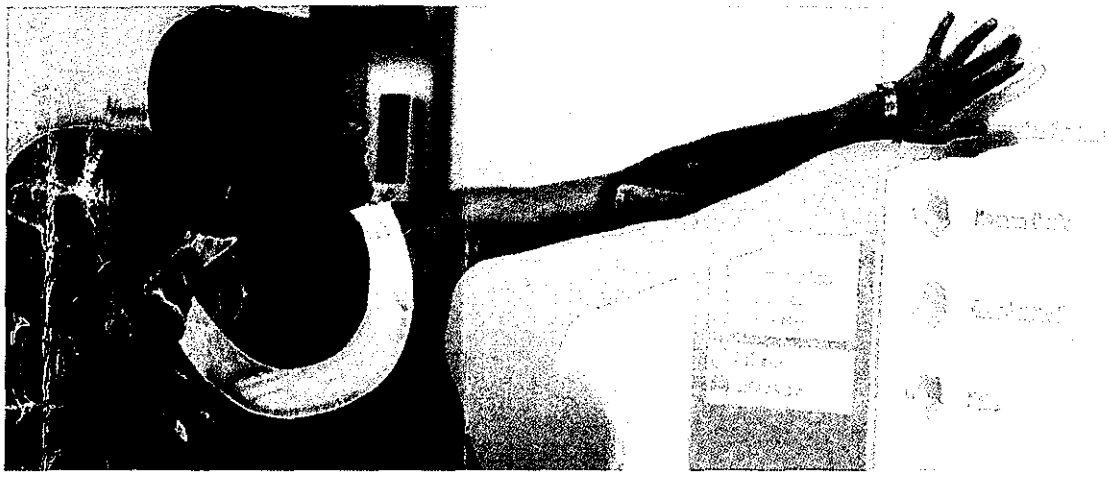
QSA syllabuses on 'Cherry-picking' student results

Cherry-picking assessment (tests and assignments) that count towards final grade		
	Wording extracted from QSA Syllabus	**Plain English translation**
1	Selective updating [heading for Syllabus section]	Cherry picking of assessment tasks (exams & assignments)
2	In conjunction with the principle of fullest and latest information, information on student achievement should be selectively updated throughout the course …	The student's "fullest and latest" assessment should be chosen to count towards the final grade.
3	The information … should be selectively and continually updated (not averaged) to accurately reflect student achievement.	Teachers are to cherry pick, rather than average the student's results across all assessment items. Note: Students therefore will not know which "assessment" counts towards their final grade.
4	The following conceptions of the principle of selective updating apply:	Apply these cherry picking principles:
5	A systemic whole subject-group approach in which considerations about the whole group of students are made according to the developmental nature of the course and, in turn, the assessment program. In this conception, developmental aspects of the course are revisited so that later summative assessment replaces earlier formative information.	Cherry pick any set of assessment results that teachers believe represents class achievement to date (and disregard all other results).
	An act of decision-making about individual students — deciding from a set of assessment results the subset which meets study area specification requirements and typically represents a student's achievements, thus forming the basis for a decision about a level of achievement.	·And/or cherry pick any set of assessment results that teachers believe represents individual student achievement to date (and disregard all other results). Even use different results for different students.

Note: These provisions are in Qld's Mathematics A, B & C Syllabuses at Section 6 and are in the Chemistry and Physics Syllabuses at Section 7.

Mathematics ABC Assessment Workshop

2009



Queensland Government

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Contents

Designing an Assessment Instrument — exam / assignment, etc

In designing an assessment instrument the following procedure will allow the construction of the instrument in which desired aspects of the general objectives will be identifiable, and these aspects will be associated with the appropriate descriptors of the standards matrix. The associated instrument-specific criteria sheet will inform students of the specific requirements of the instrument and will provide simple feedback on student performance matched to the standards descriptors.

1. **Start with the General Objectives**
2. **Determine what aspects of the General Objectives you wish to assess.**
3. **Refer to the Standards Matrix for the relevant descriptors for the aspects of the General Objectives chosen**
4. **Develop an instrument or instruments that will allow students to demonstrate these attributes**
5. **Develop an instrument-specific criteria sheet using the chosen attributes of standards matrix as a basis**

1. Start with the General Objectives

For Mathematics A, the assessable General Objectives are:

Knowledge and Procedures:

- manipulate simple rules and formulas
- access, select and apply rules and formulas
- recall, select and apply mathematical procedures to situations that are similar to situations already encountered
- apply a sequence of mathematical procedures in situations that are similar to situations already encountered
- use mathematical technology and geometrical instruments.

Modelling and problem solving:

- interpret, clarify and analyse problems
- use strategies to model and solve problems
- investigate alternative solutions and/or procedures to problems
- make decisions informed by mathematical reasoning
- reflect on the effectiveness of mathematical models, including the recognition of strengths and limitations.

Communication and justification

- interpret and use appropriate mathematical terminology, symbols and conventions
- organise and present information for different purposes and audiences, in a variety of representations (such as written, symbolic, pictorial and graphical)
- analyse information displayed in a variety of representations (such as written, symbolic, pictorial and graphical) and translate information from one representation to another
- develop logical sequences within a response expressed in everyday language, mathematical language, or a combination of both, as required, to justify conclusions, solutions or propositions
- justify the reasonableness of results obtained through technology or other means using everyday language, mathematical language or a combination of both, when appropriate.

For Mathematics B, the assessable General Objectives are:

Knowledge and procedures

- recall, access, select and apply mathematical definitions, rules and procedures
- demonstrate number and spatial sense
- demonstrate algebraic facility
- select and use mathematical technology.

Modelling and problem solving

- apply problem-solving strategies and procedures to identify problems to be solved, and interpret, clarify and analyse problems
- identify assumptions (and associated effects), parameters and/or variables during problem solving
- represent situations by using data to synthesise mathematical models and generate data from mathematical models
- analyse and interpret results in the context of problems to investigate the validity (including strengths and limitations) of mathematical arguments and models.

Communication and justification

- interpret and use appropriate mathematical terminology, symbols and conventions
- organise and present information for different purposes and audiences, in a variety of representations (such as written, symbolic, pictorial and graphical)
- analyse information displayed in a variety of representations (such as written, symbolic, pictorial and graphical) and translate information from one representation to another
- develop coherent, concise and logical sequences within a response expressed in everyday language, mathematical language or a combination of both, as required, to justify conclusions, solutions or propositions
- develop and use coherent, concise and logical supporting arguments, expressed in everyday language, mathematical language or a combination of both, when appropriate, to justify procedures, decisions and results
- justify the reasonableness of results obtained through technology or other means using everyday language, mathematical language or a combination of both, when appropriate.

For Mathematics C the assessable General Objectives are:

Knowledge and procedures

- recall, access, select and apply mathematical definitions, rules and procedures
- demonstrate number and spatial sense
- demonstrate algebraic facility
- select and use mathematical technology
- demonstrate knowledge and use of the nature of mathematical proof.

Modelling and problem solving

- apply problem-solving strategies and procedures to identify problems to be solved and interpret, clarify and analyse problems
- identify assumptions (and associated effects), parameters and/or variables during problem solving
- represent situations by using data to synthesise mathematical models and generate data from mathematical models
- analyse and interpret results in the context of problems to investigate the validity (including strengths and limitations) of mathematical arguments and models
- modify mathematical models as appropriate.

Communication and justification

- interpret and use appropriate mathematical terminology, symbols and conventions
- organise and present information for different purposes and audiences, in a variety of representations (such as written, symbolic, pictorial and graphical)
- analyse information displayed in a variety of representations (such as written, symbolic, pictorial and graphical) and translate information from one representation to another
- develop coherent, concise and logical sequences within a response expressed in everyday language, mathematical language or a combination of both, as required, to justify conclusions, solutions or propositions
- develop and use coherent, concise and logical supporting arguments, expressed in everyday language, mathematical language or a combination of both, when appropriate, to justify procedures, decisions and results

- justify the reasonableness of results obtained through technology or other means using everyday language, mathematical language or a combination of both
- provide supporting arguments in the form of a proof and recognise that a proof may require more than a verification of a number of instances.

2. Determine what aspects of the General Objectives you wish to assess.

For Mathematics A, the general objectives chosen may be:

Knowledge and Procedures:

- manipulate simple rules and formulas
- access, select and apply rules and formulas
- recall, select and apply mathematical procedures to situations that are similar to situations already encountered
- apply a sequence of mathematical procedures in situations that are similar to situations already encountered
- use mathematical technology and geometrical instruments.

Modelling + Problem Solving

Communication and justification

- interpret and use appropriate mathematical terminology, symbols and conventions
- organise and present information for different purposes and audiences, in a variety of representations (such as written, symbolic, pictorial and graphical)
- analyse information displayed in a variety of representations (such as written, symbolic, pictorial and graphical) and translate information from one representation to another
- develop logical sequences within a response expressed in everyday language, mathematical language, or a combination of both, as required, to justify conclusions, solutions or propositions
- justify the reasonableness of results obtained through technology or other means using everyday language, mathematical language or a combination of both, when appropriate.

Please note here that we are only considering the Knowledge and procedures and Communication and justification criteria in this exercise.

For Mathematics B, the general objectives chosen may be:

Knowledge and procedures

- recall, access, select and apply mathematical definitions, rules and procedures
- demonstrate number and spatial sense
- demonstrate algebraic facility
- select and use mathematical technology.

Communication and justification

- interpret and use appropriate mathematical terminology, symbols and conventions
- organise and present information for different purposes and audiences, in a variety of representations (such as written, symbolic, pictorial and graphical)
- analyse information displayed in a variety of representations (such as written, symbolic, pictorial and graphical) and translate information from one representation to another
- develop coherent, concise and logical sequences within a response expressed in everyday language, mathematical language or a combination of both, as required, to justify conclusions, solutions or propositions
- develop and use coherent, concise and logical supporting arguments, expressed in everyday language, mathematical language or a combination of both, when appropriate, to justify procedures, decisions and results
- justify the reasonableness of results obtained through technology or other means using everyday language, mathematical language or a combination of both, when appropriate.

Please note here that we are only considering the Knowledge and procedures and Communication and justification criteria in this exercise.

