University Mathematics Bridging Courses: MathsStart, MathsTrack, A Review of Existing Approaches and Recommendations for Moving Forward.

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SCHOOL OF EDUCATION

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Abstract

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Chapter 1

Introduction

University mathematics bridging courses serve an important stop-gap role in the Australian educational system, and other educational systems internationally.

This project can be thought of as consisting of two broad categories of work:

- A literature review of Australian mathematics bridging courses, a state of the field of research in this area, and commentary on the role, purpose, and approaches important to implementing effective and impactful mathematics bridging courses in Australia and internationally.
- Reflection on the mathematics bridging courses offered by the University of Adelaide: MathsStart and MathsTrack with a focus on existing strengths, and directions for potential improvement. This will be broken into two sub-sections of work, with one of the bigger contributions I offer being a curriculum mapping from the Australian Curriculum (AC) to South Australian Certificate of Education (SACE) through to MathsStart and MathsTrack. This curriculum mapping suggests potential areas for modification of the mathematics bridging courses to more closely align them with the AC and SACE. The second sub-section of work will be on the non-content aspects of the bridging courses (structure, assessment, timing, feedback, etc.), the strenghts of their approaches in comparison to others, potential weaknesses, and reccomendations moving forward both for MathsStart and MathsTrack, and for university mathematics bridging courses more broadly.

This thesis will be structured as follows:

- The remainder of this introductory chapter (Chapter 1), I will give a broad overview of the concepts, challenges, and setting for this project.
- In Chapter 2 I will provide a indepth discussion of the existing literature, what is known, approaches attempted in the past both in Australia and internationally, and some deeper discssion on some of the particularly relevant related concepts, such as maths anxiety.
- One of the major contributions of this work is the curriculum mapping of the AC to SACE, to the content currently in MathsStart and MathsTrack, with commentary on how this mapping connects with typical first-year university mathematics courses. This mapping is discussed in Chapter 3, and will identify gaps and mis-alignment, discuss the tension between different perspectives on

the role of university mathematics bridging courses and how this impacts on content decisions, and potential modifications to the bridging courses content that would allow them to be more closely aligned with the AC should that be desirable.

- Finally, I will wrap up with commentary on what is being done well, reccomendations for how to improve, and a summary of the work I have done outside of this thesis to generate resources and content that can be used to improve these programs moving forward in Chapter 4.

1.1 The Role of University Mathematics Bridging Courses

Students will usually enroll in university mathematics bridging courses because they are required to demonstrate a certain level of mathematical knowledge/ competance before commencing study at university, but either do not meet those requirements, or do but feel a lack of confidence in their abilites and feel like they need to refresh/ revise/ learn the mathematics prior to commencing their studies.

Many of these students will be adult-entry students, and reasons why these students do not either meet the entry requirements, or feel a lack of confidence in their abilities can be quite varied:

- A long period of time may have passed since they last studied mathematics (or studied at all).
- They may have performed poorly in mathematics in highschool.
- They may have chosen not to study mathematics at a higher level in highschool.
- They may suffer from maths anxiety (which would make them likely to fit into the above two categories as well).

The role of mathematics bridging courses is to take these students, and:

- Bridge their content knowledge so they are prepared for university entry.
- Support the growth of their confidence and self-efficacy surrounding mathematics.
- Ultimately prepare them to be successful in a university context.

From the perspective of content, what content should be taught in a university bridging course is actually a question that has dramatically different answers from different perspectives on the role of such a course:

- If you take the perspective that the role of such a course is to fill in the gaps in student's knowledge left from an incomplete or maths-light highschool education, then the content that should be taught should be up to and including the advanced year 12 australian curriculum. This is particularly appropriate if you do not know the direction of the students, or if they are potentially just doing the bridging course with you and they are planning on studying a degree at a different university say, interstate.

- If you take the perspective that the role of such a course is to prepare students for entry into the particular courses they are about to commence studying, the content relevant to them will be dramatically differnet. The senior mathematics australian curriculum is extremely generalist and contains many topics that would be completely irrelevant to any particular field of study.

In terms of choosing what content to teach in a university bridging course, the above two competing perspectives will often be at odds with each other.

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Chapter 2

Literature Review

2.1 Bridging Courses

- (Gordon & Nicholas, 2013) describes the perspectives of students enrolled in an Australian university bridging course.
- (Johnson & O'Keeffe, 2016) describes the impact of a bridging course on students maths anxiety and self-efficacy in Ireland.
- (?, ?) Conference proceedings analysing the impact of bridging course on students success in first year university level calculus courses.
- (Nicholas & Rylands, 2015) is very relevant but I can't find the actual paper, just references too it.

2.2 Maths Anxiety

Why is Maths Anxiety Important?

