SMC&PA Submission 30
Received: 24 April 2013

Submission to the Education and Innovation Parliamentary Committee
Parliament House Brisbane Qld 4000 Email: eic@parliament.qld.gov.au
Inquiry into *Assessment Methods for Senior Maths, Chemistry & Physics*
[19 April 2013]

Problems in paradise: Solutions for Mathematics and Science Education and Assessment in Queensland

Dr Stephen Norton (BSc., Dip Ed., Post Grad Dip., MSc, Phd)

Senior lecturer in mathematics education

About this submission

I am a senior lecturer in Mathematics Education in the School of Education and Professional Studies at Griffith University, Mt. Gravatt. Please note that this submission has been made in my personal capacity and does not represent the views of the University. I was a secondary mathematics teacher for 13 years until 1996 and since that time have worked at several universities in the field of teacher education. I have written several self-published books on specific pedagogies for teaching primary and middle school mathematics, the most recent being "Teaching and learning fundamental mathematics" as well as producing DVD material for mathematics teacher education and numerous refereed academic publications. The views I express come from sustained engagement with all levels of mathematics teaching and learning including extensive classroom practice.

This submission includes is a brief overview of mathematics teaching and learning (and hard sciences such as physics and chemistry) in Queensland. Although my focus is on Queensland, we are part of the Commonwealth, thus the issues raised in this submission have national connotations. I am not going to cite numerous articles to support the assertions (although I could supply those if needed).

Rather this is to be a readable explanation for why our State is performing poorly compared to our economic competitors, especially those in East Asia as outlined in **Appendix 1 (International and State based comparisons of mathematics and science achievement)**. Queensland's poor performance in maths and science may stem from low academic expectations in these subjects arising from current invalidities in senior school assessment.

The current debate on senior assessment is a manifestation of wider concerns about learning and the importance of discipline knowledge. This submission explains how flawed educational philosophies and funding decisions underpin sub-optimal assessment, academic outcomes, teaching and teacher training in Queensland, adversely affecting at all school year levels.

We can tinker with assessment in Senior maths, physics and chemistry, and we should, because changes have the potential to drive reform, but this will achieve little without urgent reform of teaching, teacher training and related syllabus reform in Queensland.

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

Recommendations for reform of senior maths and science assessment are set out in the body of this submission. Those recommendations are backed by the success of assessment methods in better performing States, as set out in **Appendix 2 (Senior assessment overview in Eastern States).**

Recommendations for urgently needed broader reform of teaching, teacher training and related syllabus changes are set out in **Appendix 3 (Problems in paradise: Solutions for Mathematics and Science Education and Assessment in Queensland)**.

Contents

Inquiry Terms of Reference

This submission demonstrates the limitations of Queensland assessment methods in senior maths, physics and chemistry, explains their origins as in part due to (less than effective) "inquiry-based" teaching methods and makes recommendations for reforming assessment directly and indirectly, through improving teaching in these subjects.

This submission therefore relates primarily to the inquiry's third of the three Terms of Reference –

- Ensuring assessment processes are supported by teachers
- Student participation levels

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted].

- The ability of assessment processes to support valid and reliable judgments of student outcomes.

However, the adverse outcomes relative to other States, which certainly result in part from Queensland's sub-optimal assessment, affect adversely the other two terms of reference, namely, teacher support for the current assessment system and student participation in these subjects.

1. Constructivist approach to assessment of senior maths, physics and chemistry in Queensland

The constructivist idea that children learn with "minimal guidance" through inquiry-based learning appears to have influenced the Queensland Studies Authority's push for student assessment via extended assignment work in senior maths, physics and chemistry. (See **Annexure 3: Problems in Paradise** for a detailed analysis of the constructivist approach.)

In other words, constructivist theory morphed from being about how students learn, to influencing what students learn through assessment tasks. Child-centred "horizontal" learning projects – in particular the QSA-mandated EEIs (extended experimental investigations) and ERTs (extended research tasks) – have been made to double as a key component of assessment items towards the final grade in these subjects. The combining of learning tasks with summative assessment tasks raised issues of validity. This is especially important when considering the variety of tasks across different schools and the range of interpretations in regard to the scaffolding teachers are capable of and are motivated in providing.

2. Adverse outcomes of constructivist approach

The constructivist approach to mathematics learning (and similar approaches to the teaching of physics and chemistry) in Queensland have not only influenced teaching methods but also in assessment methods. In my view this factor is significant in explaining the falling behind of Queensland compared to NSW, and Victoria. These states have less emphasis upon horizontal views of mathematics. This is reflected in their detailed syllabus documents and assessment their heavy weighted senior subject specific external examinations.

To assist this inquiry, I set out in the **Appendix 2 "Senior Assessment: Overview of Eastern States"** to this Submission, an outline of, and comparison between, the assessment approaches in senior maths, physics and chemistry in Queensland, NSW and Victoria. The analysis in Appendix 2 shows how a constructivist approach to assessment is prone to both invalidity and unreliability as well as affecting overall teaching quality, for example, in failing to adequately assess specific discipline knowledge and in rejecting the greater reliability of numerical marking and benchmark external exams.

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

RECOMMENDATIONS:

3. Recommendations on Assessment of senior maths, physics and chemistry in Queensland

My recommendation is that a committee comprised of senior teachers, assessment specialists and discipline based specialists be formed. These members should seek the input of experts from other states including NSW, and Victoria to advise on the merits and pitfalls of their assessments processes. My recommendations to the Inquiry for increasing the validity and reliability of assessment in senior maths, physics and science would be:

1. Speedy implementation of subject specific external examinations at the end of year 12 weighed at 50% of subject exit mark. This would be the major tool for state wide moderation.

2. Specific guidelines on the forms and balance of school based assessment. This would include consideration as to the length of take home assignment and their weighting towards final grades. Excessively long written assignments in mathematics, physics and chemistry are an ineffective use of student and teacher time. Assignments over the maximum length accrue penalty marks.

3. Approximately 80% of school based assessment should be test based for mathematics.

4. The use of marks for grading of assessment items be encouraged over the current use of letters for the marking of exams and assignments. The sum of marks can be used for school based quantitative moderation and ranking of students.

5. Moderation panels act as a check on school based assessment validity.

The current system of assessment is disadvantaging students by taking the focus of discipline knowledge, ineffectively using student and teacher time, has proved very difficult for teachers and the community to implement and understand and may well be discriminating against some students. All assessment systems have their strengths and weakness, however the evidence is mounting that the Queensland system is not as effective and just as alternatives models used by NSW and Victoria.

I encourage stakeholders to commence work on these considerations as a matter of urgency.

APPENDIX 1

International and State based comparisons of mathematics and science achievement

To the submission of Dr Stephen Norton

Internationally in Mathematics, Australian students are under performing, for example, 77% of South Korean Year 8 students are in the high and advanced bands compared to 29% of Australian students. Similar statistics exist for Singapore, Hong Kong, Chinese Taipei, Japan and Russia where they have much higher proportions of students in top bands and much fewer in lower bands (see appendix A). Thomson, Hillman, Wernert, Schmid, & Munene, (2012).

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

State-wide, ACT, NSW, and Victoria outperform Queensland in Year 8 mathematics. While it can be argued that ACT is a special population with atypical demographics that cannot be said of NSW. NSW has 34% of students in the top two bands, and 26% in the lowest two bands while Queensland has 26% in the top two bands and 41% in the lowest two bands. Similar comparisons can be made in Year 8 science. (eg., Masters, 2009; Thomson, Wernert, Underwood, & Nicholas, 2007; Thomson, et al., 2012). Queensland was not always a struggling State, in 1978 Queensland ranked as the top state in international test of secondary mathematics (Masters, 2009).

TIMMS

TIMSS (Trends in International Mathematics and Science Study) offers valid international and state-wide comparisons in mathematics and science in primary and lower secondary years of schooling. The Year 4 mathematics data indicates that Australia has performed very poorly compared to our sian neighbours, USA and most of Europe.

What does TIMSS tell us about Year 4 mathematics?

	Mean	SE	Average age at the testing	Gap 95th - 5th percentiles
Singapore	606	3.2	10.4	259
Korea	605	1.9	10.4	225
Hong Kong	602	3.4	10.1	214
Chinese Taipei	591	2.0	10.2	245
Japan	585	1.7	10.5	240
Northern Ireland	562	2.9	10.4	282
Belgium	549	1.9	10.0	195
Finland	545	2.3	10.8	224
England	542	3.5	10.2	292
Russian Federation	542	3.7	10.8	243
United States	541	1.8	10.2	250
Netherlands	540	1.7	10.2	174
Denmark	537	2.6	11.0	233
Lithuania	534	2.4	10.7	245
Portugal	532	3.4	10.0	225
Germany	528	2.2	10.4	206
Ireland	527	2.6	10.3	258
Australia	516	2.9	10.0	286
Serbia	516	3.0	10.8	290
Hungary	515	3.4	10.7	298
Slovenia	513	2.2	9.9	224
Czech Republic	511	2.4	10.4	234
Austria	508	2.6	10.3	205
Italy	508	2.6	9.7	236
Slovak Republic	507	3.8	10.4	261
Sweden	504	2.0	10.7	222
Kazakhstan	501	4.5	10.4	274
Malta	496	1.3	9.8	256
Norway	495	2.8	9.7	228
Croatia	490	1.9	10.7	219
New Zealand	486	2.6	9.9	275
Romania	482	5.8	10.9	349
Spain	482	2.9	9.8	231
Poland	481	2.2	9.9	243
Turkey	469	4.7	10.1	329
Azerbaijan	463	5.8	10.2	331
Chile	462	2.3	10.1	266
Thailand	458	4.8	10.5	262
Armenia	452	3.5	10.0	290
Georgia	450	3.7	10.0	296
Bahrain	436	3.3	10.4	295
United Arab Emirates	434	2.0	9.8	323
Iran	431	3.5	10.2	304
Qatar	413	3.5	10.0	345
Saudi Arabia	410	5.3	10.0	323
Oman	385	2.9	9.9	340
Tunisia	359	3.9	10.0	312
Kuwait	342	3.4	9.7	330
Morocco	335	4.0	10.5	334
Yemen	248	6.0	11.2	364