For Mathematics C, the general objectives chosen may be:

Knowledge and procedures

- recall, access, select and apply mathematical definitions, rules and procedures
- demonstrate number and spatial sense
- demonstrate algebraic facility
- select and use mathematical technology
- demonstrate knowledge and use of the nature of mathematical proof.

Communication and justification

- interpret and use appropriate mathematical terminology, symbols and conventions
- organise and present information for different purposes and audiences, in a variety of representations (such as written, symbolic, pictorial and graphical)
- analyse information displayed in a variety of representations (such as written, symbolic, pictorial and graphical) and translate information from one representation to another
- develop coherent, concise and logical sequences within a response expressed in everyday language, mathematical language or a combination of both, as required, to justify conclusions, solutions or propositions
- develop and use coherent, concise and logical supporting arguments, expressed in everyday language, mathematical language or a combination of both, when appropriate, to justify procedures, decisions and results
- justify the reasonableness of results obtained through technology or other means using everyday language, mathematical language or a combination of both
- provide supporting arguments in the form of a proof and recognise that a proof may require more than a verification of a number of instances.

Please note here that we are only considering the Knowledge and procedures and Communication and justification criteria in this exercise.

3. Refer to the Standards Matrix for the relevant descriptors for the aspects of the General Objectives chosen

For Mathematics A, the attributes of the Knowledge and procedures and Communication and justification criteria in the standards descriptors corresponding to the chosen aspects of the general objectives would be:

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	The student's work has the following characteristics: • accurate use of rules and formulas in simple through to complex situations	The student's work has the following characteristics: • accurate use of rules and formulas in simple situations or use of rules and formulas in complex situations	The student's work has the following characteristics: • use of rules and formulas in simple routine situations	The student's work has the following characteristics: • use of given rules and formulas in simple rehearsed situations	The student's work has the following characteristics: • attempted use of given rules and formulas in simple rehearsed situations
	• application of simple through to complex sequences of mathematical procedures in routine and non-routine situations	• application of simple sequences of mathematical procedures in non-routine situations or complex sequences in routine situations	• application of simple sequences of mathematical procedures in routine situations	• application of simple mathematical procedures in simple rehearsed situations	• attempted use of simple mathematical procedures in simple rehearsed situations
	• appropriate selection and accurate use of technology	• appropriate selection and accurate use of technology	• selection and use of technology	• use of technology	• attempted use of technology

Criterion	Standard A	Standard B	Standard C	Standard D	Standard E
Communication and justification	The student's work has the following characteristics: • accurate and appropriate use of mathematical terminology and conventions in simple non-routine through to complex routine situations	The student's work has the following characteristics: • accurate and appropriate use of mathematical terminology and conventions in simple non-routine and/or complex routine situations	The student's work has the following characteristics: • appropriate use of mathematical terminology and conventions in simple routine situations	The student's work has the following characteristics: • use of mathematical terminology and conventions in simple rehearsed situations	The student's work has the following characteristics: • use of mathematical terminology or conventions in simple rehearsed situations
	• organisation and presentation of information in a variety of representations in simple non-routine through to complex routine situations	• organisation and presentation of information in a variety of representations in simple non-routine and/or complex routine situations	• organisation and presentation of information in a variety of representations in simple routine situations	• presentation of information in simple rehearsed situations	
	• analysis and translation of information displayed from one representation to another in complex routine situations	• analysis and translation of information displayed from one representation to another in simple routine situations	• translation of information displayed from one representation to another in simple routine situations		
	• use of mathematical reasoning to develop logical sequences in simple non-routine through to complex routine situations using everyday and/or mathematical language	• use of mathematical reasoning to develop logical sequences in simple non-routine and/or complex routine situations using everyday and/or mathematical language	• development of logical sequences in simple routine situations using everyday and/or mathematical language		
	• justification of the reasonableness of results obtained through technology or other means				

Please note here that we are only considering the Knowledge and procedures and Communication and justification criteria in this exercise.

NOTE - must be done for every single assessment task, whether exam, prac or assignment!

For Mathematics B, the attributes of the Knowledge and procedures and Communication and justification criteria in the standards descriptors corresponding to the chosen aspects of the general objectives would be:

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	The student work has the following characteristics: • recall, access, selection of mathematical definitions, rules and procedures in routine and non-routine simple tasks through to routine complex tasks, in life-related and abstract situations	The student work has the following characteristics: • recall, access, selection of mathematical definitions, rules and procedures in routine and non-routine simple tasks through to routine complex tasks, in life-related and abstract situations	The student work has the following characteristics: • recall, access, selection of mathematical definitions, rules and procedures in routine, simple life-related or abstract situations	The student work has the following characteristics: • use of stated rules and procedures in simple situations	The student work has the following characteristics: • statements of relevant mathematical facts
	• application of mathematical definitions, rules and procedures in routine and non-routine simple tasks, through to routine complex tasks, in life-related and abstract situations	• application of mathematical definitions, rules and procedures in routine or non-routine simple tasks, through to routine complex tasks, in either life-related or abstract situations	• application of mathematical definitions, rules and procedures in routine, simple life-related or abstract situations		
	• numerical calculations, spatial sense and algebraic facility in routine and non-routine simple tasks through to routine complex tasks, in life-related and abstract situations	• numerical calculations, spatial sense and algebraic facility in routine or non-routine simple tasks, through to routine complex tasks, in either life-related or abstract situations	• numerical calculations, spatial sense and algebraic facility in routine, simple life-related or abstract situations	• numerical sense, spatial sense and/or algebraic facility in routine or simple tasks	
	• appropriate selection and accurate use of technology	• appropriate selection and accurate use of technology	• selection and use of technology	• use of technology	• use of technology

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Communication and justification	The student's work has the following characteristics: • appropriate interpretation and use of mathematical terminology, symbols and conventions from simple through to complex and from routine through to non-routine, in life-related and abstract situations	The student's work has the following characteristics: • appropriate interpretation and use of mathematical terminology, symbols and conventions in simple or complex and from routine through to non-routine, in life-related or abstract situations	The student's work has the following characteristics: • appropriate interpretation and use of mathematical terminology, symbols and conventions in simple routine situations	The student's work has the following characteristics: • use of mathematical terminology, symbols or conventions in simple or routine situations	The student's work has the following characteristics: • use of mathematical terminology, symbols or conventions
	• organisation and presentation of information in a variety of representations	• organisation and presentation of information in a variety of representations	• organisation and presentation of information	• presentation of information	• presentation of information
	• analysis and translation of information from one representation to another in life-related and abstract situations from simple through to complex and from routine through to non-routine	• analysis and translation of information from one representation to another in life-related or abstract situations, simple or complex, and from routine through to non-routine	• translation of information from one representation to another in simple routine situations		
	• use of mathematical reasoning to develop coherent, concise and logical sequences within a response from simple through to complex and in life-related and abstract situations using everyday and mathematical language	• use of mathematical reasoning to develop coherent and logical sequences within a response in simple or complex and in life-related or abstract situations using everyday and/or mathematical language	• use of mathematical reasoning to develop sequences within a response in simple routine situations using everyday or mathematical language		
	• coherent, concise and logical justification of procedures, decisions and results	• coherent and logical justification of procedures, decisions and results	• justification of procedures, decisions or results		
	• justification of the reasonableness of results				

Please note here that we are only considering the Knowledge and procedures and Communication and justification criteria in this exercise.

For Mathematics C, the attributes of the Knowledge and procedures and Communication and justification criteria in the standards descriptors corresponding to the chosen aspects of the general objectives would be:

Criterion	*Standard A*	*Standard B*	*Standard C*	*Standard D*	*Standard E*
Knowledge and procedures	The student work has the following characteristics: • recall, access, selection of mathematical definitions, rules and procedures in routine and non-routine simple tasks through to routine complex tasks, in life-related and abstract situations	The student work has the following characteristics: • recall, access, selection of mathematical definitions, rules and procedures in routine and non-routine simple tasks through to routine complex tasks in life-related and abstract situations	The student work has the following characteristics: • recall, access, selection of mathematical definitions, rules and procedures in routine, simple life-related or abstract situations	The student work has the following characteristics: • use of stated rules and procedures in simple situations	The student work has the following characteristics: • statements of relevant mathematical facts
	• application of mathematical definitions, rules and procedures in routine and non-routine simple tasks through to routine complex tasks, in life-related and abstract situations	• application of mathematical definitions, rules and procedures in routine or non-routine simple tasks, through to routine complex tasks, in either life-related or abstract situations	• application of mathematical definitions, rules and procedures in routine, simple life-related or abstract situations		
	• numerical calculations, spatial sense and algebraic facility in routine and non-routine simple tasks through to routine complex tasks, in life-related and abstract situations	• numerical calculations, spatial sense and algebraic facility in routine or non-routine simple tasks, through to routine complex tasks, in either life-related or abstract situations	• numerical sense, spatial sense and algebraic facility in routine, simple life-related or abstract situations	• numerical sense, spatial sense and/or algebraic facility in routine or simple tasks	
	• appropriate selection and accurate use of technology	• appropriate selection and accurate use of technology	• selection and use of technology	• use of technology	• use of technology
	• knowledge of the nature of and use of mathematical proof				

	Standard A	Standard B	Standard C	Standard D	Standard E
Communication and justification	The student's work has the following characteristics: • appropriate interpretation and use of mathematical terminology, symbols and conventions from simple through to complex and from routine through to non-routine, in life-related and abstract situations	The student's work has the following characteristics: • appropriate interpretation and use of mathematical terminology, symbols and conventions in simple or complex and from routine through to non-routine, in life-related or abstract situations	The student's work has the following characteristics: • appropriate interpretation and use of mathematical terminology, symbols and conventions in simple routine situations	The student's work has the following characteristics: • use of mathematical terminology, symbols or conventions in simple or routine situations	The student's work has the following characteristics: • use of mathematical terminology, symbols or conventions
	• organisation and presentation of information in a variety of representations	• organisation and presentation of information in a variety of representations	• organisation and presentation of information	• presentation of information	• presentation of information
	• analysis and translation of information from one representation to another in life-related and abstract situations from simple through to complex and from routine through to non-routine	• analysis and translation of information from one representation to another in life-related or abstract situations, simple or complex, and from routine through to non-routine	• translation of information from one representation to another in simple routine situations		
	• use of mathematical reasoning to develop coherent, concise and logical sequences within a response from simple through to complex and in life-related and abstract situations using everyday and mathematical language	• use of mathematical reasoning to develop coherent and logical sequences within a response in simple or complex and in life-related or abstract situations using everyday and/or mathematical language	• use of mathematical reasoning to develop sequences within a response in simple routine situations using everyday or mathematical language		
	• coherent, concise and logical justification of procedures, decisions and results	• coherent and logical justification of procedures, decisions and results	• justification of procedures, decisions or results		
	• justification of the reasonableness of results				
	• provision of supporting arguments in the form of proof				

Please note here that we are only considering the Knowledge and procedures and Communication and justification criteria in this exercise.