Maths anxiety is hugely prevalent, the 2012 Programme for International Student Assessment (PISA) report states that across Organisation for Economic Co-operation and Development (OECD) countries, over 30% of 15 year old students "get very nervous doing mathematics problems", and over 60% of students "worry about getting poor grades in mathematics" (OECD, 2013). As teachers our foremost concern should be for the wellbeing of our students. It has been shown that students with a high level of maths anxiety often literally experience the anticipation of a maths task as visceral pain (Lyons & Beilock, 2012b). There is a clear and overwhelming moral imperative (and ethical duty of care) on us to do everything in our power to protect students in our care from maths anxiety.

Even if the wellbeing issue was not enough, there is also a clear maths anxiety-performance connection, and all the stakeholders in a students academic success in maths. One example of this is highlighted by Foley et al. (2017) who juxtaposes the internationally rising demand for Science, Technology, Engineering and Mathematics (STEM) professionals with the negative correlation between maths anxiety and performance shown in the 2012 PISA report (OECD, 2013) to highlight the relevance of addressing maths anxiety in filling this demand. The relationship between maths anxiety and maths-qualified professionals in the workforce is supported throughout the literature: when a student has low self-concept (correlated with high maths anxiety), they will tend not to enroll in maths beyond the minimum requirements for graduation (Ashcraft, Krause, & Hopko, 2007), and students affect towards maths can predict their university major (LeFevre, Kulak, & Heymans, 1992). Beyond this example, the list of stakeholders in a students academic success in maths goes on and on: parents; the student's themselves; schools (which are often funded based on the results of standardised testing such as National Assessment Program — Literacy and Numeracy (NAPLAN)), and teachers amongst them.

Maths Anxiety as Distinct from General Anxiety

The existence of maths anxiety as "emotional disturbances in the presence of mathematics" has been noted as early as the 1950's, Dreger and Aiken Jr (1957) even postulated that what he tentatively designated "Number Anxiety" and later became to be known as Maths Anxiety could be a distinct syndrome from general anxiety. Later the landmark meta-study of Hembree (1990) supported this hypothesis, showing a correlation of only 0.38 between maths anxiety and general anxiety. In more recent times, this hypothesis has also been confirmed by Young, Wu, and Menon (2012) using functional magnetic resonance imaging (fMRI) to show that the brain activity in a person experiencing maths anxiety is measurably distinct from that in a person suffering general anxiety. These later studies, as well as the the work of Kazelskis et al. (2000) and more, have also delineated maths anxiety from test anxiety, and these different anxieties exisitng as meaningfully distinct constructs is now quite well accepted. For more on the history of maths anxiety, Suárez-Pellicioni, Núñez-Peña, and Colomé (2016) offers a more detailed review.

Frameworks for Understanding Maths Anxiety

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Only a few studies focus on maths anxiety itself (primarily fMRI studies such as those of Young et al. (2012) or Lyons and Beilock (2012b)). Instead the bulk of the literature is focused on the maths anxiety-performance link. Specifically, there seem to be two distinct theories being pursued and I will adopt the terminology of Ramirez, Shaw, and Maloney (2018) to describe them: the "Disruption Account" and the "Reduced Competency Account". Ramirez et al. (2018) go on to make a convincing argument that although these two theories might seem to compete, they are not actually mutually exclusive and instead quite compatible with each other. Ramirez et al. (2018) suggests a third "Interpretation Account" which encapsulates observations made by both lines of research, see Figure 2.1.

First, a little more detail on the existing theories. The "Disruption Account", spearheaded by the work of Ashcraft et al., is centered around the concept of working memory (Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007). Specifically that anxiety about maths takes up students working memory, which prevents them from using that working memory to complete maths tasks and thereby impacts their performance. The "Reduced Competency Account" on the other hand proposes the opposite causality: that lower ability in maths leads to negative experiences associated to maths, which in turn cause maths anxiety to develop. There is also a significant body of work to support this hypothesis, including the milestone meta-analysis of Hembree (1990) and the longitudinal study of Ma and Xu (2004) which found that

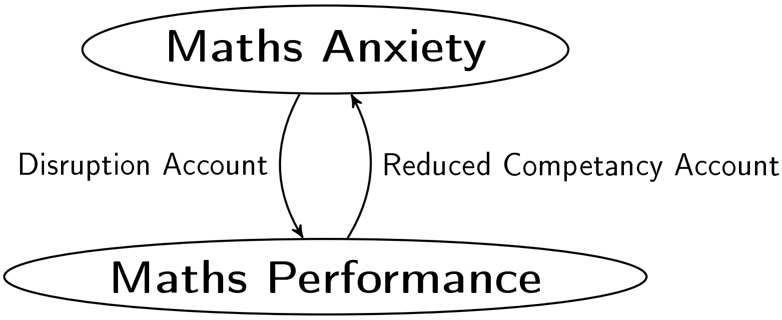

Figure 2.1: The Interpretation Account of Ramirez et al. (2018) for the maths anxiety-performance link showing how the Disruption Account and the Reduced Competency Account can be compatible.

although past maths anxiety was correlated with future maths performance it was a small effect, while past maths performance had a strong effect on future maths anxiety.