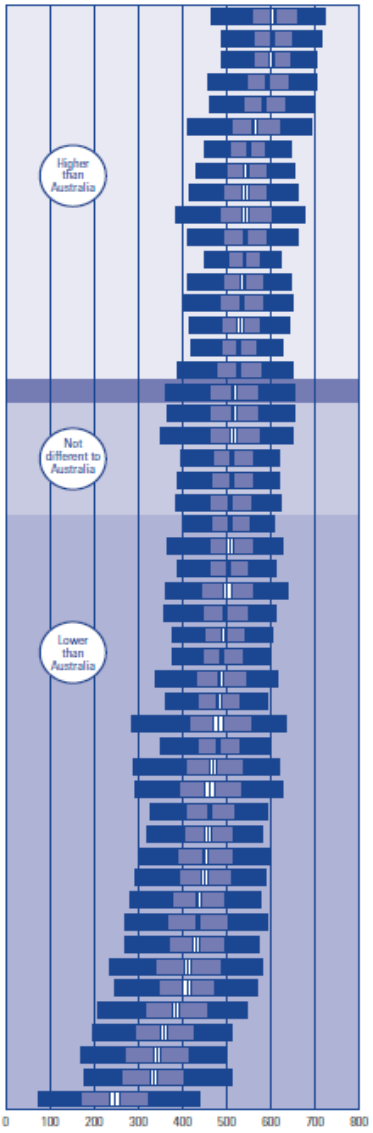


Figure 3 International achievement in mathematics – Year 4

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted].

Figure 2: Year 4 Mathematics performance (Thomson et al., 2011)

The Year 8 TIMSS data on mathematics illustrates that we still perform very poorly compared to our East Asian competitors, USA and much of Europe, but not as badly as was the case in Year 4. I put this down to the use of more subject specialist teachers in Year 8. Korea has 77% of students in the top two bands while Australia has 29%. These figures support my argument to reform teacher training outlined later in this submission.

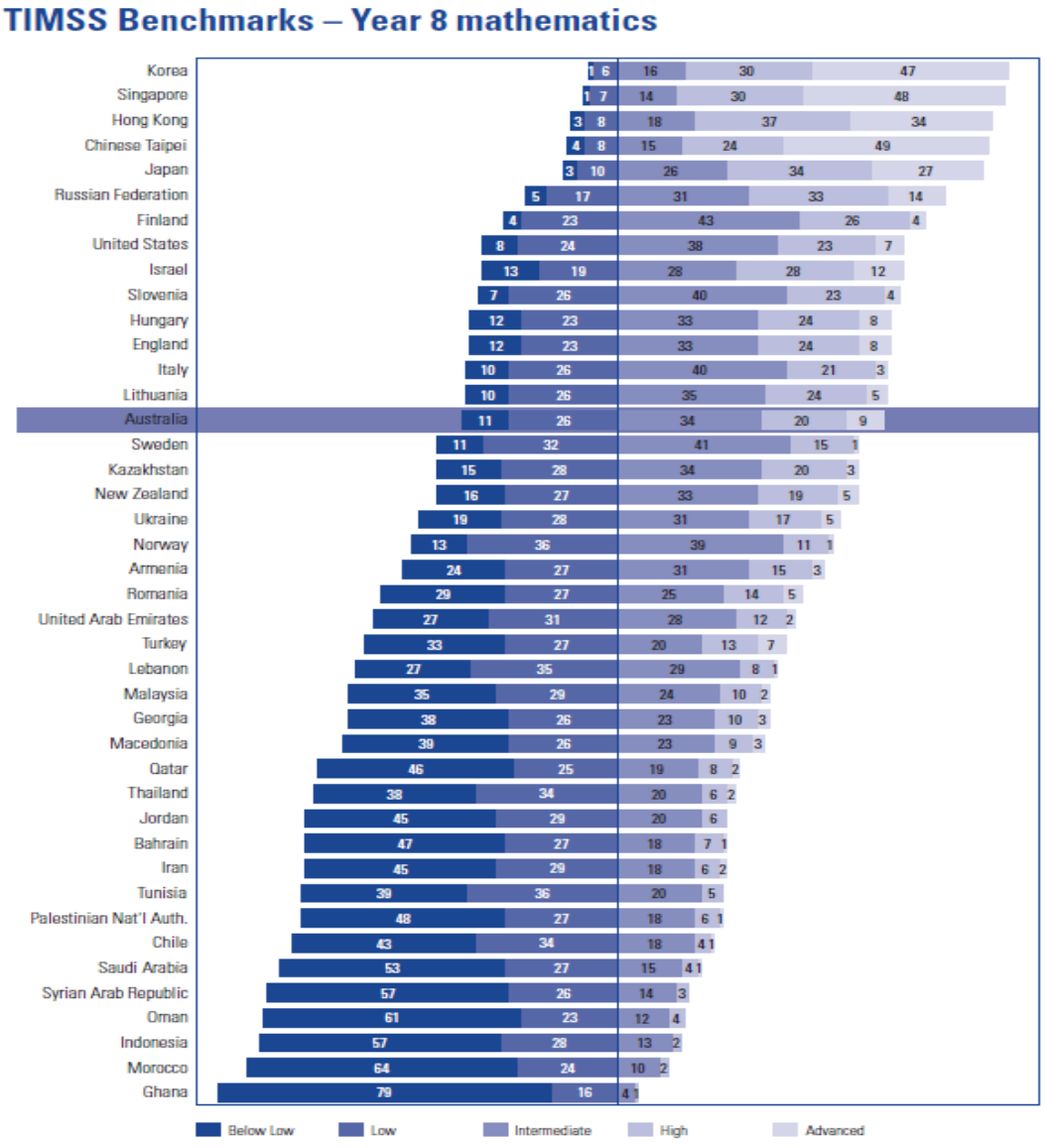


Figure 3: TIMSS Year 8 Mathematics comparison (Thomson, et al., 2011).

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

TIMSS State based mathematics comparison at Year 8 illustrates that Queensland lags behind our Eastern competitors, especially NSW. At the Year 4 level ACT, Victoria and NSW were statistically superior (Thomson et . al., 2011).

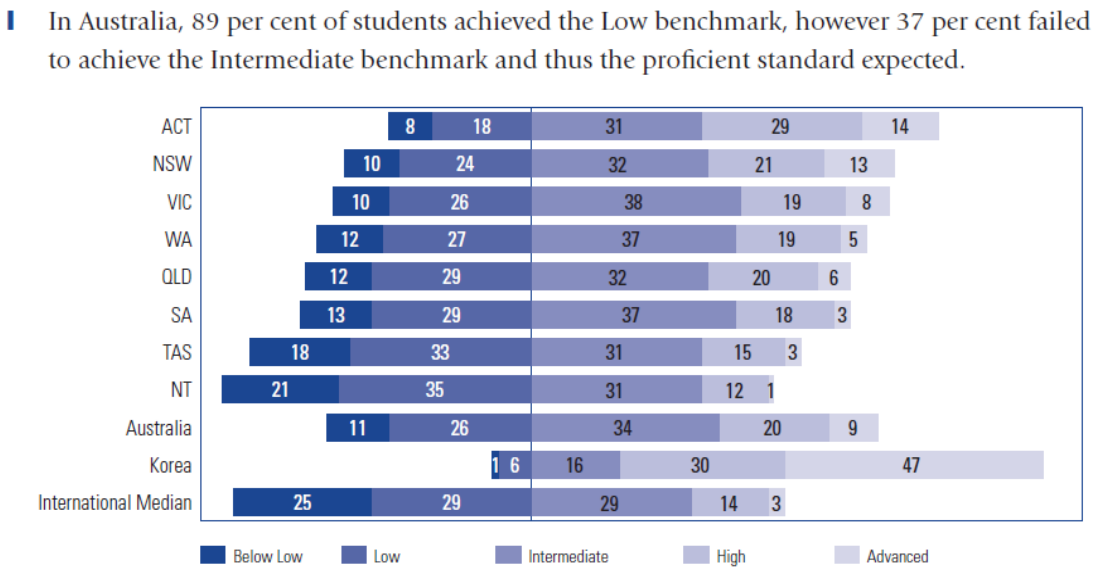


Figure 16 Percentages of students reaching the international benchmarks for mathematics achievement by state, Year 8

Figure 4: TIMSS mathematics comparison from Thomson et al., (2011).

TIMSS Year 8 science data illustrate a similar trend as was the case in mathematics, that is, we lag behind our competitors, especially NSW. NSW has 41% of students in the top two bands compared to 34% in these bands in Queensland. The Year 4 data is less flattering with ACT, Victoria, and NSW having statistically higher scores (Thomson, et al., 2011).

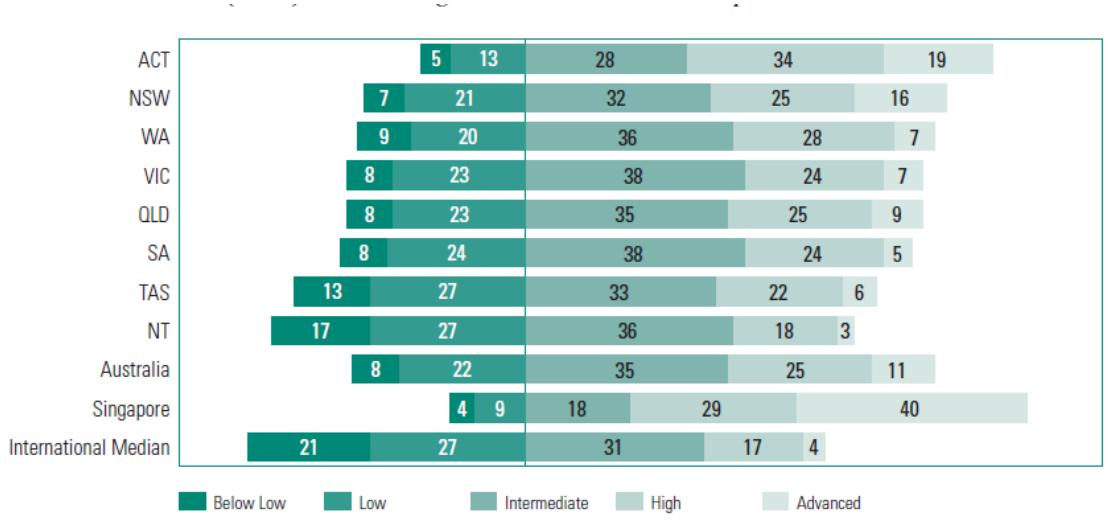


Figure 20 Percentages of students reaching the international benchmarks for science achievement by state, Year 8

Figure 5: Year 8 data on science performance from Thomson et al., (2011).