4. Develop an instrument or instruments that will allow students to demonstrate these attributes

For the particular topic you are wanting to assessment, gather/generate assessment items that will satisfy the requirements as indicated in the particular attributes that have been chosen from the standards matrix. This does not mean that traditionally used items have to be rejected – many are still valid. However care should be exercised when assessment items are developed to make sure that the aspects of the chosen attributes will be met by the items.

For Mathematics A, the following is presented as an example of items that could be presented that will satisfy the attributes identified in the standards matrix. The Modelling and problem solving criteria is not being considered in this assessment instrument. The particular attributes for each standard are included for completeness only and would not need to be included with a normal supervised assessment.

Question 1 (Standard D – application of simple mathematical procedures in simple rehearsed situation)

Using the formula

Markup = marked price – cost price

Calculate the cost price of an article which had a marked price of $280 and a markup of $26.

Question 2 (Standard C – application of simple sequences of mathematical procedures in routine situations)

(i) An aluminium dinghy that cost a boatyard $1200 to build is sold for $2160. What is the percentage markup?

(ii) A hardware shop uses a 65% markup. What would the shop charge for a spade with the cost price of $12?

(iii) Calculators are sold to shops at a trade discount of 40%. What do the shops pay for a calculator with a list price of $45?

(iv) A sales representative bought a new car for $32 500 and after using it for 2 years sold it for $18 600. What was the percentage loss?

Question 3 (Standard B – application of simple sequences of mathematical procedures in complex sequences in routine situations)

(i) A coin dealer bought a rare penny and sold it at a profit of 20%, making $64 profit. What were the buying price and the selling price for the dealer?

(ii) A local convenience store has an annual turnover of $425 000. The owner's gross profit is $98 000, but overheads, including wages, power, accounting fees, advertising rent and other charges, amount to $64 300. What is the net profit as percentage of turnover?

Question 4 (Standard A – application of simple through to complex sequences of mathematical procedures in non-routine situations)

Paolo purchased an old washstand at a deceased estate auction. The washstand was cleaned up and then sold to an antiques dealer for a profit of 15%. The dealer sold the washstand to a customer for $1890, which included a $25 delivery charge. If the dealer made a 45% profit, how much did Paolo pay for the washstand at the auction?

For Mathematics B, the following is presented as an example of items that could be presented that will satisfy the attributes identified in the standards matrix. Note that because only application of rules and definitions is being considered, there is no item which references the D standard because no "stated rule" is being considered. The Modelling and problem solving criteria is not being considered in this assessment task. The particular attributes for each standard are included for completeness only and would not need to be included with a normal supervised assessment.

Question 1 (Standard C - application of mathematical definitions, rules and procedures in routine, simple abstract situations)

Solve the following equations for x, given that the values lie in the range $0 \leq x \leq 2\pi$.

(i) $\cos x = -0.5$

(ii) $2\sin x = \sqrt{3}$

(iii) $\tan x = 1$

(iv) $2 + 2\sin x = 1$

Question 2 (Standard B - application of mathematical definitions, rules and procedures in routine complex tasks, in abstract situations)

Solve the following equations for x, given that the values lie in the range $0 \leq x \leq 2\pi$.

(i) $2\cos\left(x + \frac{\pi}{6}\right) + 3 = 4$

(ii) $2\sin 3x = -\sqrt{2}$

(iii) $\tan^2 x - 4\tan x = 0$

Question 3 (Standard A - application of mathematical definitions, rules and procedures in non- routine complex tasks, in abstract situations)

Solve the following equations for x, given that the values lie in the range $-\pi \leq x \leq \pi$.

(i) $\tan^2 x + 3\tan x - 4 = 0$

(ii) $6\cos^2 x + 5\sin x = 7$

For Mathematics C, the following is presented as an example of items that could be presented that will satisfy the attributes identified in the standards matrix. Note that because only application of rules and definitions is being considered, there is no item which references the D standard because no "stated rule" is being considered. The Modelling and problem solving criteria is not being considered in this assessment task. The particular attributes for each standard are included for completeness only and would not need to be included with a normal supervised assessment.

Question 1 (Standard C - application of mathematical definitions, rules and procedures in routine, simple abstract situations)

(a) Find the value of $\sec\theta$ if $\tan\theta$ has the value of 4.2

(b) If $\cos\theta = 0.8$, find values for $\cot\theta$.

(c) Express $\cot\theta$ in terms of $\sec\theta$.

(d) Use an expansion formula to show that $\sin 2A = 2\sin A\cos A$

Question 2 (Standard B - application of mathematical definitions, rules and procedures in routine complex tasks, in abstract situations)

(a) Use an expansion formula to show that $\cos 3A = 4\cos^3 A - 3\cos A$

(b) Prove the identity $\tan\left(\frac{\pi}{4}+x\right)+\tan\left(\frac{\pi}{4}-x\right)=\frac{2}{\cos^2 x-\sin^2 x}$

(c) Express the combined function $\sin x - 3\cos x$ as a single cosine function.

Question 3 (Standard A - application of mathematical definitions, rules and procedures in non- routine complex tasks, in abstract situations)

(a) Solve $3\sin x + \sqrt{3}\cos x = 3$ for $0 \le x \le 2\pi$

(b) Find an exact value for $\tan 255^0$

5. Develop an instrument-specific criteria sheet using the chosen attributes of standards matrix as a basis

For the Mathematics A assessment instrument developed, the instrument-specific criteria sheet could have the following format:

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	The student's work has the following characteristic: • application of complex sequences of mathematical procedures in non-routine finance situations	The student's work has the following characteristic: • application of simple sequences of mathematical procedures in complex sequences in routine finance situations	The student's work has the following characteristic: • application of simple sequences of mathematical procedures in routine finance situations	The student's work has the following characteristic: • application of simple mathematical procedures in simple rehearsed finance situations	The student's work has the following characteristic: • attempted use of simple mathematical procedures in simple rehearsed finance situations
Communication and justification	• accurate and appropriate use of mathematical terminology and conventions in simple non-routine finance situations	• accurate and appropriate use of mathematical terminology and conventions in complex routine finance situations	• appropriate use of mathematical terminology and conventions in simple routine finance situations	• use of mathematical terminology and conventions in simple rehearsed finance situations	• use of mathematical terminology or conventions in simple rehearsed finance situations

Indicate on the criteria sheet the highest standard that the student has achieved within the particular attribute of those chosen from the standards matrix.

For the Mathematics B assessment instrument developed, the instrument-specific criteria sheet could have the following format:

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	The student work has the following characteristics: • application of mathematical definitions, rules and procedures in non-routine complex tasks, in abstract situations involving trigonometry	The student work has the following characteristics: • application of mathematical definitions, rules and procedures in routine complex tasks, in abstract situations involving trigonometry	The student work has the following characteristics: • application of mathematical definitions, rules and procedures in routine, abstract situations involving trigonometry	The student work has the following characteristics:	The student work has the following characteristics:
Communication and justification	• appropriate interpretation and use of mathematical terminology, symbols and conventions in non-routine complex, in abstract situations involving trigonometry • use of mathematical reasoning to develop coherent, concise and logical sequences within a response in complex abstract situations using everyday and mathematical language	• appropriate interpretation and use of mathematical terminology, symbols and conventions in routine complex, in abstract situations involving trigonometry • use of mathematical reasoning to develop coherent and logical sequences within a response in simple abstract situations using everyday and/or mathematical language	• appropriate interpretation and use of mathematical terminology, symbols and conventions in simple routine situations involving trigonometry • use of mathematical reasoning to develop sequences within a response in simple routine situations using everyday or mathematical language	• use of mathematical terminology, symbols or conventions in simple situations involving trigonometry •	• use of mathematical terminology, symbols or conventions •

For the Mathematics C assessment instrument developed, the instrument-specific criteria sheet could have the following format:

Criterion	*Standard A*	*Standard B*	*Standard C*	*Standard D*	*Standard E*
Knowledge and procedures	The student work has the following characteristics:	The student work has the following characteristics:	The student work has the following characteristics:	The student work has the following characteristics:	The student work has the following characteristics:
	• application of mathematical definitions, rules and procedures in non-routine complex tasks, in abstract situations involving advanced trigonometry	• application of mathematical definitions, rules and procedures in routine complex tasks, in abstract situations involving advanced trigonometry	• application of mathematical definitions, rules and procedures in routine, simple abstract situations involving advanced trigonometry		
Communication and justification	• appropriate interpretation and use of mathematical terminology, symbols and conventions in complex non-routine, in abstract situations involving advanced trigonometry	• appropriate interpretation and use of mathematical terminology, symbols and conventions in complex routine tasks in abstract situations involving advanced trigonometry	• appropriate interpretation and use of mathematical terminology, symbols and conventions in simple routine situations involving advanced trigonometry	• use of mathematical terminology, symbols or conventions in simple situations involving advanced trigonometry	• use of mathematical terminology, symbols or conventions
	• use of mathematical reasoning to develop coherent, concise and logical sequences within a response in complex and in abstract situations using everyday and mathematical language	• use of mathematical reasoning to develop coherent and logical sequences within a response in complex and in abstract situations using everyday and/or mathematical language	• use of mathematical reasoning to develop sequences within a response in simple routine situations using everyday or mathematical language		

Modelling and problem solving
Mathematics A

1. Start with the General Objectives (We are only considering the Modelling and problem solving and Communication and justification general objectives in the exercise)

For Mathematics A, the assessable General Objectives are:

Modelling and problem solving:

- interpret, clarify and analyse problems
- use strategies to model and solve problems
- investigate alternative solutions and/or procedures to problems
- make decisions informed by mathematical reasoning
- reflect on the effectiveness of mathematical models, including the recognition of strengths and limitations.

