Submission

to

The Parliamentary Inquiry into Senior Mathematics, Physics and Chemistry Assessment

by

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Introduction

Unfortunately, most students arriving at The University of Queensland to study degrees in science or engineering, do not have fundamental (high school) mathematics skills required for these degrees. Many of these students even do not know the times-tables, or how to add fractions.

It is often said that assessment drives the learning. In this document I will explain how our peculiar and convoluted assessment system is largely responsible for this desperate situation. I also identify some measures for fast reform.

Why read this submission?

In relation to this inquiry into the assessment of senior mathematics, physics and chemistry in Queensland, I have a unique set of relevant experience.

- PhD in mathematics, and research in both pure and applied mathematics,
- lectured first-year science and engineering students at UQ since 2007,
- Diploma of Education and a registered Qld teacher for 20 years,
- taught International Baccalaureate Mathematics syllabus
- tutored high school mathematics in Queensland for twenty years, and
- done other practical work with surveyors, electricians and builders

This is a highly relevant combination. Not many tertiary academics in the mathematical sciences have entered the curious world of high school teaching in Queensland, and not many schoolteachers or education professionals have my mathematical knowledge and experience. University lecturers in the mathematical disciplines in Queensland all know about the decline in standards over the last twenty years, but not many are aware of the cause.

Many schoolteachers with strong knowledge of mathematical disciplines, know that QSA's approach prevents students from learning properly. Some teachers with weak discipline knowledge do not seem to realise this.

I know what mathematics is, I know how mathematics is used beyond high school level, and I'm also aware of what is going on in Queensland schools. Like Professor Peter Ridd, I have sufficient experience to identify both problems and causes. May I please meet with The Education and Innovation Committee in person to clarify points made in this submission and answer any questions you may have?

1. Assessment processes prevent valid and reliable judgments

On Standards

(i) What is a *standard*?

> "... teachers use evidence of student learning to make judgements on student achievement against clearly stated **standards** ....These syllabuses prescribe what is to be taught, how students are to be assessed and the **standards** against which they will be judged... Achievement **standards** are fixed reference points used by all schools to describe how well students have achieved the objectives in the syllabus.... Queensland teachers have all that they need to make valid and reliable judgements: syllabuses to provide them with the knowledge about what they should teach, **standards** to use in assessing student achievements and a moderation system ...The goal is to develop syllabuses that set out no more than what is essential in clear and plain language, emphasising **standards** and requirements.... The crucial activity for teachers is to go beyond these symbols and clearly show how students' work matches the **standards** in the syllabus....They are primarily concerned with the way in which a student's work meets the **standards** in the syllabus....The existence of mandated criteria and **standards** means that Queensland teachers need to design assessment instruments that allow students to demonstrate the higher levels of response.... the assessment assesses those objectives and then student achievement is judged against the **standards** in the syllabus....The school—usually the principal or a deputy principal or a head of learning—provides advice to parents and actually explains how the system works, how they mark, how they come to the **standard** of achievement, level of achievement, how they match the student work against the **standards**...."
>
> - Patrea Walton, CEO, QSA, 7 March 2013
> (bold and underline added)

The concept of a *standard* is key to QSA's assessment system. The idea of assessing students against *standards*, rather than merely against each other, is an attractive one, and is an idea I might support. Let us become clear though, what we mean when we speak of *standards*.

What is a *standard*? What is it about a *standard* that makes it attractive to us? What do we imagine when we hear the word *standard*? I think of some object which is

secure and immovable, something like a strong table which can be relied upon. Firstly, a *standard* must be fixed and objective.

Secondly, a *standard* is not just any object, but must also be known to everyone. My strong table at home is not a *standard*, but the metre rule and the kilogram weight are all well-known *standards*. Finally, the word *standard* carries with it the sense of the regular, usual or orthodox way to do things, as in *"This is the standard procedure."*

Figure 1. Some standard weights

In summary, a *standard* is

1. fixed and objective,
2. known to everyone, and
3. usual or orthodox.

(ii) Does QSA use *standards*?

Let us consider whether the tables of paragraphs which QSA refer to as *standards* have these properties.

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*
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				

Table 1: QSA's table of 51 paragraphs for assessing *Maths B and Maths C*.

1. Are QSA's criteria paragraphs fixed and objective?

Looking at the table of paragraphs for *Maths B* and *Maths C*, the *K&P* Criterion for example, we see the words 'routine', 'non-routine', 'life-related', simple', 'complex' and 'appropriate' are used to distinguish the grades. All of these words are subjective. What is considered routine, simple or appropriate by one person, may be unusual, complex or inappropriate to another. The interpretation of these words varies from person to person. Hence, they are subjective. The same goes for 'life-related' - whose life are we referring to? It follows that any meaning these paragraphs may have, varies from person to person, i.e. they are subjective, not objective.

2. Are QSA's criteria paragraphs known to everyone?

Certainly not. Parents generally do not know them, and professionals who use mathematics, such as surveyors, engineers, physicists, chemists and even mathematicians do not know them. There are so many paragraphs in the tables, that I would find it remarkable if anyone at all could recall QSA's table of paragraphs without assistance. In this sense these tables of paragraphs are in fact, not known by anyone.

3. Are QSA's criteria paragraphs the usual or orthodox method of assessing mathematics?

Again, certainly not! 'Avant-garde' is a more apt description for this method of assessment. The orthodox way to mark mathematics is to use numbers, add them up, and report a percentage. When I show these tables of paragraphs to mathematicians they gasp and find them amusing and also disturbing. Parents also find them unusual.

That's three strikes. QSA's criteria paragraphs have none of the properties one might expect from a *standard*. They are not objective, they are not well known, and they are not the usual way of marking. They simply are not standards, and no amount of calling them s*tandards* will make them so.