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted].

Masters (2009)

Master's (2009) analysis illustrates that in state based comparisons of mathematics Queensland was performed better than only the Northern Territory (with its particularly difficult and disadvantaged demographics) in lower and middle primary school. In Year 7 NAPLAN data illustrated it had recovered somewhat but was still outperformed by NSW and Victoria. It can be argued that ACT is a special case with different demographics.

Similar trends are observed in primary science achievement where multiple instruments provide evidence that Queensland lags our closest competitors (NSW and Victoria).

NUM./MATHS	8	7	6	5	4	3	2	1
Yr 3, NAPLAN 2008	NT	QLD	WA	SA	TAS	NSW	ACT	VIC
Yr 4, TIMSS 2007	NT	QLD	SA	WA	TAS	ACT	VIC	NSW
Yr 5, NAPLAN 2008	NT	QLD	SA	WA	TAS	ACT	NSW	VIC
Yr 7, NAPLAN 2008	NT	WA	TAS	SA	QLD	NSW	VIC	ACT
Yr 8, TIMSS 2007	NT	WA	TAS	SA	QLD	NSW	VIC	ACT
Yr 9, NAPLAN 2008	NT	TAS	QLD	WA	SA	VIC	NSW	ACT
15-y-olds,PISA 2007	NT	TAS	VIC	QLD	SA	NSW	WA	ACT

SCIENCE	8	7	6	5	4	3	2	1
Yr 4, TIMSS 2007	QLD	NT	SA	WA	ACT	TAS	NSW	VIC
Yr 6, NAP 2006	NT	WA	QLD	SA	TAS	VIC	NSW	ACT
Yr 8, TIMSS 2007	NT	WA	TAS	SA	QLD	VIC	NSW	ACT
15-y-olds, PISA 2007	NT	TAS	VIC	QLD	SA	NSW	WA	ACT

17

Figure 6: Multiple sources illustrate that Queensland lags behind our nearest real competitors NSW and Victoria in mathematics and science performance in primary and early secondary school.

In summary, international tests illustrate that as a nation Australia is underperforming in key disciplines and national testing shows that Queensland is one of the lower performing States.

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

APPENDIX 2

Senior assessment overview in Eastern States

To the submission of Dr Stephen Norton

Senior assessment over view in Eastern States

Dr Stephen Norton (2013)

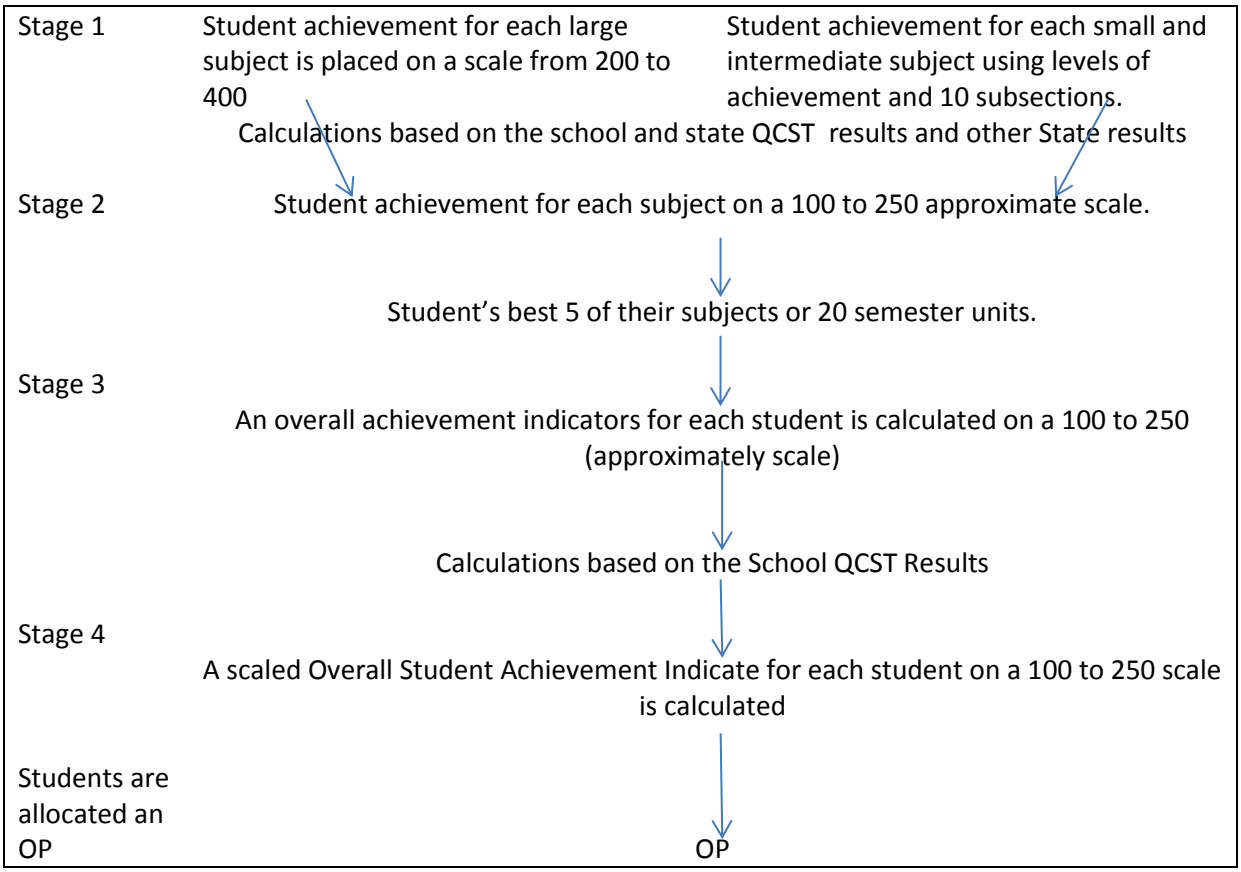
This is a brief summary of the senior assessment approaches enacted in Queensland, NSW and Victoria. The methods by which other states, including WA (not discussed here), use more reliable subject specific State-wide exams to scale subject results relates directly to the third term of reference on validity and reliability. If internal assessment by schools (such as assignments or even school-designed tests) are not scaled by common State-wide exams, then they run the risk of being less valid and reliable than scores based on subject focused State-wide common tests.

I am not an expert in this field but a brief search of the internet, even by a layperson, is quite revealing. I have spent more time on the Queensland assessment model and included comments made to me by various teaching colleagues. The purpose of this overview is to assist in the evaluation of assessment in senior mathematics and science in Queensland. This is a brief summary of the senior assessment approaches enacted in Queensland, NSW and Victoria.

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted].

Queensland Senior Assessment in a nut shell

The current OP system is complex, but the basic structure is as below (eg., Bridger, 2006).



The data in Stage 1 represents school based assessment, the data from QCST based on external examinations is one of two moderating instruments. Thus, there are two levels of testing, school based testing to determine the Level of Achievement (LOAs) for each student and these are broken into 5 levels: (Very high achievement; high achievement, sound achievement; limited achievement; very limited achievement) Within each level there are 10 sub levels. These levels of achievement are largely decided upon by the school based assessment which currently consists of a range of assessment processes according to the current syllabus documents and the way schools interpret them. For mathematics and the sciences these are a blend of written tests and take home assignments. This is where the current argument is being focused. There are several major concerns that teachers have, the first is the use of letters and criteria and the second is the forms of assessment that school are using. Teachers are also concerned about across school comparability and a reduced focus on specific discipline knowledge. Further, teachers have noted that students are continually assessed throughout the duration of their study, this means a year 11 assignment may carry weight towards the final grade even though it is relatively early in the learning cycle and there is a question as to whether it is valid to use such data for summative purposes. In recognition of this conflict of definition (continuous assessment is also summative assessment) most schools tend to use Year 12 school based assessment. A student's trend is also considered. QSA syllabus documents (eg., Mathematics B) do have a statement about fullest and latest, but just how full and how late the judgements are to be made is not explicit. There are three categories of assessment: extended modelling and problem solving tasks; reports; supervised tests. The balance of these is typically not

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

stipulated. This is a school based decision. This means that different schools weight not only the degree of "fullest and latest" differently, but there can be considerable difference in balance between extended modelling, reports and tests. In addition, since the actually tasks are school based, students in different schools are likely to succeed or fail on quite dissimilar assessment items. Some argue that given such variety of assessment it is difficult to claim that there is across school comparability. One unintended consequence of heavily weighing assignment work could be that such school disadvantage their students when it comes to testing on QCST.

Teachers are becoming increasingly concerned about the use of criteria and the forms of assignments that are used. There are in Mathematics B for example three exit criteria; knowledge and procedures; modelling and problem solving and communication. While there are guide lines, many teachers are concerned about validity and effectiveness of the process. Students' school based assessment is graded according to QSA criteria via a series of letters that reflect the markers interpretation of the student achievement. For example a VHA student needs to achieve Standard A in any two criteria, and no less than a B in the third. All marking of a complex task is a subjective process, but in cases where marks are used, it can be argued that subjectivity occurs only at the initial marking stage. It can be argued that under the current system, subjectivity occurs at multiple points.