Communication and justification

- interpret and use appropriate mathematical terminology, symbols and conventions
- organise and present information for different purposes and audiences, in a variety of representations (such as written, symbolic, pictorial and graphical)
- analyse information displayed in a variety of representations (such as written, symbolic, pictorial and graphical) and translate information from one representation to another
- develop logical sequences within a response expressed in everyday language, mathematical language, or a combination of both, as required, to justify conclusions, solutions or propositions
- justify the reasonableness of results obtained through technology or other means using everyday language, mathematical language or a combination of both, when appropriate.

2. Determine what aspects of the General Objectives you wish to assess.

Modelling and problem solving:

- interpret, clarify and analyse problems
- use strategies to model and solve problems
- investigate alternative solutions and/or procedures to problems
- make decisions informed by mathematical reasoning
- reflect on the effectiveness of mathematical models, including the recognition of strengths and limitations.

Communication and justification

- interpret and use appropriate mathematical terminology, symbols and conventions
- organise and present information for different purposes and audiences, in a variety of representations (such as written, symbolic, pictorial and graphical)
- analyse information displayed in a variety of representations (such as written, symbolic, pictorial and graphical) and translate information from one representation to another
- develop logical sequences within a response expressed in everyday language, mathematical language, or a combination of both, as required, to justify conclusions, solutions or propositions
- justify the reasonableness of results obtained through technology or other means using everyday language, mathematical language or a combination of both, when appropriate.

3. Refer to the Standards Matrix for the relevant descriptors for the aspects of the General Objectives chosen

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Modelling and problem solving	The student's work has the following characteristics: • use of strategies to model and solve problems in complex routine through to simple non-routine situations	The student's work has the following characteristics: • use of strategies to model and solve problems in routine through to simple non-routine situations	The student's work has the following characteristics: • use of familiar strategies for problem solving in simple routine situations	The student's work has the following characteristics: • use of given strategies for problem solving in simple rehearsed situations	The student's work has the following characteristics: • attempted use of given strategies for problem solving in well-rehearsed situations
	• investigation of alternative solutions and/or procedures to complex routine through to simple non-routine problems	• investigation of alternative solutions and/or procedures to routine problems			
	• informed decisions based on mathematical reasoning in complex routine through to simple non-routine situations	• informed decisions based on mathematical reasoning in routine situations	• informed decisions based on mathematical reasoning in simple routine situations		
	• reflection on the effectiveness of mathematical models including recognition of the strengths and limitations of the model	• recognition of the strengths and limitations of the model in simple situations			

Criterion	Standard A	Standard B	Standard C	Standard D	Standard E
Communication and justification	The student's work has the following characteristics: • accurate and appropriate use of mathematical terminology and conventions in simple non-routine through to complex routine situations	The student's work has the following characteristics: • accurate and appropriate use of mathematical terminology and conventions in simple non-routine and/or complex routine situations	The student's work has the following characteristics: • appropriate use of mathematical terminology and conventions in simple routine situations	The student's work has the following characteristics: • use of mathematical terminology and conventions in simple rehearsed situations	The student's work has the following characteristics: • use of mathematical terminology or conventions in simple rehearsed situations
	• organisation and presentation of information in a variety of representations in simple non-routine through to complex routine situations	• organisation and presentation of information in a variety of representations in simple non-routine and/or complex routine situations	• organisation and presentation of information in a variety of representations in simple routine situations	• presentation of information in simple rehearsed situations	
	• analysis and translation of information displayed from one representation to another in complex routine situations	• analysis and translation of information displayed from one representation to another in simple routine situations	• translation of information displayed from one representation to another in simple routine situations		
	• use of mathematical reasoning to develop logical sequences in simple non-routine through to complex routine situations using everyday and/or mathematical language	• use of mathematical reasoning to develop logical sequences in simple non-routine and/or complex routine situations using everyday and/or mathematical language	• development of logical sequences in simple routine situations using everyday and/or mathematical language		
	• justification of the reasonableness of results obtained through technology or other means				

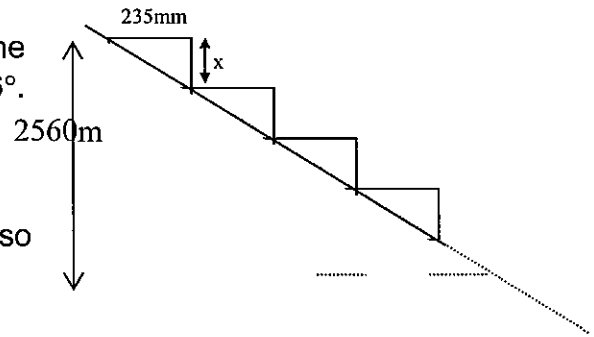
4. Develop an instrument or instruments that will allow students to demonstrate these attributes

Question (Informed decision making)

Local shire council zoning regulations state that any development on canals and waterways is restricted to a height of 30m. The local environmental committee is concerned that an apartment block under construction breaches this law. In order to get an approximate estimate of the height of this building, a measurement is taken from the opposite edge of the canal and the angle of elevation to the top of the building is found to be 32°. Another reading is taken 25m back (in a straight line) from the canal edge and the angle of elevation to the top of the building is this time recorded as 21°. The surveyor taking the readings is 1.7m tall. Does the height of the building breach the building code?

Question

The diagram represents a staircase with treads 235mm wide. This is referred to in the building industry as the "go". The angle the staircase makes with the horizontal is 36°. What is the rise of the stairs (marked x) to the nearest mm?



The building code refers to something called the Slope Relation. This relation is represented by the formula 2R + G where R is the rise and G is the go. This code also requires that $550 < 2R + G < 700$.

Does this staircase satisfy these requirements for the Slope Relation?

If the height of the steps at their highest point is 2560mm, how many steps would you plan for in the staircase? Justify your answer.

5. Develop a instrument-specific criteria sheet using the chosen attributes of standards matrix as a basis

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Modelling and problem solving	The student's work has the following characteristics: • use of strategies to model and solve problems in simple non-routine situations	The student's work has the following characteristics: • use of strategies to model and solve problems in routine situations	The student's work has the following characteristics: • use of familiar strategies for problem solving in simple routine situations	The student's work has the following characteristics: • use of given strategies for problem solving in simple rehearsed situations	The student's work has the following characteristics: • attempted use of given strategies for problem solving in well-rehearsed situations
	• informed decisions based on mathematical reasoning in simple non-routine situations	• informed decisions based on mathematical reasoning in routine situations	• informed decisions based on mathematical reasoning in simple routine situations		
Communication and justification	• accurate and appropriate use of mathematical terminology and conventions in simple non-routine situations	• accurate and appropriate use of mathematical terminology and conventions in complex routine situations	• appropriate use of mathematical terminology and conventions in simple routine situations	• use of mathematical terminology and conventions in simple rehearsed situations	• use of mathematical terminology or conventions in simple rehearsed situations

Modelling and problem solving
Mathematics B

1. Start with the General Objectives

For Mathematics B, the assessable General Objectives are:

Modelling and problem solving

- apply problem-solving strategies and procedures to identify problems to be solved, and interpret, clarify and analyse problems
- identify assumptions (and associated effects), parameters and/or variables during problem solving
- represent situations by using data to synthesise mathematical models and generate data from mathematical models
- analyse and interpret results in the context of problems to investigate the validity (including strengths and limitations) of mathematical arguments and models.

Communication and justification

- interpret and use appropriate mathematical terminology, symbols and conventions
- organise and present information for different purposes and audiences, in a variety of representations (such as written, symbolic, pictorial and graphical)
- analyse information displayed in a variety of representations (such as written, symbolic, pictorial and graphical) and translate information from one representation to another
- develop coherent, concise and logical sequences within a response expressed in everyday language, mathematical language or a combination of both, as required, to justify conclusions, solutions or propositions
- develop and use coherent, concise and logical supporting arguments, expressed in everyday language, mathematical language or a combination of both, when appropriate, to justify procedures, decisions and results
- justify the reasonableness of results obtained through technology or other means using everyday language, mathematical language or a combination of both, when appropriate.

2. Determine what aspects of the General Objectives you wish to assess.

Modelling and problem solving

- apply problem-solving strategies and procedures to identify problems to be solved, and interpret, clarify and analyse problems
- identify assumptions (and associated effects), parameters and/or variables during problem solving
- represent situations by using data to synthesise mathematical models and generate data from mathematical models
- analyse and interpret results in the context of problems to investigate the validity (including strengths and limitations) of mathematical arguments and models.

Communication and justification

- interpret and use appropriate mathematical terminology, symbols and conventions
- organise and present information for different purposes and audiences, in a variety of representations (such as written, symbolic, pictorial and graphical)
- analyse information displayed in a variety of representations (such as written, symbolic, pictorial and graphical) and translate information from one representation to another
- develop coherent, concise and logical sequences within a response expressed in everyday language, mathematical language or a combination of both, as required, to justify conclusions, solutions or propositions
- develop and use coherent, concise and logical supporting arguments, expressed in everyday language, mathematical language or a combination of both, when appropriate, to justify procedures, decisions and results
- justify the reasonableness of results obtained through technology or other means using everyday language, mathematical language or a combination of both, when appropriate.