Instead of comparing students' work to standards, QSA is in fact forcing a subjective, avant-garde and relatively unknown procedure on teachers and on all school students. One might wonder if there is anything more unlike a standard, than QSA's paragraphs.

(iii) What process would define *standards*?

If we do seek to measure a student's mathematics against known and established standards, rather than merely against each other, how can this be done? Let us consider whether exams can be used to define standards.

Unlike the marking of assignments, or the matching of students' work with subjective paragraphs, there is almost no subjectivity in assigning numerical marks to mathematics exams. Teachers agree that marking mathematics exams is very nearly objective. But exams vary in difficulty from school to school. A simple way to overcome this variability is to use a state(wide) exam. So long as state exams remain

of constant difficulty over the years, they define fixed and objective levels of achievement, satisfying property (1). Secondly, the collection of past state exams can also be made known to everyone (2). Thirdly, marking state exams is an orthodox practice (3). Thus marks for state exams are indeed *standards*.

Out of curiosity, we might also ask, "Is there a *standard* for the total number of marks on the exam?" i.e. is grading from 1 to 7, out of 10, or some other number, the *standard* way to mark? The 1 to 7 scale was used in Queensland for a long time, the number 10 is common, as in the expression "on a scale of 1 to 10...", but there is another number which is more *standard* than even these. Consider the following:

Of all the possible numbers, there is only one number, which has a common word meaning 'comparison with this number'. The unique number is 100, and the unique word is *percent.* Furthermore, of all the possible numbers, there is only one number, which has a common symbol meaning 'comparison with this number'. The number is again 100. The symbol is %. This symbol is known to everyone. Our three conditions are again satisfied: The number 100 is fixed (1), percentages are known to everyone (2), and awarding a percentage is orthodox assessment (3).

(iv) Conclusion

Thus, percentages for the state exam: 1%, 2% up to 98%, 99% and 100% are all *standards*. The state exam shows what mathematics topics were taught, and the student's percentage shows what standard has been attained. It's that easy. There is no need to rate students work against each other. The answer is simple:
marking a state exam out of 100 is **the standard** for mathematics assessment.

Figure 2. Captain Michael Clarke celebrates a century

Seven ways QSA prevents valid and reliable assessment

(i) Preventing valid judgements through three criteria

Much of the assessable work done by Queensland students in the *Maths B* and *Maths C* subjects is NOT mathematics. This is partly due to QSA's division of mathematics into these three criteria:

1. knowledge and procedures (K&P),
2. modelling and problem solving (MPS) and
3. communication and justification (C&J).

Mathematics does not divide into criteria. Unlike a simplistic view of flying, take-off and landing of a plane, mathematical skill does not divide into a specific discrete range of skills. The discipline is a unified whole. Mathematics could be loosely divided into topics: Algebra, Arithmetic, Geometry, trigonometry, and so on, but a division into criteria is entirely artificial and problematic.

In particular, QSA's three criteria introduce a range of judgements, which are not related to mathematics, and they diminish, if not remove, the value of real mathematical ability. These criteria are invalid for the following reasons:

Including the C&J criterion makes judgements about written expression up to one-third of the subject's assessment. Its introduction reduces the value of legitimate mathematics within its own subject. I discuss this further in *Queensland high school mathematics needs a back-to-thinking revision*[1].

The MPS criterion overemphasizes and/or artificially introduces 'story questions', well beyond their importance within the discipline, and this criterion tends to test English comprehension, use of a calculator, or unrelated general knowledge as much as it tests mathematics ability.

This leaves the bulk of mathematics to fit inside the remaining K&P criterion. But the K&P criterion is considered by many teachers as *lower-order-thinking* [2] so these questions tend to be only easy ones - the ones which are only worth a D or C grade!

Depending on the teacher, and the local panel's knowledge of mathematics, the result of these three criteria is that actual mathematics is diminished by up to one half of what is assessed in *Maths B* and *Maths C*. Furthermore, the actual mathematics questions which are presented to students tend to be simple, and considered of low value.

Obtaining an A grade in QSA's *Maths B* and *Maths C* subjects may require only average maths ability, excellent English ability, word-processing skills and who-

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[1] http://www.platoqld.com/?page_id=1322

[2] http://www.platoqld.com/wp-content/uploads/2012/05/3.-Re-education-captions-inserted.pdf)

knows-what, while excellent mathematics ability, if it exists, goes relatively unrewarded.

This division of mathematics into the K&P, MPS and C&J criteria is the first way that QSA's assessment of mathematics is invalid. Rather than supporting teachers in making valid judgements, QSA is preventing them from doing so. The division into these criteria also has the effect of lowering the standard of mathematics skills which students develop.

(ii) Preventing valid and reliable judgements through tables of paragraphs

As most people know, mathematics is easily marked right or wrong by a teacher, and QSA's tables of paragraphs are completely unnecessary. Earlier in this document, I showed that these paragraphs are not standards. Now I will explain how they also inhibit teachers from making valid judgements of students' work.

The paragraphs do this by introducing judgements into mathematics which do not belong, by over-emphasizing some less important aspects, and leaving others out. Here are some examples:

- None of the 'A' standard paragraphs (in any criteria) ask whether the student got any question correct.
- The top row of the MPS criterion requires *'use of problem solving strategies ... (on) tasks in life-related situations*' to get an A grade. Depending on the mathematics topic, this is not always appropriate.
- The bottom row of the K&P criterion assumes use of technology. It is often better to solve a problem without the use of a machine, but this possibility is not even considered.
- The second row of the C&J criterion "organization and presentation of information" is not necessarily mathematics. Furthermore, the "variety of representations" implies that two bad representations are to be judged better than one good one.
- The top right cell of the K&P criterion suggests that it's a bad thing (E grade) to state relevant mathematical facts. Should they have stated the irrelevant ones? Or does stating relevant mathematical facts have no value?