In the Queensland system, letters and boxes are used then these are subjected to further subjective judgments to determine which of the 50 possible rungs the student will be allocated as part of their Level of Achievement (LOA). Not least among teacher's concerns is that the system apparently weights modelling and problems solving as equivalent with communication and justification. In the quantitative sciences the emphasis on communication is questioned. Further, experienced teachers note that without marks or percentages, for example what percentage of the school based test the student could actually achieve, students LOA does not necessarily reflect what they could do. A student might not get a single solution correct but attain a reasonable LOA on the bases of communication, and some partial solutions. Since there are no marks, internal school ranking is not able to be subjected to quantitative scaling. The validity of the allocated LOA is supposed to be verified via the sample of school based assessment taken for district panel moderation and all quantitative scaling is reliant on QCST results.

It needs to be noted that for most students there is no subject specific examinations. Thus, there is no common examination in senior physics, senior biology, senior chemistry or Mathematics A, B, and C. Across school subject assessment comparability is attempted to be achieved at district moderation panels. Here experienced teachers meet and discuss the merits of each other's assessment items and student achievements and attempt to achieve comparability in the awarding of subject based ranking. The effectiveness and fairness or otherwise, of this process depends on the judgements of the teachers participating. There is also the reliance on the teacher to have selected a representative sample of student assessment for panel moderation. The moderation and school based assessment process is a time consuming process at two levels.

First, the classroom teacher and school Head of Department have to compile a representative sample of student packages that includes all of each selected students marked summative assessment work. This is hard evidence of the assessment items and student responses. The second time consuming element is the evaluation of each submission by other moderation panel teachers.

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

As noted above the quality of evaluation of assessment submissions is dependent upon the effort and knowledge brought by individual panel members. Since the schools are responsible for determining how the syllabus ought to be interpreted and evaluated (within explicit guidelines), ultimately it is the responsibility of teachers to set the standards of learning. This would work best if the teachers were experts in their discipline knowledge. Unfortunately many experienced teacher have or are about to retire and at least in Mathematics and science there are insufficient top quality teachers to replace them. Any issues that currently exist in regard to assessment are likely to become exacerbated in the next decade or so. There is also an encouragement that each school develop unique assessment protocols for their OP eligible subjects. This generates a lot of duplication of work; designing take home assignments and tests as well as making criteria or marking schemes. Work overload is one of the key concerns of senior secondary teachers, not just from a personal perspective, without guidelines assignment length creep is placing excessive load on students wishing to excel. Due to the continuous nature of Queensland assessment senior students and teachers are virtually in continuous assessment mode.

The second level of assessment is the State wide Queensland Core Skills test (QCST). All OP eligible students (few exceptions) sit the 4 paper public examination. The results of the QCST are used to compare student achievement across different subjects within the school and overall achievements of students across schools. It is worth noting that the entire QCST data is used not a subset. The mean and Gini Mean Difference (measure of spread) of the whole school group of OP eligible student and the mean and Gini Mean Difference of each of the large and intermediate subjects are considered. The involvement of all students QCST results in the calculation of the school mean and Gini explains the significant expenditure of energy some schools invest in to prepare their students for these tests. The group mean and Gini Mean Difference of the schools is important in the calculation of OPs for students within the school but it is apparent that not all schools fully understand the implications of this for individual students.

Other States (NSW and Victoria)

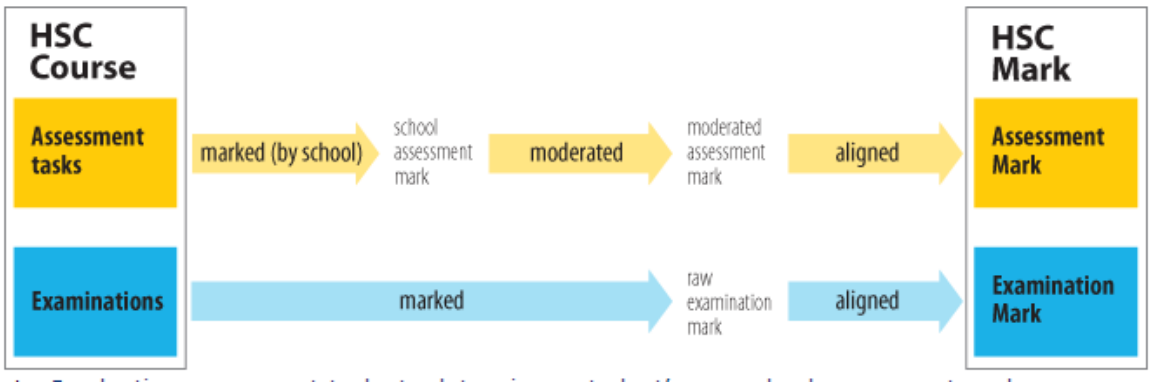
In contrast to Queensland, NSW and Victoria have subject based tests. For example NSW High School Certificate public examinations have four examinations for senior mathematics (Mathematics General; Mathematics; Mathematics Extension 1 and Mathematics Extension 2) for physics there is the physics examination and similarly senior biology and chemistry have specific exams. As with QCST these examinations are set and corrected by external bodies. The advantages of subject specific examinations are several. First the syllabus bodies have greater control of the subject discipline because the examinations enable them to focus teaching towards specific discipline outcomes. Past exams are published along with marking guide lines and sample solutions such that teachers and students have a clear idea of what is expected. Further, these examinations are marked and given a mark, marks are totalled and the student allocated to a band. Cut-offs are based on percentages and not letters, it can be argued that this is more direct and easier to manage than a series of letters over several criteria. A simple overview of the NSW calculations is for student assessment is as follows.

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted].

NSW HSC in a nutshell

School based assessment 50%		HSC Public examination 50%
Eg., Physics	⟷	Physics HSC examination
Eg., Mathematics	⟷	Mathematics HSC examination
Eg., Mathematics Extension 1C	⟷	Mathematics Extension 1C HSC examination
Eg., English	⟷	English HSC examination
Eg., Japanese	⟷	Japanese HSC Examination
Eg., Latin	⟷	Latin HSC Examination

The following steps are involved in producing the HSC results for students for each course they study:



From NSW Board of Studies http://www.boardofstudies.nsw.edu.au/hsc-results/determining-achievement.html

Victoria in a nutshell

Senior assessment in Victoria is similar in many regards to NSW. The final result of the student is subject based and subject results are a combination of school based assessment and external written examinations and moderated by external examination results of individuals. The point of difference with NSW is the additional weighting that tends to be placed on external assessment in Victoria. The table below illustrates this point.

Mathematics –MA07- Further mathematics	1 Unit 3 and 4 course work Written exam 1 Written exam 2	School –assessed 34% External 33% External 33%
Mathematics MA11 Mathematical methods (CAS) MA09 Specialist Mathematics	Units 3 and 4 course work Written exam 1- Written exam 2	School assessed 34% External 22% External 44%
Chemistry	Unit 3 Course work Unit 4 Course work Written examination	School assessed 20% School assessed 20% External 60%
Physics	Unit 3 course work Unit 4 course work Written examination	School assessed 16% School assessed 24% External 60%

Interestingly in Victoria some mathematics examinations prohibit the use of calculators. The standards for school based assessment are the responsibility of individual schools.

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

Commentary

There are a number of points of difference between the NSW and Victorian systems and the Queensland system. The first and obvious one is that is there is a much closer correlation between the school based assessment for each subject and the subject based HSC and VCE external examinations. The Queensland system has two levels of moderation and they are QCST that is sat by all OP eligible students and tends to tap into and assess more generic skills. It would be unfair for example to test all students on calculus in Queensland since only about 20% of the students doing the QCST do Mathematics B or C, and for the same reasons it is not possible to ask specific chemistry, physics or Latin questions. In effect the QCST acts as a general amplitude test and it is against this that the school based assessment scores are moderated. It can be argued that as a general aptitude measurement the QCST has the advantage of allowing comparison across all subjects. On the other hand it can be pointed out that as a general test, the importance of the QCST takes the focus off specific discipline knowledge.

The range of flexibility offered by the Queensland system seems to have spawned diversity in assessment forms, not just on specific assignments but also the balance of assessment forms used, and it is unlikely the QCST fairly accounts for this. Each school essentially becomes an island of unique assessment protocols operating within guidelines. Fairness across schools and districts is to be achieved by the second moderation tool, the district assessments panels. As we have noted above this process is very labour intensive and subjective. In fact, there would be many teachers who would have little idea of the standards of assessment outside of the few schools whose scripts they reviewed. Such lack of transparent standards is bound to invoke scepticism about state wide fairness and comparability between schools and districts. NSW and Victorian system relies entirely on the external examination results to moderate between schools and for each student's results in each subject. In short, the student's final score is an average of their HSC or VCE result and their school based assessment that has been moderated by the HSC process in the case of NSW. Overall the NSW and Victorian systems are more marked based and academic standards more closely controlled by external examiners who set the HSC and VCE examinations. I am not sure how the Victorian school based assessments is marked, but it accounts for about 40% of the students overall grade in a particular subject.

Since HSC and VCE scripts are marked by external agents the nature of the student teacher relationship is different in the states. The Queensland the teacher is responsible for designing the subject based assessment, marking it and reporting the marks with justifications at moderation meetings. Since schools are encouraged to differentiate and discouraged from sharing school based assessments tasks, each school tends to become an island inventing their assessment items and marking criteria. Further, the Queensland system is complicated and many teachers even Heads of Departments do not fully understand its workings. Frequently this lack of understanding is evidenced in some schools not spreading student scores to the best advantage of students. In addition some schools illustrate their lack of understanding of the important of the school QCST results for individual students overall OP, by not preparing their students to sit the tests. Other schools spend weeks or even months preparing students to answer QCST items and having practice tests. At the micro level many teachers struggle to interpret the letter based criteria and on occasion even very experienced Heads of Departments find it difficult to predict how their assessment and criteria will be received by different panel members. It could be argued that many panel members have limited training in assessment theory and practice.

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

NSW and Victorian teachers have less of a role in overall assessments processes. In Victoria for example about 60% of the students score is determined by external written examination and in NSW this is typically 50%. It can be argued that teachers in the southern states can consequently devote more energy into helping the students pass examinations sat at the end of Year 12 where the standard is clearly articulated with past test and marking criteria. In contrast, Queensland teachers are designing, marking and grading with criteria on a continual basis. There is a further concern about the lack of subject specific external tests and that is the focus has been taken of specific discipline knowledge, an impact that can exacerbated by a predominance of report and assignment based assessment tasks.