3. Refer to the Standards Matrix for the relevant descriptors for the aspects of the General Objectives chosen

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Modelling and problem solving	The student work has the following characteristics: • use of problem-solving strategies to interpret, clarify and analyse problems to develop responses from routine simple tasks through to non-routine complex tasks in life-related and abstract situations	The student work has the following characteristics: • use of problem-solving strategies to interpret, clarify and analyse problems to develop responses to routine and non-routine simple tasks through to routine complex tasks in life-related or abstract situations	The student work has the following characteristics: • use of problem-solving strategies to interpret, clarify and develop responses to routine, simple problems in life-related or abstract situations	The student work has the following characteristics: • evidence of simple problem-solving strategies in the context of problems	The student work has the following characteristic: • evidence of simple mathematical procedures
	• identification of assumptions and their associated effects, parameters and/or variables	• identification of assumptions, parameters and/or variables			
	• use of data to synthesise mathematical models and generation of data from mathematical models in simple through to complex situations	• use of data to synthesise mathematical models in simple situations and generation of data from mathematical models in simple through to complex situations	• use of mathematical models to represent routine, simple situations and generate data	• use of given simple mathematical models to generate data	
	• investigation and evaluation of the validity of mathematical arguments including the analysis of results in the context of problems; the strengths and limitations of models, both given and developed	• interpretation of results in the context of simple through to complex problems and mathematical models	• interpretation of results in the context of routine, simple problems		

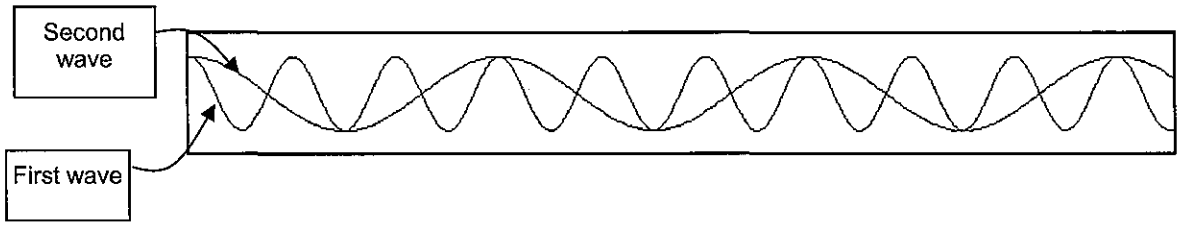
Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Communication and justification	The student's work has the following characteristics: • appropriate interpretation and use of mathematical terminology, symbols and conventions from simple through to complex and from routine through to non-routine, in life-related and abstract situations	The student's work has the following characteristics: • appropriate interpretation and use of mathematical terminology, symbols and conventions in simple or complex and from routine through to non-routine, in life-related or abstract situations	The student's work has the following characteristics: • appropriate interpretation and use of mathematical terminology, symbols and conventions in simple routine situations	The student's work has the following characteristics: • use of mathematical terminology, symbols or conventions in simple or routine situations	The student's work has the following characteristics: • use of mathematical terminology, symbols or conventions
	• organisation and presentation of information in a variety of representations	• organisation and presentation of information in a variety of representations	• organisation and presentation of information	• presentation of information	• presentation of information
	• analysis and translation of information from one representation to another in life-related and abstract situations from simple through to complex and from routine through to non-routine	• analysis and translation of information from one representation to another in life-related or abstract situations, simple or complex, and from routine through to non-routine	• translation of information from one representation to another in simple routine situations		
	• use of mathematical reasoning to develop coherent, concise and logical sequences within a response from simple through to complex and in life-related and abstract situations using everyday and mathematical language	• use of mathematical reasoning to develop coherent and logical sequences within a response in simple or complex and in life-related or abstract situations using everyday and/or mathematical language	• use of mathematical reasoning to develop sequences within a response in simple routine situations using everyday or mathematical language		
	• coherent, concise and logical justification of procedures, decisions and results	• coherent and logical justification of procedures, decisions and results	• justification of procedures, decisions or results		
	• justification of the reasonableness of results				

4. Develop an instrument or instruments that will allow students to demonstrate these attributes

The following is presented to give an indication of how a standard textbook question can be easily modified to include one of the higher order attributes required for the awarding of an A standard in Modelling and problem solving. It is not imperative that the question chosen should be one of high complexity and be necessarily non-routine to include these higher order attributes.

Question 1

Sound waves produced by synthesisers follow sinusoidal patterns and drone may be produced by constructive interference of 2 sound waves when they "peak" simultaneously as shown in the diagram below.



If the first wave is modelled by $y = 3\cos 2\left(t - \frac{\pi}{6}\right)$, give three equations that may model the second wave if the drone were to occur every 3 beats of the first as indicated?

Question 2

After insulating material has been installed into the ceiling cavity of a house, the temperature, measured in ^{0}C, inside the house at t hours after 4 am is given by the expression

$$21-3\cos\left(\frac{\pi t}{12}\right) \text{ for } 0 \le t \le 24$$

and the temperature outside the same house at the same time is given by

$$22-5\cos\left(\frac{\pi t}{12}\right) \text{ for } 0 \le t \le 24$$

Over what period of time is the temperature of the inside of the house less than the temperature of the outside?

Question 2 (Modified for evaluation of the validity of an argument)

After insulating material has been installed into the ceiling cavity of a house, the temperature, measured in ^{0}C, inside the house at t hours after 4 am is given by the expression

$$21-3\cos\left(\frac{\pi t}{12}\right) \text{ for } 0 \le t \le 24$$

and the temperature outside the same house at the same time is given by

$$22-5\cos\left(\frac{\pi t}{12}\right) \text{ for } 0 \le t \le 24$$

The manufacturer of the insulating material claims that the inside temperature of the house will be less than the temperature outside for 75% of the time during a 24-hour period. Is the manufacturer justified in making this claim?

Question 3 (Identification of assumptions and their associated effects)

The temperature, T^0C, in an electric oven being heated over a time period, t in minutes, can be represented by the following data table:

Time (in Minutes)	2	4	9
Temperature (in degrees Celcius)	80	145	250

The oven is thermostatically controlled so that the oven has a maximum temperature possible of 350 ^{0}C. If it is assumed that the change in temperature over time can be modelled by a quadratic function, when will the temperature of the oven reach 300^{0}C?

Discuss your model in relation to this result.

If however, the change in temperature over time is modelled using a logarithmic function, what effect will this have on your calculations?

5. Develop an instrument-specific criteria sheet using the chosen attributes of standards matrix as a basis

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Modelling and problem solving	The student work has the following characteristics: • identification of assumptions and their associated effects, parameters and/or variables	The student work has the following characteristics: • use of problem-solving strategies to analyse problems to develop responses to non-routine simple tasks in life-related functions • identification of assumptions, parameters and/or variables	The student work has the following characteristics: • use of problem-solving strategies to develop responses to routine, simple problems in life-related functions	The student work has the following characteristics: • evidence of simple problem-solving strategies in the context of function problems	The student work has the following characteristic: • evidence of simple mathematical procedures
Communication and Justification	• appropriate interpretation and use of mathematical terminology in complex non-routine, in life-related functions • use of mathematical reasoning to develop logical sequences within a complex response and in life-related functions using everyday and mathematical language	• appropriate interpretation and use of mathematical terminology in simple non-routine tasks, in life-related functions • use of mathematical reasoning to develop logical sequences within a response in simple life-related functions using everyday and/or mathematical language	• appropriate interpretation and use of mathematical terminology in simple routine functions • use of mathematical reasoning to develop sequences within a response in simple routine functions using everyday or mathematical language	• use of mathematical terminology in simple or routine functions	• use of mathematical terminology

Modelling and problem solving
Mathematics C

1. Start with the General Objectives

For Mathematics C, the assessable General Objectives are:

Modelling and problem solving

- apply problem-solving strategies and procedures to identify problems to be solved and interpret, clarify and analyse problems
- identify assumptions (and associated effects), parameters and/or variables during problem solving
- represent situations by using data to synthesise mathematical models and generate data from mathematical models
- analyse and interpret results in the context of problems to investigate the validity (including strengths and limitations) of mathematical arguments and models
- modify mathematical models as appropriate.

Communication and justification

- interpret and use appropriate mathematical terminology, symbols and conventions
- organise and present information for different purposes and audiences, in a variety of representations (such as written, symbolic, pictorial and graphical)
- analyse information displayed in a variety of representations (such as written, symbolic, pictorial and graphical) and translate information from one representation to another
- develop coherent, concise and logical sequences within a response expressed in everyday language, mathematical language or a combination of both, as required, to justify conclusions, solutions or propositions
- develop and use coherent, concise and logical supporting arguments, expressed in everyday language, mathematical language or a combination of both, when appropriate, to justify procedures, decisions and results
- justify the reasonableness of results obtained through technology or other means using everyday language, mathematical language or a combination of both, when appropriate.

2. Determine what aspects of the General Objectives you wish to assess.

Modelling and problem solving

- apply problem-solving strategies and procedures to identify problems to be solved and interpret, clarify and analyse problems
- identify assumptions (and associated effects), parameters and/or variables during problem solving
- represent situations by using data to synthesise mathematical models and generate data from mathematical models
- analyse and interpret results in the context of problems to investigate the validity (including strengths and limitations) of mathematical arguments and models
- modify mathematical models as appropriate.

Communication and justification

- interpret and use appropriate mathematical terminology, symbols and conventions
- organise and present information for different purposes and audiences, in a variety of representations (such as written, symbolic, pictorial and graphical)
- analyse information displayed in a variety of representations (such as written, symbolic, pictorial and graphical) and translate information from one representation to another
- develop coherent, concise and logical sequences within a response expressed in everyday language, mathematical language or a combination of both, as required, to justify conclusions, solutions or propositions
- develop and use coherent, concise and logical supporting arguments, expressed in everyday language, mathematical language or a combination of both, when appropriate, to justify procedures, decisions and results
- justify the reasonableness of results obtained through technology or other means using everyday language, mathematical language or a combination of both, when appropriate.