Many of the paragraphs are too complicated to easily work with. They remind me of watching *Stargate*, when Captain Carter says

> "If we synchronize the hyper-thrusters in phase with the polymorphous singularities to reverse the polarity, then the longitudinal magnetics will transform the hyperdrive!"

As mentioned previously, distinguishing these paragraphs relies on subjective and unreliable terms like *appropriate, life-related, simple, complex*, and *routine*. As students learn, what appears *complex* and *non-routine* one day, may be *simple* and *routine* only a week later (see also the section *Does QSA use standards*?)

(iii) Preventing valid and reliable judgements through written assignments

I've done a lot of private mathematics tutoring over the years. Once upon a time, Queensland students used to ask me how to do maths questions, or even to help them understand something. Tutoring was a delight. That doesn't happen any more. Now I hear

> "I have to do this assignment"

I do much less tutoring now, as I find it very unsatisfying trying to coax students into writing something that will fulfill paragraph requirements written by a bureaucrat.

Let's suppose the student does the assignment unassisted. What is a mathematics assignment in QSA's world? Well, there's data collection, word processing, more technology use, interpreting real-life situations, lots of explaining, general knowledge, googling, and who knows, maybe a little mathematics thrown in there as well.

Unlike regular homework, these assignments do not develop mathematics skills. They tend to prevent students from both doing their homework, and studying for exams.

Satisfying QSA's criteria demands, means that assignments add further writing and irrelevant tasks into mathematics and reduce the proportion of actual mathematics being learned and assessed. Students can pass on assignments alone, whether they participated in them or not. Clearly, assignments invalidate QSA's assessment.

A word on Writing, Mathematics and Science

"Scientists and engineers need to write reports." we are reminded,
"So it's good to have writing in mathematics, physics and chemistry classes."
Well, scientists and engineers also need to eat, sleep, wash, and exercise. Do we need to do all of these in mathematics, physics and chemistry classes too?

No. There are different kinds of knowledge. Each has value. In English we learn reading and writing. In mathematics we learn mathematics. If students are graduating without writing skills, shouldn't we ask what is going on in 12 years of English? Perhaps this also needs an investigation.

As I explained in *Queensland high school mathematics needs a back-to-thinking revision*[3], while scientists and engineers do write, writing is not the characteristic feature of their work. The characteristic features of science and engineering are sound thinking and domain knowledge. These are both developed by doing mathematics.

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[3] http://www.platoqld.com/?page_id=1322

(iv) Preventing study and valid judgments through the absence of a substantial (discipline) test.

Once upon a time, students used to do something called *study*.

Study meant preparing for a big test, by reviewing the whole semester's work, making summaries of each chapter, posting key formulas and definitions onto the back of the toilet door, carrying the summary sheet with you and re-reading it while walking along, getting Mum or Dad to quiz you on which ones you knew, circling the ones you didn't know, practicing past exam papers and basically entering deeply into the subject.

Study is an important part of self-development, excellent preparation for success at university, and essential in developing professional expertise.

QSA's demand for continuous senior assessment prevents teachers from conducting substantial tests. The phenomenon of *study* is barely part of Queensland school life. A valid assessment would recognize and reward entering deeply into a subject by internalizing a large knowledge base. QSA never allows this to happen.

(v) Discouraging valid judgments through including non-mathematics

On page 2 of the *Maths B* and *Maths C* syllabus documents, we find that only two of the seven 'key competencies' for both of these subjects are mathematics:

> **Key competencies**
> Mathematics B provides opportunities for the development of the key competencies in contexts that arise naturally from the general objectives and learning experiences of the subject. The seven key competencies are:
> - collecting, analyzing and organizing information
> - communicating ideas and information
> - planning and organizing activities
> - working with others and in teams
> - using mathematical ideas and techniques
> - solving problems
> - using technology.

(vi) Preventing valid judgments through social moderation

As has been mentioned in other submissions, it seems to me that QSA's moderation process is a game of personalities. I also gather that many personalities involved do not have a very thorough understanding of what is, and what is not mathematics. This becomes critical when grades hinge on the interpretation of subjective paragraphs.

Statewide exams would offer more reliability. If these exams are set by genuine discipline experts, they could also offer validity. On the choice of experts, please see Appendices A, B and C.

(vii) Preventing valid judgments through the QCS tests

> "It was dark and oppressive before 1972 when year 12 students across the state had to, all on the same days, sit the same exams, written by nasty university discipline experts. Fortunately now, year 12 students across the state get to, all on the same days, sit the QCS exams, written by QSA!"
>
> - Qld education folklore

These might seem similar, but there are three important differences:

1. For external exams, students had to actually remember what they were taught in years 11 and 12, whereas now, the QCS tests only go up to grade 10 level mathematics.

2. External exam marks were based purely on student's own performance. Now, a student's OP score is scaled by his/her group's QCS results. If a school offers a vacuous subject, and those students do well on the QCS tests, they get good OP scores, regardless of whether any knowledge is learned.

3. Mathematics, physics and chemistry are genuine knowledge. Mathematics is the language of the physical world[4]. The following phenomena all follow mathematical equations: air and all gases, water and all liquids, metals, crystals, soil, tides, gravity, electricity, magnetism, heat, light, planetary motion, chemical reactions, and so on.
   The QCS tests on the other hand, consist of 49 particular question types, which are merely made up by QSA. Unfortunately, Queensland students are spending many hours of their youth practicing QSA's 49 question types when they could instead be learning actual knowledge.

The QCS tests are an unfortunate and invalid part of the assessment of students' knowledge and achievement.