Complexities in Finding Effective Interventions

These theoretical views are of course broad oversimplifications of what is an incredibly complex and interconnected topic. They also imply very different approaches for intervention. The "Reduced Competency Account" would imply interventions to boost maths performance and hence allow students to experience success in math should also help to reduce maths anxiety. The results of Supekar, Iuculano, Chen, and Menon (2015) seem to support this hypothesis as when students are given an intensive 8-week tutoring program to boost their maths skills, this is associated to a reduction in maths anxiety. The earlier work by Faust (1996) further supports this by demonstrating an anxiety-complexity effect in which low and high maths anxiety groups performed similarly on low complexity problems, but in high complexity problems the high anxiety groups performance was impacted. On the other hand, Jansen et al. (2013) showed that it is not neccessarily that simple, by showing that when students experience more success they attempt more problems and perform better. However their improved performance is almost completely predicted by the number of problems they attempted, not their experience of success, and their level of maths anxiety was not affected in a significant way which raises a lot of interesting but unanswered questions about this approach.

On the other side of attempted interventions are those in line with the "Disruption Account", in which the maths anxiety itself is addressed in the hopes that will free up extra working memory and hence boost students performance. Park, Ramirez, and Beilock (2014) demonstrate a direct and successful attempt at this in which they used expressive writing exercises to help guide students self-perceived narratives about their maths experiences and thereby reduce their maths anxiety. Notably the approach of Park et al. (2014) is in line with successful treatments for clinical anxiety disorders (see McNally (2007); Becker, Darius, and Schaumberg (2007); Foa et al. (2005)). Another approach that has shown success in this vein does not attempt to directly reduce the anxiety experienced, but rather reappraise it's symptoms (Jamieson, Peters, Greenwood, & Altose, 2016). This is another technique from clinical psychology in which stress is reconceptualised as a coping tool, an evolutionary method for heightening performance in response to a challenge to be overcome, instead of a symptom of exposure to something to be feared and avoided. This change in the perspective of stress is also very much in line with the "Interpretation Account" of Ramirez et al. (2018).

The work of Wang et al. (2015) showed the role that intrinsic motivation has mediating the relationship between maths anxiety and performance, and suggested the importance of a mindset centred on viewing the process of learning maths as one of "productive struggle". This reconceptualisation to a 'productive struggle' model is supported by other literature as well, Lin-Siegler, Ahn, Chen, Fang, and Luna-Lucero (2016) exposes students in a classroom to struggles experienced by famous scientists in order to help normalise the concept of productive struggle, and Hiebert and Grouws (2007) discuss the importance of this same concept in a maths context.

One of the implications of the "Interpretation Account" is that if an intervention targets only one of these two possible links in the cycle (see Figure 2.1), the cycle may re-establish itself after the intervention is over and negate any potential longterm effects. However there is only a very limited amount of research out there on such longterm effects, and several authors have discussed the need for further research into this (Suárez-Pellicioni et al., 2016; Chang & Beilock, 2016). My hypothesis is that a multi-faceted approach targetting both directions simultaneously could disrupt the cycle shown in Figure 2.1 and result in significant longterm effects.

Instruments for Measuring Maths Anxiety

In order to track the effectiveness of these interventions, we will be collating assessment results as a measure of performance, but will also want to measure maths anxiety and maths affect/ self-concept. Significant work has been done over the years to develop psychometrics to measure maths anxiety, almost exclusively consisting of self-reporting surveys (with the exception of some more modern fMRI work, such as that of Lyons and Beilock (2012a)). We will use a recently developed scale: the Maths Anxiety Scale — Revised (MAS-R) of Bai, Wang, Pan, and Frey (2009), which has been shown to be remarkably self consistent by incorporating both positive and negative affect items (Bai, 2011). It is short, easy to implement, and cheap in comparison to fMRI methods. In order to measure maths self-concept, Jansen et al. (2013) modified the Perceived Competence Scale for Children of Harter (1982) to measure "Math Competance". The methodological process imployed by Jansen et al. (2013) was quite rigorous and so we will use their instrument, or a minor modification thereof (we will do it in English), to measure maths self-concept.

Chapter 3

Curriculum Mapping

One of the important roles of university mathematics bridging courses (such as MathsStart and MathsTrack) is to fill the content knowledge gap for students who did not complete mathematics to a sufficiently high level in highschool, or completed it long enough ago that they need to re-learn the material, but wish to commence study at a university level in subjects that have a high level of required knowledge in mathematics.