3. Refer to the Standards Matrix for the relevant descriptors for the aspects of the General Objectives chosen

	Standard A	*Standard B*	*Standard C*	*Standard D*	*Standard E*
Modelling and problem solving	The student work has the following characteristics: • use of problem-solving strategies to interpret, clarify and analyse problems to develop responses from routine simple tasks through to non-routine complex tasks in life-related and abstract situations	The student work has the following characteristics: • use of problem-solving strategies to interpret, clarify and analyse problems to develop responses to routine and non-routine simple tasks through to routine complex tasks in life-related or abstract situations	The student work has the following characteristics: • use of problem-solving strategies to interpret, clarify and develop responses to routine, simple problems in life-related or abstract situations	The student work has the following characteristics: • evidence of simple problem-solving strategies in the context of problems	The student work has the following characteristic: • evidence of simple mathematical procedures
	• identification of assumptions and their associated effects, parameters and/or variables	• identification of assumptions, parameters and/or variables			
	• use of data to synthesise mathematical models and generation of data from mathematical models in simple through to complex situations	• use of data to synthesise mathematical models in simple situations and generation of data from mathematical models in simple through to complex situations	• use of mathematical models to represent routine, simple situations and generate data	• use of given simple mathematical models to generate data	
	• investigation and evaluation of the validity of mathematical arguments including the analysis of results in the context of problems, the strengths and limitations of models, both given and developed	• interpretation of results in the context of simple through to complex problems and mathematical models	• interpretation of results in the context of routine, simple problems		
	• refinement of mathematical models				

	Standard A	Standard B	Standard C	Standard D	Standard E
Communication and justification	The student's work has the following characteristics: • appropriate interpretation and use of mathematical terminology, symbols and conventions from simple through to complex and from routine through to non-routine, in life-related and abstract situations	The student's work has the following characteristics: • appropriate interpretation and use of mathematical terminology, symbols and conventions in simple or complex and from routine through to non-routine, in life-related or abstract situations	The student's work has the following characteristics: • appropriate interpretation and use of mathematical terminology, symbols and conventions in simple routine situations	The student's work has the following characteristics: • use of mathematical terminology, symbols or conventions in simple or routine situations	The student's work has the following characteristics: • use of mathematical terminology, symbols or conventions
	• organisation and presentation of information in a variety of representations	• organisation and presentation of information in a variety of representations	• organisation and presentation of information	• presentation of information	• presentation of information
	• analysis and translation of information from one representation to another in life-related and abstract situations from simple through to complex and from routine through to non-routine	• analysis and translation of information from one representation to another in life-related or abstract situations, simple or complex, and from routine through to non-routine	• translation of information from one representation to another in simple routine situations		
	• use of mathematical reasoning to develop coherent, concise and logical sequences within a response from simple through to complex and in life-related and abstract situations using everyday and mathematical language	• use of mathematical reasoning to develop coherent and logical sequences within a response in simple or complex and in life-related or abstract situations using everyday and/or mathematical language	• use of mathematical reasoning to develop sequences within a response in simple routine situations using everyday or mathematical language		
	• coherent, concise and logical justification of procedures, decisions and results	• coherent and logical justification of procedures, decisions and results	• justification of procedures, decisions or results		
	• justification of the reasonableness of results				
	• provision of supporting arguments in the form of proof				

4. Develop an instrument or instruments that will allow students to demonstrate these attributes

Question 1

The Millikan oil droop experiment is a famous experiment which was used to determine the charge on an electron. In order to perform the calculations, it is necessary to solve the equation that describes the speed of a small oil drop falling under the action of gravity. This equation is

$$\frac{dv}{dt} = 9.8 - \frac{cv}{d^2}$$

where $c = 3.1 \times 10^{-6}$ ms^{-1} and d = the diameter of the oil drop measured in metres. It is assumed that the oil drop starts from rest.

If the oil drop has a diameter of 1 mm, calculate, correct to 4 decimal places, its velocity after 2 seconds.

Question 2

A skyrocket is projected vertically upwards in air with an initial velocity of 20 ms^{-1}. If its acceleration, a ms^{-2}, at any time t seconds after initial projection is given by $a = -(g + 0.1v^2)$, find the greatest height reached by the skyrocket.

Question 2 (Modified for evaluation of the validity of an argument)

A skyrocket is projected vertically upwards in air with an initial velocity of 20 ms^{-1}. The acceleration, a ms^{-2}, at any time t seconds after initial projection is given by $a = -(g + 0.1v^2)$.

The manufacturer of the skyrocket claims that the rocket will reach a vertical height of at least 25 metres after initial projection. Determine if this claim is valid or not.

Just more English comprehension

Question 3

A group of students are modelling a bungy jump. A body of mass 8kg is attached to one end of an elastic string of length 2 metres and modulus of elasticity 60 newtons. The free end of the string is attached 4 metres up the side of a building from the ground, and the mass is allowed to fall from a position adjacent to where the string is attached to the building.

By using a mathematical argument, decide if the string is long enough for the experiment to work.

5. Develop an instrument-specific criteria sheet using the chosen attributes of standards matrix as a basis

	Standard A	*Standard B*	*Standard C*	*Standard D*	*Standard E*
Modelling and Problem solving	The student work has the following characteristics: • use of problem-solving strategies to interpret problems to develop responses to non-routine complex tasks in life-related dynamics	The student work has the following characteristics: • use of problem-solving strategies to interpret problems to develop responses to routine complex tasks in life-related dynamics	The student work has the following characteristics: • use of problem-solving strategies to interpret responses to routine, simple problems in life-related dynamics	The student work has the following characteristics: • evidence of simple problem-solving strategies in the context of dynamics	The student work has the following characteristic: • evidence of simple mathematical procedures
	• investigation and evaluation of the validity of mathematical arguments including the analysis of results in the context of dynamics problems	• interpretation of results in the context of simple through to complex dynamics problems	• interpretation of results in the context of routine, simple dynamics problems		
Communication and Justification	• appropriate interpretation and use of mathematical terminology in complex non-routine, in life-related dynamics situations	• appropriate interpretation and use of mathematical terminology in complex routine, in life-related dynamics situations	• appropriate interpretation and use of mathematical terminology in simple routine dynamics situations	• use of mathematical terminology in simple or routine dynamics situations	• use of mathematical terminology
	• use of mathematical reasoning to develop logical sequences within a response to complex and in life-related dynamics situations using mathematical language	• use of mathematical reasoning to develop logical sequences within a response in simple life-related dynamics situations using mathematical language	• use of mathematical reasoning to develop sequences within a response in simple routine dynamics situations using mathematical language		

Unpacking the Standards

The standards descriptors indicate how the various attributes change from one level to another. The key words which can be classified broadly into "doing" or "verb type" words, "nouns" and "adjective" or descriptive words.

Within the Mathematics standards there are words which cannot be changed when creating an instrument specific criteria sheet.

Words which describe the situation or context can be changed as the situation or context changes.

Where multiple descriptors are used, one, some or all of these may be used as appropriate.

The highlighted standards which follow attempt to show these words and how they change from one standard to another.

1. Highlighted Standards for Mathematics A

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	The student's work has the following characteristics: accurate use of [redacted] in [redacted] situations	The student's work has the following characteristics: accurate use of [redacted] in [redacted] situations [redacted] use of [redacted] in [redacted] situations	The student's work has the following characteristics: use of [redacted] in [redacted] situations	The student's work has the following characteristics: use of [redacted] in [redacted] situations	The student's work has the following characteristics: attempted use of [redacted] in [redacted] situations
	application of [redacted] sequences of mathematical procedures in [redacted] situations	application of [redacted] sequences of mathematical procedures in [redacted] situations [redacted] sequences in [redacted] situations	application of [redacted] sequences of mathematical procedures in [redacted] situations	application of [redacted] mathematical procedures in simple [redacted] situations	attempted use of [redacted] mathematical procedures in simple [redacted] situations
	appropriate selection and accurate use of technology	appropriate selection and accurate use of technology	selection and use of technology	use of technology	attempted use of technology

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Modelling and problem solving	The student's work has the following characteristics: use of [redacted] problems in [redacted] situations	The student's work has the following characteristics: use of [redacted] problems in [redacted] situations	The student's work has the following characteristics: use of [redacted] for problem solving in [redacted] situations	The student's work has the following characteristics: use of [redacted] for problem solving in [redacted] situations	The student's work has the following characteristics: attempted use of [redacted] for problem solving in [redacted] situations
	investigation of alternative solutions and/or procedures to [redacted] problems	investigation of alternative solutions and/or procedures to [redacted] problems			
	informed decisions based on mathematical reasoning in [redacted] through to [redacted] situations	informed decisions based on mathematical reasoning in [redacted] situations	informed decisions based on mathematical reasoning in [redacted] situations		
	reflection on the effectiveness of mathematical models including recognition of the strengths and limitations of the model	recognition of the strengths and limitations of the model in simple situations			

Criterion	Standard A	Standard B	Standard C	Standard D	Standard E
Communication and justification	The student's work has the following characteristics: accurate and appropriate use of mathematical terminology [redacted] conventions in [redacted] situations	The student's work has the following characteristics: accurate and appropriate use of mathematical terminology [redacted] conventions in [redacted] situations	The student's work has the following characteristics: appropriate use of mathematical terminology [redacted] conventions in [redacted] situations	The student's work has the following characteristics: use of mathematical terminology [redacted] conventions in [redacted] situations	The student's work has the following characteristics: use of mathematical terminology [redacted] conventions in [redacted] situations
	organisation and presentation of information in a variety of representations in [redacted] situations	organisation and presentation of information in a variety of representations in [redacted] situations	organisation and presentation of information in a variety of representations in [redacted] situations	presentation of information in [redacted] situations	
	analysis and translation of information displayed from one representation to another in [redacted] situations	analysis and translation of information displayed from one representation to another in [redacted] situations	translation of information displayed from one representation to another in [redacted] situations		
	use of mathematical reasoning to develop logical sequences in [redacted] situations using everyday and/or mathematical language	use of mathematical reasoning to develop logical sequences in [redacted] situations using everyday and/or mathematical language	development of logical sequences in [redacted] situations using everyday and/or mathematical language		
	justification of the reasonableness of results obtained through technology or other means				

2. Highlighted Standards for Mathematics B

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	The student work has the following characteristics: recall, access, selection of mathematical definitions, rules and procedures in [redacted] tasks, in life-related [redacted] abstract situations	The student work has the following characteristics: recall, access, selection of mathematical definitions, rules and procedures in [redacted] tasks, in life-related [redacted] abstract situations	The student work has the following characteristics: recall, access, selection of mathematical definitions, rules and procedures in [redacted] life-related [redacted] abstract situations	The student work has the following characteristics: use of stated rules and procedures in [redacted] situations	The student work has the following characteristics: statements of relevant mathematical facts
	application of mathematical definitions, rules and procedures in [redacted] in life-related [redacted] abstract situations	application of mathematical definitions, rules and procedures in [redacted], in either life-related [redacted] abstract situations	application of mathematical definitions, rules and procedures [redacted] life-related [redacted] abstract situations		
	numerical calculations, [redacted] in [redacted] tasks, in life-related [redacted] abstract situations	numerical calculations, [redacted] in [redacted] tasks, in either life-related [redacted] abstract situations	numerical calculations, [redacted] in life-related [redacted] abstract situations	numerical sense, [redacted] in [redacted] tasks	
	appropriate selection and accurate use of technology	appropriate selection and accurate use of technology	selection and use of technology	use of technology	use of technology