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[4] see http://www.platoqld.com/wp-content/uploads/2012/05/1.-Why-maths-captions-inserted.pdf

2. Assessment processes are not supported by many teachers

Mansfield Meeting 2012

On 16th June 2012, around 150 senior mathematics, physics and chemistry teachers attended a meeting at Mansfield to discuss their concerns about senior mathematics, physics and chemistry assessment. Teachers travelled from as far as Toowoomba, the Gold Coast and the Sunshine Coast. It was pointed out to me by some teachers, that even more of their colleagues would have been present, if the date chosen was not during a weekend when teachers were their busiest with exam and assignment marking.

Figure 3. Unanimous voting for numerical marks, Mansfield, 2012 (image blurred to preserve anonymity)

At this meeting, many teachers raised their hands to speak. Those who did speak complained bitterly about QSA's assessment processes. Several mentioned leaving the profession. One person who spoke was in tears. So many teachers wanted to complain and tell their stories that we did not have enough time to hear them all. Though various views were raised, and senior QSA employees were present, I do not recall anyone speaking in favour of QSA or their assessment methods. At this meeting the following motions were voted on unanimously or almost unanimously:

(1) That the use and scope of long written assignments in Physics, Chemistry and Maths be considerably reduced or eliminated.
(2) That the non-marks based assessment schemes be replaced with a marks based system modeled on other states.
(3) That external exams be implemented for at least a fraction of the total assessment.

Earlier Meetings

The same concerns were also expressed by teachers in meetings in Townsville and in Cairns in 2012 [5].

In 2010 I had attended a similar meeting organized by Prof. Ridd and attended by around 100 senior mathematics, physics and chemistry teachers. Many of the teachers present were experienced teachers, and from good schools. Almost all teachers present were unhappy with QSA and their assessment system.

Later in 2010, a few of these teachers and I were invited to meet with Peter Luxton, the former head of QSA, and a small group of his staff. At this time I shared with Mr Luxton my attached article *Queensland high school mathematics needs a back-to-thinking revision.*

Many of the teachers who attended Prof Ridd's meetings also commented that all, or most of the mathematics, physics and chemistry teachers in their district, also shared their concerns about QSA and assessment.

I have repeatedly been impressed with the character of the teachers I have met at the recent 'protest' meetings. They are caring, dedicated, levelheaded and intelligent people trying to do their best and do the right thing by their students, in a difficult system. They tend to be the teachers with solid knowledge of their discipline.

I also find that teachers who have experience teaching anywhere outside of Queensland tend to be strongly critical of QSA's approach, while the few who express loyalty to the QSA, tend not to have experienced any alternative.

Surveys

Last year a teacher I know conducted a survey on the topic of senior mathematics and sciences assessment in Queensland. Two hundred people responded. Half of these were teachers. Here are the main results:

75% said there were too many assignments,
78% said assignments were too long,
87% said that in-class tests are fairer between students, than assignments,
90% said that tests judge a student's ability better than long assignments,
85% said criteria sheets are too complicated, and
89% said teachers should return to marking with marks and percentages.

The Qld Independent Education Union's recent survey reported that less than 50% of mathematics and science teacher respondents are happy with QSA's assessment processes. I understand that other surveys are also being conducted.

I know enough mathematics to know that gambling generally works against you. I also know enough statistics to know that truly representative surveying is very difficult and seldom achieved. It is very easy to unwittingly obtain unrepresentative

[5] see http://www.platoqld.com

results. On this occasion, it is the personal accounts and arguments of teachers, which I find most convincing.

State-wide Frustration With Red Tape

In 2012, Queenslanders resonated with Premier Newman's message of eliminating red tape and freeing up people to get on with their jobs and their lives. Queensland voted in the Newman government by the largest majority in Queensland history.

In recent years, teachers have felt the frustration of excessive red tape as more than most. QSA's extensive moderation and work-program validation demands, the introduction of long written assignments, and their insistence on using tables of paragraphs, all unnecessarily waste teachers' time and take them away from teaching.

Figure 4. An appropriately-sized graphic

3. Student participation levels in decline

Participation

Are we referring to participation in miscellaneous busy-work, or participation in actual mathematics? As explained in section 1 of this submission, QSA's assessment methods have had a disastrous effect on senior school mathematics:

1. up to half of *Maths B* and *Maths C* assessment assesses something other than mathematics (*Maths A* even more so),
2. the remaining mathematics assessed in these courses tends to be superficial,
3. not so much mathematics is actually being learned.

Participation in *Maths A, B* and *C*

In the 2012 enrollment figures provided to the Inquiry on 7th March, we see that Maths A is now the preferred mathematics subject, completed by about 35% of the age weighted cohort, while only 20% complete *Maths B*.

This indicates a decline over the last 30 years. In the 1970's and 1980's, the rigorous *Maths 1* was the main mathematics subject, completed by the majority of students. It would be very interesting to compare the percentage of students who completed *Maths 1* in the 1970's and 1980's with the percentage of students currently completing *Maths B*.

I would also be interested in seeing the graph for completion of *Maths A* from 1998 to 2012. It seems that the current system encourages students to take *Maths A*. This is unfortunate as many of these students have the ability to do *Maths B*, and while *Maths A* keeps students busy, it does not go far beyond year 9 and 10 level, mathematically speaking.