There are two angles from which this required knowledge can be seen: the knowledge required for the university study intended, and knowledge expected from highschool graduates. As we will come to see, these two angles or perspectives can be quite dramatically different. From the perspective of knowledge expected from highschool graduates, the AC serves as a good guide, but even so the exact content knowledge expected of students having completed highschool in Australia varies for a number of reasons:

- To begin with, the AC specifies four levels of mathematics: essential mathematics, general mathematics, mathematical methods, and specialist mathematics. Our focus will be on the higher two of these: mathematical methods and specialist mathematics, as these are the ones often associated to university entry into mathematics-intensive courses.

- Different states within Australia teach different curriculums, with varying degrees of alignment to the AC. In South Australia the primary curriculum taught in senior secondary school is SACE, and so we will focus on that.

The other perspective is of course the knowledge required for entry level university mathematics courses. This will vary hugely from course to course: a entry level calculus course will require very different knowledge than an entry level statistics course, for example. Even within one discipline of mathematics, different universities will have very different expectations of entry level students: in particular, South Australian universities will often structure their entry level mathematics courses to align with SACE even though not all their students have completed SACE, because of the majority who have it is still useful for them to do so. For example, the University of Adeliade re-structured it's first year mathematics courses in 2018 to match changes in SACE. Similarly, universities interstate will often structure their entry level courses to align with their local senior highschool curriculum.

This places a difficult tension on mathematics bridging courses as to what content to teach. Although many of the students enrolling in the mathematics bridging courses at the university of adelaide do so with the intention to begin study at the University of Adelaide (and hence might benefit from SACE structured content), many do not. Even amongst those that do, some may end up going to a different university interstate or even overseas — plans change. So it is important to try and maintain some connection to a broader set of knowledge expected in general and not neccessarily remain laser focussed on the requirements of the particular university courses most students are going to be attempting. This is one of the reasons why the AC is a useful construct as even though some states do not align to the AC as well as others, it still forms a guiding structure at a national level and individually considering the curriculum taught in each state is... beyond the scope of this work. Tailoring the content of the bridging courses more narrowly to target entry into particular disciplines (say calculus/ matrix alebra/ statistics for example) could potentially still be of interest down the line, but is likely to be unrealistic with the current resources available to the maths learning center.

This chapter will examine the alignment of the content of MathsStart and MathsTrack (the mathematics bridging courses offered at the university of adelaide) with the AC and SACE. First, in Section 3.1, some notation will be introduced and the content of each of the three curriculums will be reviewed:

- The AC senior mathematics subjects mathematical methods and specialist mathematics,
- The SACE curriculum stage 1 mathematics, stage 2 mathematical methods, and stage 2 specialist mathematics,
- The University of Adelaide's bridging courses: MathsStart, and MathsTrack.

Then, these will be mapped to each other in Section 3.2 (see Figure 3.1), and alignments/ misalignments discussed. Finally, the discussion throughout around alignment and gaps between the content of these curriculums and courses will be summarised, explanations and reasons for these discrepancies discussed, and potential modifications to content suggested.

Beyond that, this chapter will also briefly discuss the alignment of these bridging courses to first year university mathematics courses and bridging courses offered by other universities in Australia, and discuss the relationship between the gaps in alignment between the AC/SACE and the bridging courses and the requirements of these first year university courses.

3.1 Content

3.1.1 Notation

Each of the senior highschool curriculums, as well as the university bridging courses, being considered here is broken down into topics, with each topic containing a number of key concepts. In Section 3.2, the alignment between these curriculums and bridging courses will be considered thoroughly at both a topic-level, and to the finer detail of particular key concepts. In order to abstract away some of the complexity of considering the topic-level alignment, and be able to present the topic-level alignment in a meaningful way abbreviated codes will be used to identify each topic. These abbreviated codes are presented in Table 3.1 and will be used for the remainder of this chapter.

Table 3.1: Abbreviated codes for topics within the AC and SACE senior mathematics subjects: Mathematical Methods nd Specialist Mathematics, as well as the Unviersity of Adelaides bridging courses: MathsStart and MathsTrack. Square brackets ([]) are used to indicate numeric values that can vary.

Code	Meaning
MMu[#1]t[#2]	AC Senior Mathematical Methods Unit [#1], Topic [#2]
MMu[#1]t[#2]	AC Senior Specialist Mathematics Unit [#1], Topic [#2]
S1M[#]	SACE Stage 1 Mathematics, Topic [#]
S2MM[#]	SACE Stage 2 Mathematical Methods, Topic [#]
S2SM[#]	SACE Stage 2 Specialist Mathematics, Topic [#]
MS[#]	Maths Start, Topic (Booklet) [#]
MT[#]	Maths Track, Topic (Booklet) [#]

3.1.2 Within-Topic Key Concepts

Description of each topic in the AC Mathematical Methods and Specialist Mathematics Topics, SACE stage 1 mathematics, stage 2 mathematical methods and stage 2 specialist mathematics, and the University of Adelaides MathsStart and MathsTrack programs. For brevity a code is used to identify each topic, see Table 3.1, and then for each topic it's name is given in bold followed by a list of the key concepts covered in that topic. These are discussed at length below, and this table is intended to be used as reference material for that discussion.