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

APPENDIX 3

Problems in Paradise: Solutions for Mathematics and Science Education and Assessment in Queensland

To the submission of Dr Stephen Norton

CONTENTS

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

1. Theories of learning

The following section on theories of learning is largely based on the work of Bernstein (1996; 2000) and Muller (2000). While the comparison below relates to learning theories in mathematics, similar theories apply to the hard sciences.

Inquiry based, constructivist "horizontal" learning

For about two decades Queensland Curriculum documents have reflected "inquiry based" or "constructivist" oriented pedagogical principals. Sometimes this is called *constructivism.* Constructivist orientation was strongly reflected in the 2004 QSA *Mathematics Year 1 to 10 Syllabus* and even more extremely expressed in the *New Basics* experiment. *New Basics* was quietly dropped after an external review politely reported the processes of implementing it did not enhance student learning of mathematics. The QSA *Essential Learning* document was a simplification and abbreviation of the earlier Mathematics 1 to 10 syllabuses (2004). The idea underpinning constructivism is that children build on their current understanding and learning by engaging with their environment in social settings. No one argues that this is not the case. Disagreement comes when we start to consider what forms of knowing are most important, what the role of the teacher ought to be in the process of learning, what activities the teacher emphasises and how the teacher assesses what has been learnt.

The recent past Queensland Syllabus documents, in attempting to promote constructivist teaching have tried to emphasise "*horizontal knowledge*" forms. The knowledge is horizontal because it reaches horizontally into the community and can be learnt in context. The idea here is that children can learn mathematics in *everyday* contexts and through "authentic" investigations and projects. A simple example might be that children could learn geometry by building a model home, about statistics by doing surveys or algebra by developing a spread sheet for the fate. They might learn some aspects of all strands while doing a project on planning to rebuild playground equipment. This sounds good because the maths is linked into what is considered the world of the child, and the mathematics in the community, such as the maths a tradesman might use. The boundaries between school and community become blurred.

Authentic, everyday mathematics was intended to be intrinsically motivating because it was supposed to reflect realities in the child's world. Assessment based on a horizontal view of mathematical knowledge favours take home assignments typically described as extended experimental investigations in senior years and just assignments in junior years. QSA has put out a range of these authentic assignments (eg., Rich Tasks) that children are to complete. Teachers have reported to me that to a considerable degree the student is responsible for self-teaching by accessing community knowledge either via the internet or via tutors and parents. They also report that most students, particularly the less able do not find many of the tasks particularly authentic or motivating.

Hierarchical or "vertical" learning

The alternative to this horizontal view of mathematics is a "*vertical*" or hierarchical and is much more traditional. For example, the children are expected to learn to name and rename numbers, then to add, then subtract, then multiply, then divide and then do all the processes again in sequence with fractions and later algebra. When children have mastered middle school algebra they

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted].

can begin to work with calculus, statistics and geometry in the senior school. Since the model and assumptions are vertical, if the child does not learn key knowledge at the beginning, they struggle to work with the concepts that depend on them. Vertical knowledge forms need not be taught in authentic settings, they can, but frequently it is only much later in schooling that children are expected to combine many skills to solve "authentic" complex problems. Even in Senior Mathematics B and C authentic problems are narrowly defined in most Queensland text books and in interstate senior examinations.

The vertical view of mathematics was strongly criticized for being disconnected from children's lives and the emphasis on repetition of similar activity was rejected. It is interesting to note that those Nations that top international league tables in maths and science [eg., Singapore, South Korea, Chinese Taipei, Japan, Russian Federation-Thomson et al, 2012] tend to favour a view of mathematics that is vertical and emphasise the important role of basic facts and procedural knowledge in complex problem solving. The emerging ACARA (2013) documents also acknowledge the importance of facts, algorithms and procedures in problem solving. In fact ACARA demands *fluency* in facts and basic processes.

2. The role of the teacher

Constructivist model: de-emphasises teacher expertise, emphasises children's ability to teach themselves

In a constructivist classroom associated with *horizontal* images of mathematics, the role of the teacher tends to be more of a *facilitator* and less of an expert. He/she is encouraged to let children develop their own methods to solve problems and prove their methods. Children assume greater responsibility for what they learn and the pace of their learning. In Queensland schools, this model of classroom discourse has found much favour in the primary schools and less in secondary schools since senior mathematics teachers; many who have served in schools for decades frequently view mathematics vertically.

A further constraint on secondary school teacher's adoption of constructivist teaching methods is that most secondary text books are vertical in nature and pay lip service to horizontal views of mathematics. The chapters are quite distinct and carefully sequenced. The texts contain investigations, but the focus of these is usually narrow and designed to allow students to apply the new skills and processes they are learning in problem setting that they might consider are life related. Traditional text books usually contain worked examples and significant expectation of repetition on similar structured problems. They tend to work on the assumption that meaningful repetition has a positive role in learning complex tasks. Most secondary mathematics textbooks in Australia including Queensland are of this form. It could be argued that the textbook forms work against the implementation of the intended Queensland mathematics curriculum.

Hierarchical or vertical model: teacher expertise required to closely guide and teach children

In a traditional classroom where the verticality of knowledge is assumed, the teacher tends to control the discourse carefully. The teacher selects the material, explains it logically and guides children through worked examples and considerable repetition until the structures and facts are committed to long term memory. A good teacher is one who can get the child to understand and uses a range of strategies including some investigations, modelling, logical explanations, and

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

sequenced practice. A vertically orientated teacher tends to use small and target investigations and carefully unpacks the findings with the students.

Many older teachers, most teachers of advanced mathematics, most mathematicians and probably all tutors who get paid by the hour to get results tend to teach this way. The main challenge with this approach to teaching is that the teacher really has to know their subject matter deeply and has to be able to communicate this knowledge to students. A teacher with poor discipline knowledge is usually unable to explain the mathematics coherently and tends to resort to telling the children short cut rules or pointing to the text book to allocate tasks, but is unable to diagnose and remediate student misconceptions. These are the very aspects of traditional teaching that constructivism was supposed to fix.

3. So what works and why?

Limited value of constructivist inquiry-based "horizontal" learning

In theory, capable students taught by very knowledgeable teachers with lots of time available could potentially thrive in constructivist classrooms. However, as discussed later, this potential is rarely realised in practice.

There is in my view a valid place for an emphasis on constructivist, inquiry-based, assignment based learning. Subjects that prepare students directly for industry where the mathematics is quite specific can justify a focus on horizontal knowledge forms. Generally this happens late in secondary school or TAFE college. In this circumstance, the student has made a decision to focus their learning, and the teacher has the opportunity to capitalise on the student's motivation to get a job in a particular industry. Both intrinsic and extrinsic motivational factors can become real. In Queensland *Mathematics A* [This subject focuses upon trade and finance orientated mathematics as distinct from Mathematics B and C that are more abstract with significant components of calculus] might be considered part of that subset.

It needs to be recognised that trades or industry specific mathematics subjects do not give student a good grounding in the powerful mathematics that is generally associated with university degrees with significant elements of mathematics, or trades that require across discipline problem solving. My view is that students should not be forced or channelled into trade specific or everyday community mathematics until Year 11 or late in Year 10.

Hierarchical approach must not be watered down with "everyday" constructivist horizontal maths

From prep to Year 10, I believe we should be attempting to give all students the opportunity to learn powerful mathematics normally associated with the discipline. This includes an understanding of fractions and some algebra. I believe that an early focus on "everyday" mathematics prematurely limits student's options. Unfortunately QSA has emphasised everyday or horizontal mathematics from prep onwards.

From my observations, classrooms that emphasise constructivist teaching disadvantages most students. Most students learn less effectively than they could with traditional teaching. Hattie

(2009. P, 6) agrees and says of student- centred inquiry, problem-based, task-based; "authentic," "discovery" and "intrinsically motivated learning" : *"These kinds of statements are almost directly opposite to the successful recipe for teaching and learning."* Kirschner, Sweller and Clark (2006) describe constuctivist orientated pedagogy as "*minimal guidance*" and state:

> "The past half-century of empirical research on this issue has provided overwhelming and unambiguous evidence that minimal guidance during instruction is significantly less effective an efficient than guidance specifically designed to support the cognitive processing necessary for learning." (p. 76).

Constructivist approach may engage students, but frequently not with mathematics structure

Many students in constructivist classrooms learn little for much of the lesson because they are not thinking about mathematics. They might be playing with blocks, talking to their friends, slowly trying to figure the pattern, trying to figure out what the teacher wants or just waiting until a peer or the teacher finally tells them. Frequently they are highly engaged, but most often it is not with mathematics. Then they go home and have to do a long written assignment that focuses on academic writing but which contains limited opportunity to apply the key maths concept under study.

Maths concepts underlying "rich tasks" tend to be overly complex and the mathematical structures not apparent to students

Sometimes there may be so many concepts that are simultaneously under study, that it is difficult for the student to remember any of what they were supposed to learn. *Rich tasks* are an example of the complexity of some investigations. Queensland Common Assessment Tasks (QCAT) followed a similar model of learning through authentic settings. QCATs were done in class time and teachers reported to me that students with good fundamental number frequently found them interesting and managed to succeed. However, in the case of QCATs, teachers interpreted the degree to which they could involve themselves in supporting the learning considerably differently. Teachers with low personal levels of numeracy struggle to provide adequate support and in the main less able students found the tasks very difficult. QCATs were discontinued in 2013. In regard to take home assignments in general, the most, capable manage to succeed, often with the assistance of parents or tutors who tend to adopt a vertical view of the disciple of mathematics. The students who are most discriminated against by constructivism, inquiry based learning and assessment based upon extended assignments and the like are the middle and less able students, especially those without the resources to employ quality tutors or who have teachers without deep and connected discipline knowledge.

Why constructivism or inquiry based learning fails most students?