Evidence less mathematics is done now

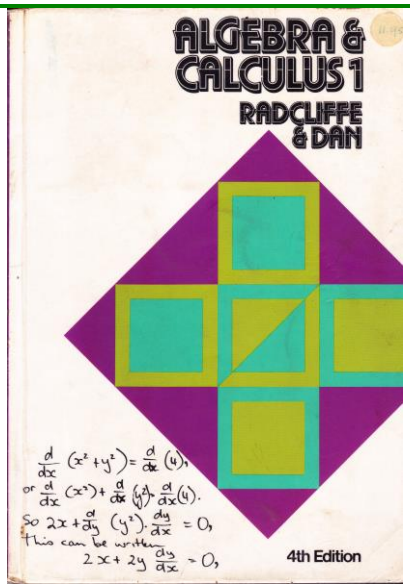
Lecturers at universities in Queensland have seen a huge decline in the mathematics ability of Queensland school graduates over the last 20 years. I have been lecturing first-year students enrolling in Engineering and Science degrees since 2007. I find that these students generally are aware of the senior mathematics topics, but lack the ability to do this mathematics. Many students also lack basic algebra skills, such as adding fractions. Some even do not know the times tables. In section 3, I explain how this is a direct consequence of the inquiry-based, constructivist approach to assessment adopted by QSA.

I feel that exposure to senior school mathematics topics, without developing the ability to do the mathematics, must be a somewhat demoralizing, rather than confidence-building experience for these students.

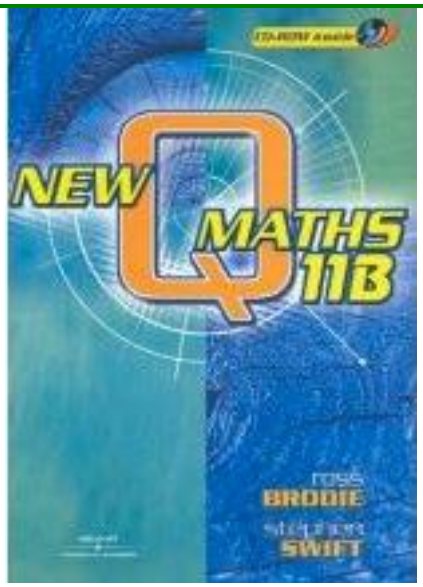
The table below compares the number of exercises on key mathematics topics in a text from 1970/80s with a popular text in current use[6]. Under the inquiry-based, constructivist approach, today's *Maths B* students generally do not do enough practice to master these important topics.

Comparison of the number of exercises on key topics:

Maths 1 (1970-90)
vs
Maths B (2012)



Maths 1: 1970 - 1990



Maths B: 2012

Topic	Number of Exercises	Number of Exercises
Index Laws	165	98
Differentiation Laws	225	63
Log functions	236	160
Log Identities	71	27

Students lacking the ability to do senior school mathematics have great difficulty pursuing science and engineering degrees. They are disadvantaged when competing for jobs, and their ability to practice in these fields is limited.

If the decline in Queensland school mathematics standards were only over the last two years, this problem would be very easily fixed. But the decline has persisted over at least the last 20 years. Unfortunately, the prevailing mood and philosophy of secondary education in Queensland has been ineffective for learning mathematics (see Appendix A).

[6] With all their faults, the Q Maths texts have done a good job with helping students see some applications of mathematics.

Appendix A. How did we sink so low?

Queensland school mathematics and sciences are amongst the lowest in the first world[7] because our school system (including QSA) has for a generation, followed the (constructivist) ideas of the academic discipline called *education*, and been disconnected from all other disciplines.

About Tertiary Disciplines

May I first introduce the tertiary sector? The figure below illustrates a typical university campus. It could easily be any university in the western world. Universities may consist of around forty departments. Each department researches and teaches students its own particular discipline.