Some notes on the way the key concepts are summarised:

- This key concept summary is intended for a reader deeply familiar with the content, and as such it is heavily condensed and uses notation and terminology without the usually appropriate rigorous definitions.
- Concepts relating to "interpretation" and application in a general sense are ommited. The assumption is that to the intended readers, these should go without saying. For example, in S1M2 the key concept "Quadratic Equations in Vertex and Factorised Form" is included, but this implies a variety of auxillary knowledge which is not explicity included in the key concept summary: the interpretation of roots and vertices, deducing vertices and roots from the equation of a quadratic, or deducing the equation of a quadratic given these bits of information, etc. It is intended that an experienced maths educator should be able to deduce such surrounding concepts from the key concepts that are listed.

Producing this curriculum mapping was a delicate balance between being broad and vague in order to be able to present the entire curriculum mapping within a single frame of view, and yet still be granular enough so that specific content is clear and explicity and useful actionable reccomendations can be made. This balance was acheived by presenting these curriculums are two levels of detail:

- At a topic level (see Figure 3.1). This is intended to give the broad strokes, and show the entire mapping in a single frame of view (a page, in this case).

It is also intended to be reference material for the following more detailed discussion, to aid the reader in structuring the information contained in the more detialed discussion and place each peice of information into where it belongs in the bigger picture.

- At a key concept level, this is what will be presented for the remainder of this section, and intended to be the grandular level at which content is presented specifically enough that reccomended actions can be understood explicitly and implemented easily. Note that although the key concept level is much more granular than the topic level discussion, it is still intended as a summary and does not include every single detail of the content, as discussed above.

Note: This is a huge table. I could maybe put it in an apprendix?

Code	**Name** and Key Concepts
MMu1t1	**Functions and graphs**: Midpoint of a Line, $y = mx + c$, Quadratic Equations in Vertex and Factorised Forms, Inverse Proportions, Polynomials, Relations, Translations and Dilations
MMu1t2	**Trigonometric functions**: Unit Circle, Radians, SOH CAH TOA, Sine Rule, Exact Values, Amplitude/ Period/ Phase, Sum of Angles Identities
MMu1t3	**Counting and probability**: Binomial Coefficients, Set Complement Intersection and Union, Probability, $P(A \cup B) = P(A) + P(B) - P(A \cap B)$, Conditional Probability, Independance
MMu2t1	**Exponential functions**: Index Laws, Fractional Indices, Functions, Asymptotes, Graphs
MMu2t2	**Arithmetic and geometric sequences and series**: Arithmetic and Geometric Sequences as Recurrence Relations, Limiting Behaviour, and Partial Sum Formulae, Growth and Decay
MMu2t3	**Introduction to differential calculus** Average Rate of Change, First Principles, Leibniz Notation, Instantaneous Rate of Change, Slope of Tangent, Derivitive of Polynomials, Linearity of Differentiation, Optimisation, Anti-Derivitives, Interpret Position-Time Graphs
MMu3t1	**Further differentiation and applications**: Define e as a s.t. $\lim_{h \to 0} \frac{a^h - 1}{h} = 1$, Derivitives of e^x $\sin(x)$ and $\cos(x)$, Chain Product and Quotient Rules, Second Derivitives
MMu3t2	**Integrals**: Integrate Polynomial Exponential and Trigonometric Functions, Linearity of Integration, Determine Displacement given Velocity, Definite Integrals, Fundamental Theorem of Calculus, (signed) Area Under a Curve
MMu3t3	**Discrete random variables**: Frequencies, General Properties, Expected Value, Variance, Standard Deviation, Bernoulli and Binomial Distribtions
MMu4t1	**The logarithmic function**: Logs as Inverse of Exponentials, Log-Scales, Log Function Graphs, Natural Log, $\frac{d}{dx}\ln(x) = \frac{1}{x}$, $\int \frac{1}{x} dx = \ln(x) + c$ for $x > 0$