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Modelling and problem solving	The student work has the following characteristics: use of problem-solving strategies to interpret, clarify and analyse problems to develop responses from [redacted] tasks in life-related and abstract situations	The student work has the following characteristics: use of problem-solving strategies to interpret, clarify and analyse problems to develop responses to [redacted] in life-related or abstract situations	The student work has the following characteristics: use of problem-solving strategies to interpret, clarify and develop responses to [redacted] problems in life-related or abstract situations	The student work has the following characteristics: evidence of simple problem-solving strategies in the context of problems	The student work has the following characteristic: evidence of simple mathematical procedures
	identification of assumptions and their associated effects, parameters and/or variables	identification of assumptions, parameters and/or variables			
	use of data to synthesise mathematical models and generation of data from mathematical models in [redacted] situations	use of data to synthesise mathematical models in [redacted] situations and generation of data from mathematical models in [redacted] situations	use of mathematical models to represent [redacted] situations and generate data	use of given simple mathematical models to generate data	
	investigation and evaluation of the validity of mathematical arguments including the analysis of results in the context of problems; the strengths and limitations of models, both given and developed	interpretation of results in the context of [redacted] problems and mathematical models	interpretation of results in the context of [redacted] problems		

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Communication and justification	The student's work has the following characteristics: appropriate interpretation and use of mathematical terminology, symbols and conventions from [redacted] and from [redacted], in life-related [redacted] abstract situations	The student's work has the following characteristics: appropriate interpretation and use of mathematical terminology, symbols and conventions in [redacted] and from [redacted], in life-related [redacted] abstract situations	The student's work has the following characteristics: appropriate interpretation and use of mathematical terminology, symbols and conventions in [redacted] situations	The student's work has the following characteristics: use of mathematical terminology, symbols or conventions in [redacted] situations	The student's work has the following characteristics: use of mathematical terminology, symbols or conventions
	organisation and presentation of information in a [redacted]	organisation and presentation of information in a [redacted]	organisation and presentation of information	presentation of information	presentation of information
	analysis and translation of information from one representation to another in [redacted] situations from [redacted] from [redacted]	analysis and translation of information from one representation to another in [redacted] situations, [redacted] from [redacted]	translation of information from one representation to another in [redacted] situations		
	use of mathematical reasoning to develop coherent, concise and logical sequences within a response from [redacted] situations using everyday [redacted] mathematical language	use of mathematical reasoning to develop coherent and logical sequences within a response in [redacted] situations using everyday [redacted] mathematical language	use of mathematical reasoning to develop sequences within a response in [redacted] situations using everyday [redacted] mathematical language		
	coherent, concise and logical justification of [redacted] decisions and results	coherent and logical justification of [redacted] decisions and results	justification of [redacted] decisions and results		
	justification of the reasonableness of results				

3. Highlighted Standards for Mathematics C

Criterion	Standard A	Standard B	Standard C	Standard D	Standard E
Knowledge and procedures	The student work has the following characteristics: recall, access, selection of mathematical definitions, rules and procedures in [redacted] tasks, in life-related [redacted] abstract situations	The student work has the following characteristics: recall, access, selection of mathematical definitions, rules and procedures in [redacted] tasks in life-related [redacted] abstract situations	The student work has the following characteristics: recall, access, selection of mathematical definitions, rules and procedures in [redacted] life-related [redacted] abstract situations	The student work has the following characteristics: use of stated rules and procedures in [redacted] situations	The student work has the following characteristics: statements of relevant mathematical facts
	application of mathematical definitions, rules and procedures in [redacted] tasks, in life-related [redacted] abstract situations	application of mathematical definitions, rules and procedures in [redacted] tasks, in either life-related [redacted] abstract situations	application of mathematical definitions, rules and procedures in [redacted] life-related [redacted] abstract situations		
	numerical calculations, [redacted] in [redacted] tasks, in life-related [redacted] abstract situations	numerical calculations, [redacted] in [redacted] tasks, in either life-related [redacted] abstract situations	numerical sense, [redacted] in [redacted] life-related [redacted] abstract situations	numerical sense, [redacted] in [redacted] tasks	
	appropriate selection and accurate use of technology	appropriate selection and accurate use of technology	selection and use of technology	use of technology	use of technology
	knowledge of the nature of and use of mathematical proof				

	Standard A	Standard B	Standard C	Standard D	Standard E
Modelling and problem solving	The student work has the following characteristics: use of problem-solving strategies to [redacted] to develop responses from [redacted] tasks in life-related [redacted] abstract situations	The student work has the following characteristics: use of problem-solving strategies to [redacted] to develop responses to [redacted] tasks in life-related [redacted] abstract situations	The student work has the following characteristics: use of problem-solving strategies to [redacted] and develop responses to [redacted] problems in life-related [redacted] abstract situations	The student work has the following characteristics: evidence of simple problem-solving strategies in the context of problems	The student work has the following characteristic: evidence of simple mathematical procedures
	identification of assumptions and their associated effects, parameters and/or variables	identification of assumptions, parameters and/or variables			
	use of data to synthesise mathematical models and generation of data from mathematical models in [redacted] situations	use of data to synthesise mathematical models in [redacted] situations and generation of data from mathematical models in [redacted] situations	use of mathematical models to represent [redacted] situations and generate data	use of given simple mathematical models to generate data	
	investigation and evaluation of the validity of mathematical arguments including the analysis of results in the context of problems, the [redacted]	interpretation of results in the context of [redacted] problems and mathematical models	interpretation of results in the context of [redacted] problems		
	refinement of mathematical models				

	Standard A	Standard B	Standard C	Standard D	Standard E
Communication and justification	The student's work has the following characteristics: appropriate interpretation and use of mathematical terminology, symbols and conventions from [redacted] and from [redacted], in life-related and abstract situations	The student's work has the following characteristics: appropriate interpretation and use of mathematical terminology, symbols and conventions in [redacted] and from [redacted], in life-related or abstract situations	The student's work has the following characteristics: appropriate interpretation and use of mathematical terminology, symbols and conventions in [redacted] situations	The student's work has the following characteristics: use of mathematical terminology, symbols and conventions in [redacted] situations	The student's work has the following characteristics: use of mathematical terminology, symbols and conventions
	organisation and presentation of information in a variety of representations	organisation and presentation of information in a variety of representations	organisation and presentation of information	presentation of information	presentation of information
	analysis and translation of information from one representation to another in [redacted] situations from [redacted] and from [redacted]	analysis and translation of information from one representation to another in [redacted] situations, [redacted], and from [redacted]	translation of information from one representation to another in [redacted] situations		
	use of mathematical reasoning to develop coherent, concise and logical sequences within a response from [redacted] and in [redacted] situations using everyday and mathematical language	use of mathematical reasoning to develop coherent and logical sequences within a response in [redacted] and in [redacted] using everyday and mathematical language	use of mathematical reasoning to develop sequences within a response in [redacted] situations using everyday and mathematical language		
	coherent, concise and logical justification of procedures, decisions and results	coherent and logical justification of procedures, decisions and results	justification of procedures [redacted]		
	justification of the reasonableness of results				
	provision of supporting arguments in the form of proof				

Developing a Profile

This example of a way to develop a profile suggests a different method of data collection. It is hoped that this will promote discussion about the effectiveness of the ways in which data about students' work is gathered.

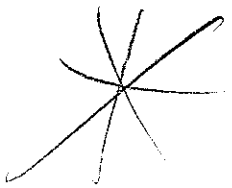
This particular format allows for more than just a means of aggregating information.

At any point in time, an "on balanced" judgment can be made on overall performance.

Overall student performance within a particular criterion can be assessed at a glance. Areas of concern, where performance within certain attributes is not consistent with others, can be easily identified. The format shows this to students.

The completeness of the assessment package, ie all individual dot points of all three criteria are included, can be easily determined. If anything is missing at a particular point in time, it can be identified and included in later assessment.

The balance of the overall package can also be easily identified and adjustments can be made accordingly.



Developing a Profile

1. The Blank Profile
2. Criteria Sheet for Instrument 1
3. Profile after Instrument 1
4. Criteria Sheet for Instrument 1
5. Cumulative Profile after Instrument 2
6. Criteria Sheet for Instrument 3
7. Cumulative Profile after Instrument 3
8. Criteria Sheet for Instrument 4
9. Cumulative Profile after Instrument 4

The Blank Profile

Criterion		Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	***K1***					
	K2					
	K3					
Modelling and problem solving	***M1***					
	M2					
	M3					
	M4					
Communication andd justification	***C1***					
	C2					
	C3					
	C4					
	C5					

Criteria Sheet for Instrument 1

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	The student's work has the following characteristics: • accurate use of rules and formulas in complex situations	The student's work has the following characteristics: • accurate use of rules and formulas in simple situations	The student's work has the following characteristics: • use of rules and formulas in simple routine situations	The student's work has the following characteristics: • use of given rules and formulas in simple rehearsed situations	The student's work has the following characteristics: • attempted use of given rules and formulas in simple rehearsed situations
	• appropriate selection and accurate use of technology	• appropriate selection and accurate use of technology	• selection and use of technology	• use of technology	• attempted use of technology
Modelling and problem solving	• use of strategies to model and solve problems in simple non-routine situations	• use of strategies to model and solve problems in routine situations	• use of familiar strategies for problem solving in simple routine situations	• use of given strategies for problem solving in simple rehearsed situations	• attempted use of given strategies for problem solving in well-rehearsed situations
	• informed decisions based on mathematical reasoning in complex routine situations	• informed decisions based on mathematical reasoning in routine situations	• informed decisions based on mathematical reasoning in simple routine situations		
Communication and justification	• accurate and appropriate use of mathematical terminology and conventions in complex routine situations	• accurate and appropriate use of mathematical terminology and conventions in simple non-routine situations	• appropriate use of mathematical terminology and conventions in simple routine situations	• use of mathematical terminology and conventions in simple rehearsed situations	• use of mathematical terminology or conventions in simple rehearsed situations
	• organisation and presentation of information in a variety of representations in complex routine situations	• organisation and presentation of information in a variety of representations in simple non-routine situations	• organisation and presentation of information in a variety of representations in simple routine situations	• presentation of information in simple rehearsed situations	
	• use of mathematical reasoning to develop logical sequences in complex routine situations using everyday language	• use of mathematical reasoning to develop logical sequences in simple non-routine situations using everyday language	• development of logical sequences in simple routine situations using everyday language		
	• justification of the reasonableness of results obtained through technology or other means				