In summary:

1. It demands deep and connected personal discipline knowledge of teacher. Few primary school teachers in particular have this, simply because they are generalists and teach across 5 or more discipline areas. (Top nations; Taipei; South Korea, Japan, Singapore, Hong Kong tend to have specialist primary maths and English teachers).

2. A minority of primary school teachers trained in Queensland have received in-depth learning in specific mathematics pedagogies. Many high school mathematics teachers have been drafted from other subjects such as physical education, home economics or science and mathematics teaching is not their speciality. This is an increasing trend as few students with high levels of mathematical knowledge elect to become teachers at any level.
3. Investigations and extended assignments take a lot of time and much of this time is not focused on mathematics. Rather an undue focus can be placed upon academic literacy.
4. Frequently, investigations contain several or in some cased many new concepts and students struggle with information overload. This is particular true of average and less able students.
5. Many students fail to make the connection between the activity and the underpinning mathematics.
6. There is limited opportunity to commit vital facts and procedures into long term memory.
7. The supposed intrinsically motivating, and authentic mathematics does not teach mathematics well except in uncommon circumstances, let alone motivate students to learn mathematics.

Constructivism may be an appealing theory, but it does not work well in most classrooms for most students.

Many senior teachers recognise the ineffectiveness of constructivist methods, especially as discipline knowledge demands become greater (eg, algebra, calculus and statistics) and this current inquiry is to a large degree related to these concerns.

4. Does verticality work?

In my opinion vertically orientated curriculum taught by teachers with deep and connected discipline base works best for all student types. An example of a vertical curriculum at work is insistence that students develop proficiency with concepts in a particular sequence. The most capable students can quickly grasp the logic of well-presented explanations and with limited repetition can commit problem structures, facts and algorithms to long term memory.

Emphasis on standard algorithms

An algorithm is a systematic method of solving a certain kind of problem. Vertical learning emphasises standard mathematics algorithms. Standard algorithms give students the simplest, most efficient way to solve problems and they work every time. An example, familiar to most parents is the standard algorithm for double-digit multiplication. The constructivist approach, on the other hand, de-emphasises the use of standard algorithms (Norton, 2012a). This approach in many Queensland classrooms requires students to struggle to "discover" a mathematics solution by trial-and-error experimentation with a range of less efficient alternatives. Capable student can and do devise personal methods, most students struggle and become confused. Good students are not disadvantaged by learning algorithms with meaning.

Memorisation enables accelerated learning, reduces boredom

Students who understand the structures and have committed facts and algorithms to long term memory can accelerate through the curriculum and are less likely to get bored and disrupt the classroom. I think most middle ability students can grasp most concepts up to about quadratic

equations in Year 10. Students who are least able, benefit the most, and with sufficient opportunity and structure, much mathematics finally makes sense to them. With sufficient opportunity to meaningfully commit structures to memory, most students gain a great deal of satisfaction in being able to do mathematics. In advanced senior mathematics the pace of learning increases and less able (or less interested/committed?) students struggle to keep up. This is a natural time for these students to begin to focus on everyday mathematics.

Teacher-centred highly guide teaching

Teacher-centred lessons utilise the greatest resource in the classroom, which is a well-trained teacher's expertise. Well trained teachers with deep discipline knowledge use all tools at their disposal including targeted investigations and teacher-centred direct instruction as well as group work and individual work. In the process of unpacking the structures, vertically orientated teachers tend to control the pace and modelling of mathematical structures. Where possible they use materials, geometric and logical proofs (if they know them) to unpack and make explicit the logic of various algorithms and mathematical rules and protocols. Using tightly controlled vertically based teaching methods I sometimes have students in my teacher education courses tell me "I have learnt more maths in 3 weeks here than in 12 years of schooling."

Vertical learning occurs in a logical sequence

Verticality requires learning mathematics concepts in a logical sequence. Failure to adopt this approach leaves gaps in students' knowledge that hamper learning of more advanced concepts. If you cannot do whole number calculations, then fractions are likely to be very problematic, and if you cannot do fractions and whole number operations and do not know number facts, algebra is virtually impossible (even with a calculator at hand).

Streaming and remediation required to remedy gaps

Failure to methodically teach children using the vertical, sequenced approach has led to many students falling behind and requiring remedial teaching. Many primary students simply do not know the necessary mathematics to attempt fractions, proportional reasoning and algebra that commence in earnest in lower secondary school (Norton, 2009). A significant minority do not know effective algorithms for whole number computation (addition, subtraction, multiplication and division) and have not learnt addition and multiplication facts (Norton, 2012a).

Heads of departments understand this and habitually stream classes according to "ability", which is really "primary maths proficiency" as soon as the students reach high school. When these students pool in low stream classes in early high school, some of them tend to disrupt the learning of their peers. Early secondary (Years 7, 8 and 9 teachers tend to find teaching such classes extremely stressful. Senior teachers of Mathematics A and social mathematics know they are effectively teaching Year 8 and 9 mathematics concepts in Year 12. In many cases the teachers in these classes have not been trained to remediate what are essentially primary school skills. I believe that increasingly teachers of Mathematics B are finding some of their students are hampered by a failure to understand middle year concepts (the evidence is starting to come in).

Vertical approach delivers best results under federal testing and syllabus requirements

Federal initiatives including NAPLAN and the emerging ACARA (2013) mathematics syllabus documents are placing considerable emphasis on the importance of discipline knowledge. NAPLAN

results indicate that Queensland is an underperforming state (eg., Masters, 2009). ACARA documents are much more prescriptive in terms of content than previous Queensland syllabus documents and ACARA mathematics syllabus documents have proficiency strands that demand: understanding, *fluency*, problem solving and reasoning. *Fluency* means quick and slick with facts, algorithms and procedures. This was a proficiency strand that was not encouraged in earlier QSA documents. Education Queensland C2C documents are in essence an interpretation of ACARA guidelines and are highly prescriptive. That is C2C their structure closely resembles a vertical curriculum even if the recommended teaching philosophy remains constructivist.

Teachers need the right skills to teach maths

In recent times Queensland primary school teachers are being pressured to improve their students' results on NAPLAN tests, but as we shall see below, mostly they do not have to tools to effect these changes, nor are they likely to gain them without very significant professional renewal. Unfortunately, primary school teachers are already very busy teaching across 5 or more subject domains and trying to reform their teaching to meet increasing demands across these domains. This observation leads us to consider the importance of teacher training. In 2009 Masters made recommendations for ensuring deep content knowledge of teachers including specialist training for teachers of literacy, numeracy and science and mandatory content testing, but such recommendations have yet to come into effect.

5. Views of Knowledge and Teacher Training

In the following section I will focus on primary teacher preparation, in part because most trainee teachers who enrol in senior teacher education courses have pretty good personal discipline knowledge; anyway, I believe most of the damage to children's mathematics learning is affected in primary school.

Education academics mostly favour constructivist theory

I have worked in teacher training at several universities since 1996. Almost every mathematics and science educator I know strongly advocates horizontal knowledge forms associated with constructivist theory. There are some notable exceptions that come to mind including Mr George Booker (and some of his students) who focuses on teaching primary mathematics in a highly structured and hierarchical manner. There are other academics I could name who have also focused on the specific teaching of mathematics discipline knowledge and pedagogy, but most of them have retired to rest or retired to research.

Symbiosis between beliefs and practice

There are several advantages in being a constructivist focused academic. First, if knowledge is horizontal it can be found everywhere in the community, the lecturer does not have to concern him or herself with the personal discipline knowledge of the trainee teachers. This is reflected in the fact that the lecturer does not test for basic knowledge at intake and exit tests do not demand personal numeracy. Of course this varies between individuals, however, I believe there are few academics (in Queensland) that routinely test his/her intake of students for their basic maths knowledge and tries to insist they do not pass without demonstrating a minimal standard of personal numeracy.

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted]

Academics relieved of teaching "how to teach", as teachers are "facilitators"

Further in the constructivist world view the teacher is primarily a *facilitator* of learning, someone who sets up activities for the children to learn through. Facilitators by definition are not expected to be *experts* and can potentially learn along with the students. In addition, constructivist lecturers tend to believe that because the community has many ways to solve problems; all ways tend to be valued. This is called relativism. These are the justifications the lecturer can use to teach general theories rather than specific pedagogies.

Academics more concerned with student's feelings, than how much is learnt or how to teach

A review of the research profiles of most education academics will find that constructivist research focuses on student's feelings and identities rather than how much the child learns. If there is a focus on learning through inquiry or horizontal curricula, it tends to be small case study based. Often the insights of a few talented students are reported. The findings of these studies are difficult to replicate and it is very difficult to tease out the placebo effect or the role of the researcher in changing the classroom dynamic or what is correlation as distinct from causal. I know because I have many publications with these flaws (over 35 refereed journal, book chapters or refereed conference proceedings). Yes, it is hard to admit, there were some good insights, but mostly the method was flawed.

Future maths teachers are taught little about how to teach

The constructivist and relativist view has implications for course structures. For example; in a four year undergraduate degree for primary teacher education, 2 subjects in 32 are currently assigned as essential mathematics curriculum subjects. This might amount to 60 hours of contact or zero hours if the university runs online courses. The 30 odd hours in a semester typically allocated to me can be taught in eight or less weeks (eg., 6 weeks). Even if we assume there is 60 hours of interactive learning with a lecturer is allocated to learn to teach mathematics, much of it may be irrelevant to the actual process of helping a child understand mathematics.

After teaching mathematics with numerous academics in SE Queensland, discussing mathematics education and examining assessment items, I have come to the conclusion that in most teacher education mathematics subjects, especially primary teacher subjects, there is limited teaching of effective pedagogy or demand for reasonable levels of numeracy from trainee teachers. So, if the lecturer does not teach much maths, or how to teach it, what do the students do? Well, the students read a lot of articles and summarise learning theories. In some mathematics courses much of this reading is on relevant topics such as the role of technology, mathematics of indigenous cultures, articles in support of constructivism, indigenous mathematics, learner's attitudes towards mathematics teaching and curriculum trends. By focusing on reading and critiquing articles, students do more of what they are best at, and that is academic literacy. It is not that I consider such study unimportant; it is just that I consider trainee teachers' knowledge of mathematics and how to explicitly teach it more important.