Code	**Name** and Key Concepts
MMu4t2	**Continuous random variables and the normal distribution**: Probability Density Function, Cumulative Distribution Function, Probabilites Expected Value, Variance and Standard Deviation as Integrals, Linear Transformation of Random Variables, Normal Distribution using Technology
MMu4t3	**Interval estimates for proportions** Simple Random Sampling, Bias, Sample Proportion, Normal Approximation to the Binomial Proportion, Wald Confidence Interval, Trade-Off Between Width and Level of Confidence
SMu1t1	**Combinatorics** Multiplication of Possibilities, Factorial Notation, Permutations with and without Repeated Objects, Union of Three Sets, Pigeon-Hole Principle, Combinations, Pascals Triangle
SMu1t2	**Vectors in the plane**: Magnetude and Direction, Scalar Multiplication, Addition and Substraction as a Triangle, Vector Notation, $a\mathbf{i}+b\mathbf{j}$ Notation, Scalar Dot Product, Projection, Parallel and Perpendicular Vectors
SMu1t3	**Geometry**: Notation for Implication ($\Rightarrow$) and Equivalence ($\Leftrightarrow$), Converse ($B \Rightarrow A$) Negation ($\neg A \Rightarrow \neg B$) and Contrapositive ($\neg B \Rightarrow \neg A$), Proof by Contradiction, $\forall$ and $\exists$ Notation, Counter-Examples, Circle Theorems, Quadrilateral Proofs in $\mathbb{R}^2$
SMu2t1	**Trigonometry**: Graph and Solve Trig Functions, Prove Various Trig Indentities, Reciprocal Trig Functions
SMu2t2	**Matrices**: Notation, Addition and Scalar Multiplication of Matrices, Multiplicative Identity and Inverse, Determinant, Matrices as Transformations
SMu2t3	**Real and complex numbers**: Rationality and Irrationality, Induction, $i=\sqrt{-1}$, Complex Numbers $a+bi$ and Arithmetic ($+$, $-$, $\times$, $\div$), Complex Conjugates, Complex Plane, Complex Conjugate Roots of Polynomials
SMu3t1	**Complex numbers**: Modulus and Argument, Arithmetic ($\times$, $\div$, and z^n) in Polar Form, Convert between Polar and Cartesian Form, De Moivre's Theorem, Roots of Complex Numbers, Factorising Polynomials
SMu3t2	**Functions and sketching graphs**: Composition of Functions, One-to-One, Inverse Functions, Absolute Value Function, Rational Functions
SMu3t3	**Vectors in three dimensions**: $a\mathbf{i}+b\mathbf{j}+c\mathbf{k}$ Notation, Equation for Spheres, Parameterised Vector Equations, Equations of Lines, the Cross Product, Equation for a Plane, Systems of Linear Equation (Elimination Method) and Geometric Interpretation of Solutions, Kinematics via Differentiation of Vector Equations, Projectile and Circular Motion
SMu4t1	**Integration and applications of integration** Substitution, $\int \frac{1}{x}dx = \ln\|x\|+c$ for $x \neq 0$, Inverse Trig Functions and their Derivitives, Integrate $\frac{\pm 1}{\sqrt{a^2-x^2}}$ and $\frac{a}{a^2+x^2}$, Partial Fractions, Integration by Parts, Volume of Solids of Revolution, Numerical Integration using Technology
SMu4t2	**Rates of change and differential equations**: Implicit Differentiation, First-Order Seperable Differential Equations, The Logistic Equation, Kinematics (Rates of Change)

Code	Name and Key Concepts
SMu4t3	**Statistical inference**: Central Limit Theorem and the Resulting Confidence Interval for a Mean
S1M1	**Functions and graphs**: Equations for a Line, Slope, y-intercept, Intersection of Lines, Reciprocal Function, Asymptotes, Functions vs Relations, Domain, Range, Function Notation
S1M2	**Polynomials**: Quadratic Equations in Vertex and Factorised Forms, Quadratic Formula, Completing the Square, The Leading Coefficient and Degree of a Polynomials, Cubics, Quartics
S1M3	**Trigonometry**: Pythagoras, SOH CAH TOA, Cosine Rule, Sine Rule, Unit Circle, Sine and Cosine Functions, Radians, Length of Arc, Area of Sector, Amplitude, Period, Phase, $\tan(x) = \frac{\sin(x)}{\cos(x)}$
S1M4	**Counting and statistics**: Factorial, Permutations, Multiplication Principle, Combinations, Discrete vs Continuous Random Variables, Mean, Median, Mode, Range, Interquartile Range, Standard Deviation, Normal Distribution,
S1M5	**Growth and decay**: Index and Logarithm Laws, Exponential Functions and their Graphs
S1M6	**Introduction to differential calculus**: Average Rate of Change, First Principles, Notation $f'(x) = \frac{df}{dx}$, $\frac{d}{dx}x^n = nx^{n-1}$, Linearity of Differentiation, Slope of Tangent, Increasing vs Decreasing, Local and Global Maxima and Minima, Stationary Points, Sign Diagram
S1M7	**Arithmetic and geometric sequences and series**: Arithmetic and Geometric Series as Recurrance Relations and Explicit Expressions, Partial Sums, Limiting Behaviour
S1M8	**Geometry**: Circle Properties, Proofs (Direct, Contradiction, and Contrapositive)
S1M9	**Vectors in the plane**: Component (column) vs $ai + bj$ Notation, Length and Direction, Linear Combinations of Vectors, Scalar Dot Product, Projection, Angle Between Two Vectors and Parallel/ Perpendicular, Geometric Proof
S1M10	**Further Trigonometry**: Sketch Trigonometric Functions with Translations and Dilations, Solve for Angles, Trigonometric Identities, Reciprocal Trigonometric Functions
S1M11	**Matrices**: Linear Combinations of Matrices, Matrix Multiplication, The Identity, Inverse Matrices, The 2×2 Inverse, The 2×2 Determinant, Linear Transformations (including rotations, reflections and composition)
S1M12	**Real and complex numbers**: Rationals, Irrationals, Interval Notation, Induction, $i = \sqrt{-1}$, Real and Imaginary Components, Complex Conjugates and Arithmetic, Argand Diagram, Modulus, Complex Roots of Polynomals
S2MM1	**Further differentiation and applications**: S1M6, Chain Product and Quotient Rules, $e = 2.718\ldots$, $\frac{d}{dx}e^x = e^x$, $\frac{d}{dx}\sin(x) = \cos(x)$, $\frac{d}{dx}\cos(x) = -\sin(x)$, Second Derivatives, Concavity and Points of Inflection