Profile after Instrument 1

Criterion		Standard A	Standard B	Standard C	Standard D	Standard E
Knowledge and procedures	K1		X			
	K2					
	K3	X				
Modelling and problem solving	M1			X		
	M2					
	M3			X		
	M4					
Communication and justification	C1		X			
	C2		X			
	C3					
	C4			X		
	C5					

Criteria Sheet for Instrument 2

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	The student's work has the following characteristics: • accurate use of rules and formulas in complex situations	The student's work has the following characteristics: • use of rules and formulas in complex situations	The student's work has the following characteristics: • use of rules and formulas in simple routine situations	The student's work has the following characteristics: • use of given rules and formulas in simple rehearsed situations	The student's work has the following characteristics: • attempted use of given rules and formulas in simple rehearsed situations
	• application of complex sequences of mathematical procedures in non-routine situations	• application of complex sequences of mathematical procedures in routine situations	• application of simple sequences of mathematical procedures in routine situations	• application of simple mathematical procedures in simple rehearsed situations	• attempted use of simple mathematical procedures in simple rehearsed situations
Modelling and problem solving	• use of strategies to model and solve problems in simple non-routine situations	• use of strategies to model and solve problems in routine situations	• use of familiar strategies for problem solving in simple routine situations	• use of given strategies for problem solving in simple rehearsed situations	• attempted use of given strategies for problem solving in well-rehearsed situations
	• investigation of alternative solutions and/or procedures to simple non-routine problems	• investigation of alternative solutions and/or procedures to routine problems			
	• reflection on the effectiveness of mathematical models including recognition of the strengths and limitations of the model	• recognition of the strengths and limitations of the model in simple situations			
Communication and justification	• accurate and appropriate use of mathematical terminology and conventions in simple non-routine situations	• accurate and appropriate use of mathematical terminology and conventions in simple non-routine situations	• appropriate use of mathematical terminology and conventions in simple routine situations	• use of mathematical terminology and conventions in simple rehearsed situations	• use of mathematical terminology or conventions in simple rehearsed situations
	• analysis and translation of information displayed from one representation to another in simple non-routine situations	• analysis and translation of information displayed from one representation to another in simple non-routine situations	• translation of information displayed from one representation to another in simple routine situations		
	• use of mathematical reasoning to develop logical sequences in simple non-routine situations using mathematical language	• use of mathematical reasoning to develop logical sequences in simple non-routine situations using mathematical language	• development of logical sequences in simple routine situations using mathematical language		

Profile after Instrument 2

Criterion		Standard A	Standard B	Standard C	Standard D	Standard E
Knowledge and procedures	K1		X X			
	K2		X			
	K3	X				
Modelling and problem solving	M1		X	X		
	M2		X			
	M3			X		
	M4	X				
Communication and justification	C1		X X			
	C2		X			
	C3		X			
	C4	X		X		
	C5					

Criteria Sheet for Instrument 3

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	The student's work has the following characteristics: • application of simple through to complex sequences of mathematical procedures in non-routine situations	The student's work has the following characteristics: • application of complex sequences of mathematical procedures in routine situations	The student's work has the following characteristics: • application of simple sequences of mathematical procedures in routine situations	The student's work has the following characteristics: • application of simple mathematical procedures in simple rehearsed situations	The student's work has the following characteristics: • attempted use of simple mathematical procedures in simple rehearsed situations
	• appropriate selection and accurate use of technology	• appropriate selection and accurate use of technology	• selection and use of technology	• use of technology	• attempted use of technology
Modelling and problem solving	• use of strategies to model and solve problems in simple non-routine situations	• use of strategies to model and solve problems in routine situations	• use of familiar strategies for problem solving in simple routine situations	• use of given strategies for problem solving in simple rehearsed situations	• attempted use of given strategies for problem solving in well-rehearsed situations
	• investigation of alternative solutions and/or procedures to simple non-routine problems	• investigation of alternative solutions and/or procedures to routine problems			
	• informed decisions based on mathematical reasoning in simple non-routine situations	• informed decisions based on mathematical reasoning in routine situations	• informed decisions based on mathematical reasoning in simple routine situations		
Communication and justification	• accurate and appropriate use of mathematical terminology and conventions in simple non-routine situations	• accurate and appropriate use of mathematical terminology and conventions in simple non-routine situations	• appropriate use of mathematical terminology and conventions in simple routine situations	• use of mathematical terminology and conventions in simple rehearsed situations	• use of mathematical terminology or conventions in simple rehearsed situations
	• organisation and presentation of information in a variety of representations in simple non-routine situations	• organisation and presentation of information in a variety of representations in simple non-routine situations	• organisation and presentation of information in a variety of representations in simple routine situations	• presentation of information in simple rehearsed situations	
	• justification of the reasonableness of results obtained through technology or other means				

Profile after Instrument 3

Criterion		Standard A	Standard B	Standard C	Standard D	Standard E
Knowledge and procedures	K1		X X			
	K2		XX			
	K3	X X				
Modelling and problem solving	M1		XX	X		
	M2		XX			
	M3			X X		
	M4	X				
Communication and justification	C1		X XX			
	C2		X	X		
	C3		X			
	C4	X		X		
	C5					

Criteria Sheet for Instrument 4

Criterion	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	The student's work has the following characteristics: • accurate use of rules and formulas in complex situations	The student's work has the following characteristics: • accurate use of rules and formulas in simple situations	The student's work has the following characteristics: • use of rules and formulas in simple routine situations	The student's work has the following characteristics: • use of given rules and formulas in simple rehearsed situations	The student's work has the following characteristics: • attempted use of given rules and formulas in simple rehearsed situations
	• application of complex sequences of mathematical procedures in non-routine situations	• application of simple sequences of mathematical procedures in non-routine situations	• application of simple sequences of mathematical procedures in routine situations	• application of simple mathematical procedures in simple rehearsed situations	• attempted use of simple mathematical procedures in simple rehearsed situations
Modelling and problem solving	• use of strategies to model and solve problems in complex routine situations	• use of strategies to model and solve problems in routine situations	• use of familiar strategies for problem solving in simple routine situations	• use of given strategies for problem solving in simple rehearsed situations	• attempted use of given strategies for problem solving in well-rehearsed situations
	• investigation of alternative solutions and/or procedures to complex routine problems	• investigation of alternative solutions and/or procedures to routine problems			
	• reflection on the effectiveness of mathematical models including recognition of the strengths and limitations of the model	• recognition of the strengths and limitations of the model in simple situations			
Communication and justification	• accurate and appropriate use of mathematical terminology and conventions in complex routine situations	• accurate and appropriate use of mathematical terminology and conventions in complex routine situations	• appropriate use of mathematical terminology and conventions in simple routine situations	• use of mathematical terminology and conventions in simple rehearsed situations	• use of mathematical terminology or conventions in simple rehearsed situations
	• analysis and translation of information displayed from one representation to another in complex routine situations	• analysis and translation of information displayed from one representation to another in simple routine situations	• translation of information displayed from one representation to another in simple routine situations		
	• use of mathematical reasoning to develop logical sequences in complex routine situations using everyday language	• use of mathematical reasoning to develop logical sequences in complex routine situations using everyday l language	• development of logical sequences in simple routine situations using everyday language		

Profile after Instrument 4

Criterion		Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	*K1*		X XX			
	K2		X XX			
	K3	X X				
Modelling and problem solving	*M1*		XX	XX		
	M2		XXX			
	M3			X X		
	M4	X	X			
Communication and justification	*C1*	X	X XX			
	C2		X	X		
	C3		X X			
	C4	X	X	X		
	C5					

Overall Grade: B

Finally, something that you may find useful in your schools.

Questions for an EMPS

Question 1

An oil refinery has a tall chimney stack from which a pollutant gas is emitted at the rate of 2000 kilograms per day. Engineers at the refinery have developed new technology which allows the reduction of these emissions to a minimum of 250 kilograms per day. To achieve this minimum level, the emissions are to be reduced by a constant amount each day until the minimum emission of 250 kilograms is reached.

Calculate the constant amount by which the emissions are reduced each day if the installation is completed by the end of the 10^{th} day, and from the 11^{th} day the emission will be 250 kilograms per day.

Determine the total emissions during the 10 days of installation.

Due to fortuitous circumstances, the installation is completed by the end of the 7^{th} day, so that from the 8^{th} day the emission will be 250 kilograms per day. Calculate the new constant amount by which the emissions must be reduced each day during this installation period.

By using a different installation method, the emissions will be reduced by a constant percentage each day until the minimum emission of 250 kilograms per day is reached. The engineers have determined that the constant percentage to be used is 25.7%.

Determine, using the constant percentage method, on which day the daily emissions (within 1 kilogram) will reach the minimum of 250 kilograms per day.

By comparing the constant percentage method to the constant amount method, determine the difference, to the nearest kilogram, in the total emissions during the first ten days of operation.

If it is not desired that the minimum of 250 kilograms of emissions be reached until the 10^{th} day, what constant percentage must the emissions be reduced by each day to reach this target?

New government legislation requires that the minimum emissions for this particular installation be 200 kilograms per day. By considering both the constant amount and the constant percentage methods of reduction, determine the effects that the new legislation would have on the calculations of the engineers.

Question 2

A micro-organism under investigation has an initial population of 10 000, which increases by 2000 microbes each hour. A group of scientists is investigating the control of this particular organism.

By completing the following table

Hour	0	1	2	3
Population of microbes				

construct a graph showing the population growth of the microbes, and determine what the population would be after 8 hours.

The scientists introduce a control organism after 8 hours that reduces the population of the microbes by 12% each hour.

By completing the following table

Hours after introduction of control	0	1	2	3
Population of microbes				

determine how many microbes are present 5 hours after the introduction of the control.

The organism is considered to be under control when the population is reduced to one-quarter of the population from the time the control organism was introduced.

Determine, to the nearest hour, how long after the introduction of the control organism when the micro-organism is considered to be under control.

To establish the effect of the response time, the experiment is repeated, but this time the original microbe is left for 10 hours before the control is introduced. Determine the effect of this variation on the time to control the micro-organism.

Determine if there is an optimal time for introduction of the control in relation to the time when the micro-organism is considered to be under control.