What trainee teachers do in limited amounts is mathematics and how to teach specific mathematical concepts. As usual there is a range of compliance to this behaviour, but it is in my view that limited effective mathematics teacher preparation occurs in most of Queensland teacher training

institutions. Of course it is very hard to gather hard publishable data on this because academics are reluctant to share their tests and be open for scrutiny. My colleague in science education tells me the pattern is the same in primary science education. That is in both science and primary mathematics education there are few academics with high regard and matching knowledge of their discipline of science and mathematics as distinct from education. These academics hold the view that curriculum subjects ought to focus on general curriculum issues rather than specific pedagogy and specific content knowledge. In any case there is so little time to prepare teachers.

Teacher Training: Look it up on the web!

There is one further trend that needs discussion, and that is the trend to prepare teachers online rather than face to face. The offering of online teacher training is increasing across Queensland and the nation. For example in 2014 a master of primary teaching will be offered to domestic students at some Queensland universities completely online. A major incentive for universities to offer online teacher education courses are due to economics. In fact I have 154 online students that I managed by myself with one casual staff member paid short hours. Without the need to pay for rooms or fully funded academics the cost is a fraction of face to face learning. Generally the charge to the student is the same as face to face subjects. Since online courses in teacher education are offered by other tertiary institutions in Queensland and interstate, all teacher training institutions feel compelled to offer online courses or lose market share. Little research has been carried out in regard to the effectiveness of this approach to teacher education.

Online students are enticed by the flexibility of learning at home and being free to maintain their part time or full time jobs or other commitments. A student who has not received quality face to face teaching hardly has a basis upon which to make a judgment about the effectiveness of an online course. Of course philosophy comes into play as well. After all, if you have an *everyday* and relativist view of knowledge, just tell the students to check *U-tube* or *Khan Academic* for their pedagogy (this was recommended to me) or put up a list of articles that relate to mathematics teaching to review and write essays on the articles. Again, academic literacy and not discipline knowledge and specific pedagogy tend to be valued.

My personal view is that I can use online delivery to teach mathematics subject matter to prospective primary teachers with very carefully crafted DVDs and tests, albeit their home work load is much greater. However, I question the wisdom of teaching how to teach mathematics (or science) via an online medium. In the last two years I have surveyed my students about the prospect of online learning. Without exception these prospective primary school teachers say they want more face to face contact and they want online medium to be available as a support, not a replacement to face to face learning. Below are the reasons students have given for their preference for face to face teacher training:

1. They can see the pedagogy modelled.
2. They can get their hands on the materials used to teach mathematics and this is central for early childhood and middle primary education in particular.
3. They learn more than specific pedagogy, they learn lesson pace, classroom management and subtly of people to people interactions face to face and less so online.

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted].

4. They are motivated in a group learning situation.

5. They can stop and ask me or peers questions at will and just in time.

Arguments against a focus on discipline knowledge in teacher training

In his report on Queensland education Masters (2009) stressed the importance of deep discipline knowledge. It can be argued that it is not necessary to teach mathematics content since the trainee teachers have had at least 12 years of schooling and their numeracy can be assumed. I have data going back 5 years and have published 3 refereed articles that contradict this assumption (Norton, 2012b; 2011; Norton & Nesbit; 2011). These articles provide strong evidence that trainee primary school teachers on average enrol with a personal numeracy level of about the average Year 8 or 9 children in the state of Queensland, and this is for the graduate students who already have a degree, most undergraduates have lower levels of personal numeracy and about half exist with levels of personal numeracy that indicates they would struggle with a Year 9 NAPLAN test. Masters (2009) recommended the testing of teacher's content knowledge prior to registration but this has not occurred and tertiary education institutions have done little to account for any shortfall in student's knowledge.

Some wonderful trainee teachers enrol; however, a minority have strong levels of personal numeracy. If this is not remediated during teacher training, it is very difficult to do so once teachers are practicing. Effective professional development is expensive and time consuming. The cheapest and most effective way to remediate teacher's knowledge is in teacher education programs. A similar argument can be constructed about the generality of teaching including classroom management. It can be claimed that trainee teachers learn about the reality of detailed pedagogy (how to teach) and classroom management when they are in practicum placement or on the job. These are the rationale training institutions can put forward to avoid the necessity of ensuring graduates know their subject and how to teach it. Unfortunately, as evidenced by Queensland's poor performance in National and International tests, and from my own observations, I am aware that many practicing teachers have low levels of personal numeracy and they struggle to effectively teach mathematics.

It is a little better for specialist middle and secondary students, since to a considerable extent those who chose to become specialist secondary school teachers have robust personal numeracy. However, middle school and high school trainee teachers still need time to develop specialist pedagogies. In some institutions there are good lecturers who do a good job of this with the time constraints available. Others do little; there is no consistency, even in some instances across campuses in one University. The reason for this is the sanctity of "academic independence." Put simply, at present there is no effective quality control and few guidelines for that control.

The role of teacher registration in the decline of discipline knowledge

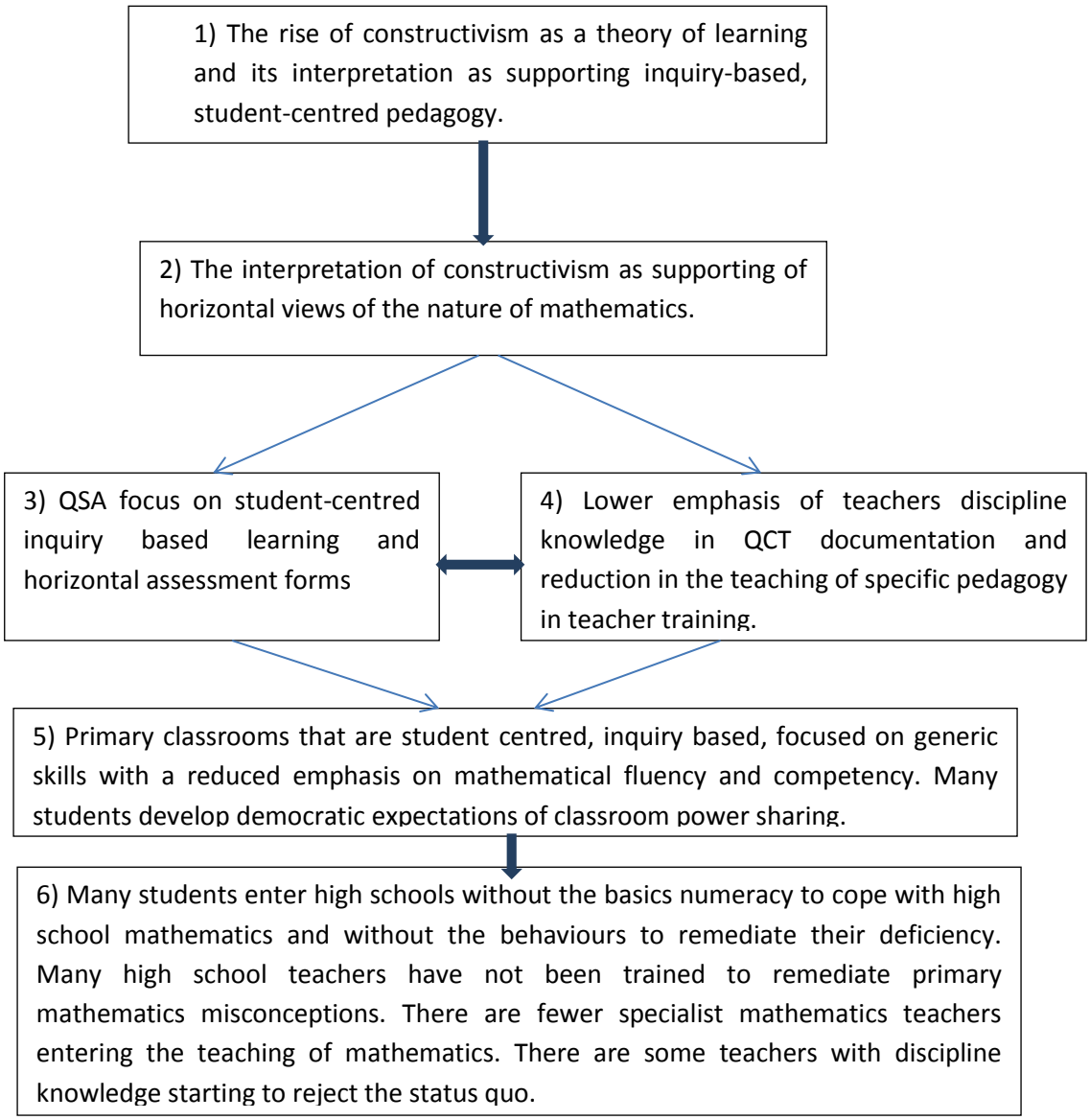
Before a teacher can teach in a Queensland registered school they must be accredited by *The Queensland College of Teachers* (QCT). QCT has had an important role in shaping the standards of Queensland teacher training and has guided teacher training institutions via professional standards. Until recently there were ten standards. One of these contained the objective "*Develop language, literacy and numeracy."(QCT, 2009. p. 4).* This was almost a passing reference to the importance of discipline knowledge. The emphasis of the QCT standards was upon largely social variables such as;

designing flexible learning experiences; intellectual challenges; value of diversity; personal participation in society; creating safe and supporting learning environments; fostering productive relationships with family; contribute to professional teams and commit to reflective practice and professional renewal. While these are important attributes for a teacher, without discipline knowledge I believe the teacher cannot teach effectively.

The more recent Australian Professional Standards for teachers has been adopted by QCT (2011) and this new set has seven standards. The second standard "*Know content and how to teach it*"(p. 10) places more emphasis upon discipline knowledge. It remains to be see how teacher training institutions interpret this change in emphasis and if QCT has the political will and capacity to manage teacher training institutions to ensure that their graduates *Know content and how to teach it.*

6. Overview of factors influencing mathematics & science learning in Queensland

The diagram below sums up the situation described above.



Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted].