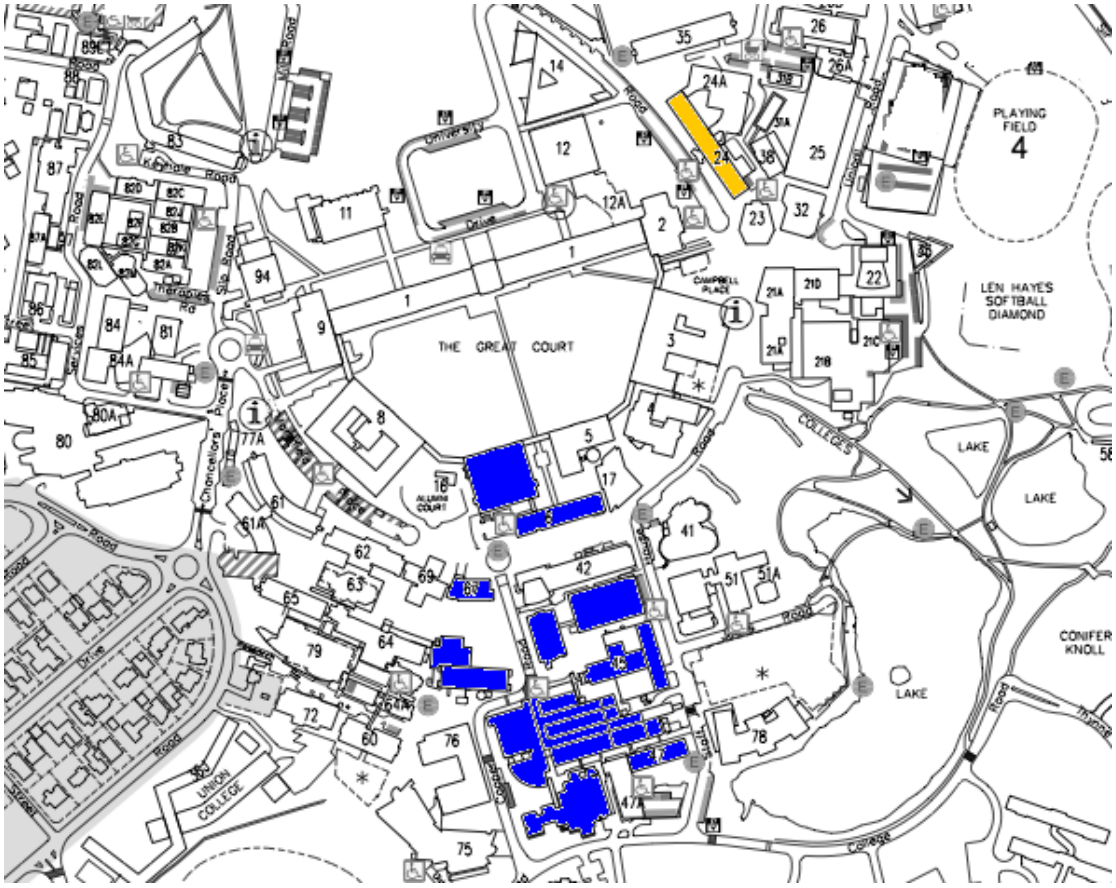


Figure 5: A typical university. (i) blue: mathematical disciplines (Mathematics, Physics, Chemistry, Engineering); (ii) yellow: Education

Academics in one department generally have more in common with their counterparts overseas, than with academics in another department, at the same university.

Typically, one part of campus will have what we might call the mathematical disciplines; mathematics, physics, chemistry and engineering (shaded in blue). These

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[7] for example J. Ridd, *Through Measurement to Knowledge*, http://www.onlineopinion.com.au/view.asp?article=13273

departments do mathematics, and publish mathematical research. These academics know high school mathematics back-the-front since they must do up to ten years of further successful mathematical study beyond school level, before obtaining an ongoing position.

In another part of the university, amongst the social sciences (sociology, psychology and so on), we might find an *education* department (shaded in orange). These social disciplines also publish research and require many years of study. However, their study and research is not of a mathematical nature[8]. Even *mathematics education* specialists within *education* departments write opinion essays rather than actually do mathematics. Furthermore, their mathematical knowledge may not extend far beyond high school level.

As these disciplines are so different, using *education* theory to run senior mathematics, physics and chemistry, is a bit like asking a hairdresser to fix the plumbing.

Queensland is not the first place to make this mistake. According to Prof David Klein, in the United States, more than 200 mathematicians added their names to an open letter expressing their concern with American school mathematics programs designed by *education* theorists[9].

Prof Klein is well known as the lead author of the Fordham Foundation sponsored report *The State of State Math Standards 2005* [10], which systematically evaluated and compared the mathematics standards of each of the individual states in the United States. I took the initiative of sending him a copy of QSA's *Maths B* syllabus and asked for his comments. His letter of review is included as Appendix C. He concludes

> "In my view, the Syllabus is in need of substantial improvement. It resembles state standards documents in the USA that have been abandoned as ineffective in the last several years. I strongly recommend that the committee appoint a panel of university mathematicians (holding PhDs in mathematics, not education or mathematics education) to review and revise the Syllabus. It would also be worthwhile to consider incorporating portions of high-quality mathematics standards documents from other countries whose students do well in the subject."

One might wonder why he specified mathematicians rather than *education* or even *mathematics education* specialists. The reason becomes clear after seeing the contrast between mathematics and the *education* version of school mathematics. This contrast was meticulously noted by Prof Bill Quirk in his article *Understanding the Original NCTM Standards: They're Not Genuine Math Standards* [11]. It is no coincidence that these concerns match the concerns of our Queensland high school

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[8] Social scientists may use statistical software, but they tend to be interested in interpreting the results, rather than the mathematical underpinnings of the statistical packages they use.

[9] http://www.csun.edu/~vcmth00m/bshm.html

[10] http://www.math.jhu.edu/~wsw/ED/mathstandards05FINAL.pdf

[11] http://www.wgquirk.com/TruthK12.html

mathematics teachers. I have summarized the differences between mathematics and *education*-mathematics in the following table:

Mathematics ...	***Education*-maths ...**
- has sufficient clarity to distinguish right from wrong.	- favours vague questions which have many interpretations.
- is mastered through much practice "there is no royal road to geometry".	- discourages repetition.
- uses standard procedures such as long multiplication, long division.	- prefers children invent their own methods, or use a calculator.
- requires memorizing some basic facts, such as the times-tables.	- discourages memorization of facts, even of the times tables.
- teachers can add up a student's marks to get a percentage.	- teachers consult tables of criteria paragraphs, written by education specialists, to grade students' work.
- includes algebra as a main part.	- discourages the manipulation of symbols.
The defining characteristic of mathematics is proof.	- omits proof.
- uses mathematics' own succinct international notation.	- students collect data and write essays.
- uses textbooks.	- prefers not to use textbooks.
- is done with pencil and paper.	- pencil and paper work is de-emphasized.
- is examined by tests.	- prefers open-ended, take-home, word-processed assignments.
- develops skills and methods unique to the discipline (of mathematics).	- is merely another setting for students to learn the 'higher order skills' and 'attitudes' of education.
- students learn abstract concepts whose truth is independent of, but may be applied to, specific contexts.	- students must always consider problems in some concrete context.
- students' mastery of the subject is independent of machines.	- students rely on calculators throughout primary school, and learn which buttons to press on a graphics calculator in high school.
- is difficult, requires concentration and often silence.	- can be done chatting as a group sitting cross-legged on the carpet.
- topics have a logical sequence.	- topics are covered in a spiral sequence.
- prefers to cover fewer topics well.	- skips through many topics.
- concerns timeless truths.	- constantly rewrites itself.

Our problem is not so much that Education theorists lack discipline knowledge; it is that they oppose discipline knowledge, in preference to their own ideas.

This is called an *anti-content* approach (the word *content* refers to knowledge). We can see this anti-content attitude in one of the popular notions of education theory called *Bloom's taxonomy*, or *higher-order thinking skills*.