Code	**Name** and Key Concepts
S2MM2	**Discrete random variables**: Random Variables, Discrete vs Continuous, Probability Functions and Distributions, Properties of Probabilities, Frequency, Expected Value $E[X] = \sum xp(x) = \mu_X$, Standard Deviation $\sigma_X = \sqrt{\sum (x - \mu_X)^2 p(x)}$, Uniform Bernoulli and Binomial Distributions
S2MM3	**Integral calculus**: Anti-differentiation, If $F'(x) = f(x)$ then $\int f(x)dx = F(x) + c$, Reversing Chain Rule for $\int f(ax+b)dx$, Linearity of Integration, Finding the Constant of Integration, Area Under the Curve as Upper and Lower Sum Approximations, Definite Integral, Area Between Two Functions and Between a Negative Function and the x-axis, Fundamental Theorem of Calculus,
S2MM4	**Logarithmic functions**: Sketching $y = a\ln(b(x-c))$, $\frac{d}{dx}\ln(x) = \frac{1}{x}$, For $x > 0$ $\int \frac{1}{x}dx = \ln(x) + c$
S2MM5	**Continuous random variables and the normal distribution**: $P(X = x) = 0$, Probability Density Function, $\mu_X = \int_{-\infty}^{\infty} xf(x)dx$, $\sigma_X = \int_{-\infty}^{\infty} (x - \mu_X)^2 f(x)dx$, $f(x) = \frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$, Standard Normal $Z = \frac{X-\mu}{\sigma}$, Simple Random Sampling, For $X \sim (\mu, \sigma)$ and $X_i \sim iidX$ Sampling Distributions of $S_n = \Sigma_{i=1}^{n} X_i$ $(n\mu, \sigma\sqrt{n})$ and $\bar{X}_n = \frac{S_n}{n}$ $(\mu, \frac{\sigma}{\sqrt{n}})$, If X is Normally Distributed, then so are S_n and $\bar{X}_n$, Central Limit Theorem (CLT)
S2MM6	**Sampling and confidence intervals**: Confidence Interval for a Mean using CLT $\left(\bar{x} - z^* \frac{s}{\sqrt{n}}\right) \leq \mu \leq \left(\bar{x} + z^* \frac{s}{\sqrt{n}}\right)$, Wald Interval for a Proportion
S2SM1	**Mathematical induction**: Initial Case and Induction Step
S2SM2	**Complex numbers**: Cartesian vs Polar Form, Real and Imaginary Components, Modulus and Argument, Arithmetic in both Cartesian and Polar Forms, de Moivre's Theorem including Negative and Fractional Powers, Geometric Properties of the Argand Plane, Complex Arithmetic as Transformations, n^{th} Roots of a Complex Number, Factorising Polynomials with Complex Roots
S2SM3	**Functions and sketching graphs**: Function Composition, Informal Intro to Domain and Range, One-to-One, Inverse Functions, Absolute Value Function, Graphing Rational Functions
S2SM4	**Vectors in three dimensions**: Notation, Equations of a Line in $\mathbb{R}^3$, Scalar Dot Product, Vector Cross Product, $\lvert\mathbf{a} \times \mathbf{b}\rvert$ is the Area of their Parallelogram, Equation for a Plane in $\mathbb{R}^3$, Systems of Linear Equations, Geometric Interpretation of No/Unique/Infinite Solutions to a System of Linear Equations in $\mathbb{R}^3$
S2SM5	**Integration techniques and applications**: Integration by Substitution, Using Trigonometric Identities for Integration, Derivatives of Inverse Trigonometric Functions (so $\int \frac{\pm 1}{\sqrt{a^2 - x^2}}dx$ and $\int \frac{a}{a^2 + x^2}dx$, Integration by Parts, Area Between two Curves, Volume of Solids of Revolution