Figure 1: Overview of factors influencing mathematics and science learning in Queensland

I do not think the authors of constructivist theory imagined that their thinking on how students learn in social settings and building on current understandings while being guided by teachers would imagine it would be used to support the above chain. There are 6 steps in the above chain and each of them is under scrutiny. (1) The link between constructivist theory and the inquiry-based student-centred pedagogy is currently being debated in academia. The validity of the second point (2) is also becoming debated in academia and increasing numbers of academics are questioning the usefulness of horizontal views of the nature of mathematics in societies that demand increasing numbers of citizens with strong discipline knowledge. In regard to point (3) the QSA syllabus is being pressured by NAPLAN results and ACARA to emphasise discipline knowledge including fluency. The most recent primary and middle school documents (QSA) are much more specific than earlier documents and in any case, some schools are using ACARA documents.

Federal changes may bring assessment in line with NSW and Victoria

I believe that the federal political push will increasingly bring Queensland primary and middle school syllabus documents into line with national expectations. It remains to be seen whether a national senior syllabus applies similar pressure to senior syllabus documents in Queensland. Nation-wide external tests of senior mathematics and sciences would likely force Queensland to adopt assessment approaches much more like those of NSW and Victoria that I recommend (under heading *Recommendations about Assessment* below) including external exams, marks that can be added to a final percentage result instead of "letters" and reduced emphasis on extended tasks.

Reform of teacher training

In Masters (2009) presented a detailed report recommending radical changes in teacher training. I have seen no effective reform at the tertiary level since that time. In fact I believe the quality of teacher training has gone backwards in some institutions. No one contests that a teacher with deep and connected discipline knowledge, a range of effective specific strategies who can also relate to students will not outperform a teacher with limited personal knowledge and ineffective or few strategies. Yet this is the area of reform we are neglecting. Possibly part of the explanation for this reluctance is the deep entrenchment of academics predisposed to a constructivist world view or hierarchy focused on cutting costs.

Part of the resistance is due to economics. Short, online and theory based courses are cheaper to run. I think tertiary institutions see themselves first as a business rather than a solution to national educational challenges. I have done some research into the viability of preparing teachers to teach via online courses. While it is theoretically possible, in practice it is very difficult to model effective teaching using video hook ups. Part of the difficulty is that much of primary teaching involves materials and practice with materials and explicit modelling with peers. Overwhelmingly my primary education students recognise this and want more face to face learning not less.

So, what can bring pressure/incentive to drive tertiary teacher training reform? A national or State based **test** on teacher's personal discipline knowledge, either prior to entering teacher training or prior to registration would certainly encourage training institutions to attend to this deficiency. Further, I see no reason why practising teachers should be immune from similar accountability. Since

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted].

teacher preparation is my special interest, I intend to elaborate on this subject. I think the training institutions will increasingly move towards online delivery of teacher education courses unless they are compelled by legislation to offer face to face tuition. The argument can always be constructed that trainee teachers can learn face to face aspects of teaching when they are on school placement. My concern with this argument is that many practising primary teachers in particular, have limited effective specific pedagogy to offer trainee teachers. I have sat in enough classrooms over the past five years to be convinced that this is reality. Most primary teachers are doing their best with increasing demands across many curriculum areas and do not have the time or opportunity to develop deep knowledge of mathematics and how to teach it.

Recommendations on teacher training

In my view, it is not possible to support a valid or reliable assessment in the subjects covered by this inquiry, without also improving teacher training. Teachers cannot set appropriate assessment tasks linked to the underlying syllabus or prepare their students for external assessment unless they are properly trained to do so.

It seems the main focus of the senior high school teachers involved with Peter Ridd, is to take the focus off academic literacy and place more emphasis on discipline knowledge as well as to steam-line marking, grading and reporting. I fully support this endeavour. The big picture seems to be a push for a lift in discipline standards. Tinkering with assessment is a good idea, but there are more fundamental issues that need confronting. I list these critical issues.

1. Quality primary teacher education is essential. I suggest that the balance of academic writing vs hard science and mathematics courses needs urgent review.
2. There needs to be a dramatic increase in the time allocated to training in the discipline areas where teachers are weakest. This means mathematics and science. Most primary teacher education students have a focus in literacy and the arts. Few have specialised in the hard sciences at high school or tertiary training.
3. The trend to teaching teachers online rather than face to face needs further research before online teaching training becomes industry standard. This is especially the case in mathematics and science that rely on learning through tactile models and social participation. Perhaps music, art, physical education and English teachers can construct a similar argument.
4. I go further to suggest that primary mathematics teachers ought to be specialist and devote the majority of their academic study to gaining a deep and connected knowledge of their discipline and an extensive range of specific teaching strategies
5. While the situation is less urgent with secondary school mathematics teachers in terms of their personal numeracy, in many cases a portion of them can do little more than replicate the way they were taught. This is because they are frequently exposed to few alternatives during teacher training. A review of middle school and senior mathematics (and science) teacher training course structures is also relevant to ensure that middle and senior mathematics teachers consolidate their personal discipline knowledge and learn a range of reform strategies. This includes accounting for total time and course content.
6. Academic advancement on the basis of publications and service to the university by carrying our administrative duties needs to be balanced with advancement for delivering

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted].

quality measurable teaching. The measurement of teaching performance should go beyond being popular. It needs to consider cognitive outcomes. That is, can the graduates do the mathematics and can they explain how it should be taught?

7. An inquiry into teacher preparation for mathematics and science is warranted. Since we operate in a national competition for market share this inquiry ought to be national.

To the extent that any of the above recommendations are considered to fall outside your Terms of Reference, I request that you advise the avenue for seeking their implementation by the Queensland government.

Concluding comments

I would be happy to appear in person before the Inquiry to provide more details on these matters. I hope this relatively simple summary of my thinking about the challenges facing Queensland mathematics reform have prompted some reflection on your part. To a considerable degree I think the same situation exists with the hard sciences (Chemistry and Physics). I welcome you to add your own perspective or to provide evidence to refute my thinking. I do not wish to appear to be critical of classroom teachers, after all I was one for 13 years, and I think, in the main teachers struggle to do the best they can for their students with the tools they have.

I have particular sympathy for primary school teachers who attempt to become experts in so many domains with so little training and support. I feel for secondary mathematics teachers confronted with students who know very limited mathematics and avoid the confrontation of this reality through escape by disrupting the class or just turning away from academia. I believe the reform of teaching in this state (and nation) is not only an issue of social justice; it is an issue important to our success as a nation. I think it can be fixed and I call for an inquiry into teacher training as a starting point. In my view quality teacher education is the cheapest and most effective way to reform classroom practice.

References

Australian Curriculum, Assesment and Reporting Authority (ACARA). (2013).*The Australian Curriculum: Mathematics*; Available from: http://www.australiancurriculum.edu.au/Mathematics/Content-structure

Bernstein, B. (1996). *Pedagogy, Symbolic Control and Identity. Theory, Research, Critique*. London and New York: Taylor and Francis.

Bernstein, B. (2000). *Pedagogy, Symbolic Control and Identity* (Revised ed.). Lanham, Boulder, New York, Oxford: Rowan & Littlefield Publishers, Inc.

Bridger, D. (2006). A guide to the Queensland OP Tertiary Entrance System. (Unpublished notes)

Hattie, J. (2009). *Visible Learning: A synthesis of over 800 Meta-Analyses Relating to Achievement*. London. Routledge.

Kirschner, P., Sweller, J., & Clark, R. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75-86.

Masters, G. (2009). *A shared challenge: Improving literacy, numeracy and science learning in Queensland schools.* Austrlaian Council for Eucational Research.

Muller, J. (2000). *Reclaiming Knowledge: Social Theory, Curriculum and Education Policy*. London and New York. Routledge: Falmer.

Norton, S. (2012a). The use of alternative algorithms in whole number computation. *International Journal of Mathematics Teaching and Learning.* (October 26: 2012; p. 2-16) Available from; http://www.cimt.plymouth.ac.uk/journal/default.htm

Norton, S. (2012b). Prior study of mathematics as a predictor of pre-service teachers' success on mathematics content and pedagogical content knowledge tests. *Mathematics Teacher Education and Development, 14*(1), 2-26.

Norton. S. (2011). How deeply and how well? How ready to teach mathematics after a one year program? *Mathematics Teacher Education and Development, 12*(1), 65-82.

Norton, S., & Nesbit, S. (2011). Ready to teach fractions to the Year 7 National Standards? *Curriculum Perspectives, 31*(1), 1-9.

Norton. S. J. (2009). *Year 9 NAPLAN Numeracy Test 2008 and the response of One School*. *Australian Mathematics Teacher*, AAMT, 65(4), 26-37.

NSW Board of Studies (2012) http://www.boardofstudies.nsw.edu.au/

Queensland College of Teachers (2011). *Australian Professional Standards for Teachers*. Available from; http://www.qct.edu.au/standards/

Queensland College of Teachers (2009).*Professional Standards for Queensland Teachers (Graduate Level*). Available from: http://www.qct.edu.au/standards/documents/PSQT_GradLevel_v3_Web.pdf

Queensland Studies Authority. (2004). *Mathematics: Years 1 to 10 Syllabus*. Spring Hill, Brisbane: Queensland Studies Authority.

Queensland Studies Authority. (2010). *Essential learnings and standards Years 1-9: Mathematics*. Accessed from http://www.qsa.qld.edu.au/7296.html

Thomson, S., Wernert, N., Underwood, C., & Nicholas, M. (2007). *TIMSS 07: Taking a closer look at mathematics and science in Australia.* ACER. Available from http://www.acer.edu.au/documents/TIMSS_2007-AustraliaFullReport.pdf

Thomson, S., Hillman, K., Wernert, N., Schmid, M., & Munene, A. (2012). Highlights from the TIMMS AND PIRLS 2011 from Australia's perspective. (pp. 36). Melbourne: Australian Council for Educational Research.

Victorian Curriculum and Assessment Authority (2013) http://www.vcaa.vic.edu.au/Pages/index.aspx

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted].

Dr Stephen Norton 24 April 2013; Mobile [redacted] Mailing address: [redacted].