The words '*higher-order*' sound good, but they have a very specific meaning: According to Bloom's taxonomy, *remembering* and *understanding* are regarded as less important and 'lowest-order' skills, while *evaluating* and *creating* are regarded as the highest-order skills[12]. Under the heavy influence of education theory, the Queensland mathematics, physics and chemistry syllabus documents require students to write essays so that they may have the opportunity to demonstrate the so-called 'higher-order skills', as well as the 'lower-order' regular mathematics, physics and chemistry.

In Queensland, we see much frustration with the anti-content thinking of QSA. For example, Merv Myhill entitles his comments of concern *Content is King* [13]. Prof Bill Quirk, quoting E.D. Hirsch's *The Schools We Need & Why We Don't Have Them* explains the origin of anti-content thinking:

> "Beginning eighty years ago, the anti-content ideas of Columbia Teachers-College Professor William Heard Kilpatrick began to dominate American public education. In his 1918 article, 'Project Method', Kilpatrick argued that knowledge is changing so fast that no specific subject matter should be required in the curriculum. He also claimed that following the project method would develop "critical thinking skills".[14]

In Queensland, teachers are also taught by education specialists, that knowledge is changing so fast that it is not important for children to learn it (knowledge). Of course, nothing could be further from the truth, particularly for mathematical sciences, which describe the unchanging laws of the physical world around us.

Even though there are many practicing high school teachers who can see the problems with the constructivist, anti-content approach[15], remarkably, in Queensland, as far as I know, we have just one tertiary *education* academic, Dr Stephen Norton, who has recognized the problems with the constructivist, anti-content (*education)* approach. I thoroughly recommend reading his submission to this Inquiry, and his recent comments on teaching mathematics. If there are other *education* academics with this insight, please accept my apology.

Dominance of education theory in Queensland

Before 1972, our secondary system was anchored to mathematical discipline knowledge through the external exams (set by relevant tertiary discipline academics). Since then our school system has gradually come adrift and been vulnerable to an overemphasis of anti-content education theory.

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[12] http://www.platoqld.com/wp-content/uploads/2012/05/3.-Re-education-captions-inserted.pdf

[13] http://www.platoqld.com/?p=359

[14] *The Anti-Content Mindset , The Root Cause of the "Math Wars"* by Bill Quirk http://www.wgquirk.com/content.html)

[15] see for example, Pat Whalen's insightful submission to this Inquiry

Academics from tertiary disciplines other than education theory have been excluded from significant involvement in our secondary system. For example, amongst the staff in the QSA and the central Education Department offices, are there any with a higher degree in mathematics, physics or chemistry? And yet, how many of these staff have studied higher degrees in education? With our current laws, a PhD in chemistry may teach university chemistry, but not high school chemistry. Also, in Queensland, all school mathematics teachers must have a degree or diploma in education, while the majority of our high school mathematics teachers have no tertiary training at all in mathematics.

Appendix B. Recommendations

1. Accept Responsibility

Passing responsibility for education to Canberra will not save us. It took forty years for Queensland education to gradually sink as low as it has. But already in its infancy, the so-called 'national curriculum' is already doing silly things with criteria paragraphs[16] and has other problems with validity. It is clearly also run by education theorists instead of discipline experts. We can do better than this.

2. Recommendations from Prof David Klein

Referring to the *Maths B* syllabus, Prof Klein, an experienced reviewer of US state mathematics programs, made the following remarks (see Appendix C for full letter)

> "The Committee would be well advised to appoint competent mathematicians to go through the entire document, including the glossary, in order to correct and improve the mathematical content...."
>
> "The assessment procedures described in Section 6 of the Syllabus are so bureaucratic and cumbersome that there is a danger that evaluations based upon them could be inconsistent across schools, overly subjective, or even meaningless...."
>
> "Finally, a well-crafted statewide exam is worthy of consideration and might serve a better purpose than the complex assessment procedures called for by the Syllabus...."
>
> "... In my view, the Syllabus is in need of substantial improvement. It resembles state standards documents in the USA that have been abandoned as ineffective in the last several years. I strongly

[16] http://www.australiancurriculum.edu.au/SeniorSecondary/Mathematics/Mathematical-Methods/AchievementStandards

recommend that the committee appoint a panel of university mathematicians (holding PhDs in mathematics, not education or mathematics education) to review and revise the Syllabus. It would also be worthwhile to consider incorporating portions of high-quality mathematics standards documents from other countries whose students do well in the subject."

3. My Recommendations

(a) Immediate action (2013)

- Appoint small and efficient 'Examination Teams' consisting of PhD's in each relevant discipline and teachers with at least 15 years recent experience, to revise the syllabus and set state-exams. These examination teams should revise the list of topics to teach and examine (the syllabus) by Oct 2013.

(b) Interim measures (2014)

- Examination teams to make available at least two practice state exams in each discipline to all schools by Oct 2014.
- Legislate that all teachers of mathematics, physics and chemistry should add up marks to report percentages and for SAI scores, instead of using criteria paragraph sheets.
- Beginning in 2014, Schools must make the weighting scheme for internal assessment tasks explicitly clear and publicly available at the beginning of each school year.
- Written assignments (including EEI's, ERT's, EMPS's and ERT's) should be optional and limited to a total of 10% of internal assessment for physics and chemistry and 0% for mathematics. These assignments should have a word limit of 500 words, with a penalty for exceeding this.

(c) Long term solution (2015 and beyond)

- Commence state exams set by Examination teams, worth 50% of the exit score for each discipline. End the QCS tests.
- For the internal assessment worth 50% of the exit score, instead of adjusting results by social moderation, the state exam results should be used to scale internal school results (similar to current practice with QCS tests).
- End central approval requirements for each school's internal work programs, teaching and assessment. With statewide exams, this will be unnecessary.

(d) Teacher training, registration and professional development

- These also need urgent revision to increase the lack of discipline knowledge, and reduce the overemphasis on education theory.

Appendix C. Letter from Prof. David Klein

California State University
Northridge

Department of Mathematics
College of Science and Mathematics

April 12, 2013

The Education and Innovation Committee
Parliament House
Brisbane Qld 4000
Australia

Dear Education and Innovation Committee,

I am a professor of mathematics at California State University, Northridge, USA. I was contacted by Dr. Matthew Dean who asked me to review and offer an opinion of the *2008 Queensland Maths B Syllabus*. I do so here in the hope that this may be of some use to you.

My background in K-12 mathematics education includes evaluating textbooks for the California State Board of Education, contributing portions to the California State Framework for Mathematics, working as Math Content Director for the Los Angeles County Office of Education. I was also the lead author of the Fordham Foundation sponsored report, The State of State Math Standards 2005, which systematically evaluated and compared the mathematics standards of the individual states of the United States. In addition I am the author of several publications on the history of mathematics education and related topics.

Criticisms

The *2008 Queensland Maths B Syllabus* (hereafter, the Syllabus) has many commendable strengths, but also some serious weaknesses from my point of view. In the hope that this letter may assist you in making improvements, I'll focus only on the latter.

The Syllabus raises concerns already on page 2, where only two of the seven listed Key Competencies are manifestly related to mathematics. Among the others is "using technology." The use of technology should not be an end in itself in a mathematics syllabus. The danger in making it so is that mathematical topics will be chosen or overemphasized so as to find a reason to use technology. This may be the case for the Syllabus. For example, in Section 5.2, one finds the SLEs:

- Use a graphing calculator to investigate the shapes of different functions.
- Use a graphing calculator to investigate possible functions for data.

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- Investigate the difficulties encountered in using a graphing calculator or computer software to draw graphs of relations which are not functions.

By searching for activities with little mathematical content so as to find a reason to use graphing calculators, these activities waste time, essentially placing the cart before horse. Mathematics should be primary and the use of technology secondary. Here is an example of the misuse of technology that occurred in some US high schools that followed programs similar to the Syllabus about a decade ago. Students were instructed to deduce the trigonometric identity,

$$\sin^2 x + \cos^2 x = 1,$$

by graphing the left side on their graphing calculators and observing the right side as the result on the calculator screen. The proper way to deduce this identity is via the Pythagorean theorem, and not through technology. The Syllabus would be improved by using this and/or similar examples for what *not* to do with technology.

There is insufficient attention to proofs in the Syllabus, and some of the mathematical topics are treated poorly. For example, in the glossary, "Generalisation" is poorly defined and "Example 1" which follows is difficult to understand. "Example 2," which then follows, is also poorly presented, and if retained, it should include the use of mathematical induction, an important method of proof not referenced in the Syllabus. Under the definition of "Outlier" reference is made to a line of best fit, but the concept of line of best fit does not otherwise appear in the Syllabus, and it should not. That topic is best left for a multivariate calculus course, so that the formulas for finding it can be easily justified. The Committee would be well advised to appoint competent mathematicians to go through the entire document, including the glossary, in order to correct and improve the mathematical content.

The Statistical Analysis topics and associated SLEs are problematic. If the intention is that this material would be incorporated into a calculus course, then there is far too much of it. Doing this would distract from more important topics in calculus, and students would receive both a poor education in calculus and a poor education in statistics. If, on the other hand, this material is intended for a separate course on probability and statistics, then the material is woefully lacking. For example, there is no mention of conditional probabilities, variance and standard deviation for a continuous random variable, the central limit theorem, or hypothesis testing. The SLEs stray too far into sociology and away from mathematics.

The assessment procedures described in Section 6 of the Syllabus are so bureaucratic and cumbersome that there is a danger that evaluations based upon them could be inconsistent across schools, overly subjective, or even meaningless. In addition, along with the requirement for spiraling, the assessment procedures impose questionable pedagogical constraints. On page 29, one finds the requirement,

> "An extended modelling and problem-solving task or a report or similar must be included at least twice each year. These should contribute significantly to the decision-making process in each of the three exit criteria."

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Student projects are time consuming. While a well conceived project enables students to learn a narrow subject deeply, the class time lost reduces the overall content that may be presented in a course. Such a trade-off deserves serious consideration. In my view, projects of this sort required twice a year with a complicated assessment procedure is excessive, and questionable even with only one required report per year. Moreover, the wording of the Syllabus appears to usher the subject matter of reports toward data gathering and statistics, at the expense of other mathematical topics. Under the heading "What might a student do to complete a report?" the examples given are:

- Gather and sort information and data from a variety of sources.
- Process information to identify assumptions and parameters.
- Interpret, analyse and synthesise data.
- Explain relationships to develop and support mathematical arguments
- Reflect on and evaluate data collected, propositions, results and conclusions
- Communicate ideas.

Four of the six bullets involve data collection, which is too narrow. Finally, a well-crafted statewide exam is worthy of consideration and might serve a better purpose than the complex assessment procedures called for by the Syllabus.

Recommendations

In my view, the Syllabus is in need of substantial improvement. It resembles state standards documents in the USA that have been abandoned as ineffective in the last several years. I strongly recommend that the committee appoint a panel of university mathematicians (holding PhDs in mathematics, not education or mathematics education) to review and revise the Syllabus. It would also be worthwhile to consider incorporating portions of high-quality mathematics standards documents from other countries whose students do well in the subject.

Sincerely,

David Klein
Professor of Mathematics

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