Code	**Name** and Key Concepts
S2SM6	**Rates of change and differential equations**: Implicit Differentiation, First-Order Seperable Differential Equations, The Logistic Differential Equation, Parameterised Curves, Example: if $\mathbf{v} = \frac{d}{dt}(x(t), y(t))$ is Velocity, $\lvert\mathbf{v}\rvert$ is Speed, and so the Arc Length along the Parameterised Curve is $\int_a^b \sqrt{\mathbf{v} \bullet \mathbf{v}}dt$, Trigonometric Parameterisations (unit circle, and non-circular parameterisations)
MS1	**Numbers & Functions**: Natural Numbers, Integers, Rational Numbers, Real Numbers, Functions, Intervals
MS2	**Linear Functions**: Equation for Linear Functions, Simultaneous Linear Equations, Sketching Linear Inequalities
MS3	**Quadratic Functions**: Sketching a Parabola, General Form of a Quadratic, Translations and Dilations
MS4	**Rational Functions**: Sketching Reciprocal Functions (Hyperbola), Lines of Symmetry, Limits and Asymptotes
MS5	**Trigonometry I**: Pythagoras, Similar Triangles, SOH CAH TOA, Trigonometric and Inverse Trigonometric Functions using Technology, Exact Values
MS6	**Trigonometry II**: Unit Circle, Sketching Trigonometric Functions, Finding all Solutions to Trigonometric Equations, The Sine Rule, The Cosine Rule, Introductory Trigonometric Identities, Radians
MS7	**Exponential Functions**: Index Laws, Sketching Exponential Functions, $e = 2.718\ldots$, Growth and Decay
MS8	**Logarithms**: Natural Logarithm, Logarithm Laws, Using Logarithm to Fit Growth/Decay Functions, Half-Life/ Doubling Time
MT1	**Polynomials**: Polynomial Division and "Remainder Theorem", Factor Theorem Linking Zeros to Factors, Continuous vs Discontinuous Functions, Smoothness, Sketching Factorised Form of Polynomials, Factorising Polynomials, The Quadratic Formula
MT2	**Matrices**: Order, Notation, Linear Combinations of Matrices, Matrix Multiplication (Associative but not Commutative, Distributes across Linear Combinations), The Identity Matrix, Powers of Square Matrices, Matrix Transpose, Systems of Linear Equations, Matrix Inverse, 2×2 determinant, The 2×2 Inverse, $n \times n$ Inverses, Elementary Row Operations,
MT3	**Vectors and Applications**: Directed Line Segment Notation for Vectors, Magnetude/ Length and Direction, Linear Combinations of Vectors, Component and $a\mathbf{i} + b\mathbf{j}$ Notation, Vectors in $\mathbb{R}^2$ and $\mathbb{R}^3$, Scalar Dot Product, Equation for a Plane in $\mathbb{R}^3$
MT4	**Systems of Linear Equations**: Augmented Matrix for Systems of Linear Equations, Elementary Row Operations, Row-Echelon Form, Solutions to Systems of Linear Equations and Geometric Interpretations in $\mathbb{R}^2$ and $\mathbb{R}^3$, Matrix Inverses by Gauss-Jordan Elimination

Code	**Name** and Key Concepts
MT6	**Differentiation**: Rates of Change, Gradient, First Principles, Limit Notation, Derivative Notation, $\frac{d}{dx}x^n = nx^{n-1}$ (including $n = 0$ and $n = 1$), Linearity of Differentiation, Product Rule, Quotient Rule, Chain Rule, Implicit Differentiation, Normal to a Curve
MT7	**Applications of Differentiation**: Sketching Polynomials and Rational Functions (Intercepts and Asymptotes), Continuity, Sign Diagrams, Increasing and Decreasing, Stationary Points, Points of Inflection, Concavity, Optimisation,
MT8	**Exponential and Logarithm Functions**: Sketching Exponential Functions, $e = 2.718\ldots$, $\frac{d}{dx}e^x = e^x$, Natural Logarithm, $\frac{d}{dx}\ln(x) = \frac{1}{x}$, Growth and Decay, Surge Models, Logistic Models
MT9	**Integration**: Area Under a Curve, Lower and Upper Sums, Definite Integrals, Definite Integrals of Negative Functions, Linearity of Integration, Properties of Definite Integrals, Fundamental Theorem of Calculus, Antiderivatives, Indefinite Integrals, Integrating by Reversing the Chain Rule, Integration by Substitution, Area Between two Curves, Summation Notation (Appendix)

3.1.3 AC Mathematical Methods and Specialist Mathematics

AC has four levels of mathmatics, including also essential and general mathematics. Mathematical Methods and Specialist Mathematics are the two highest level mathematics, intended (partly) for preparation to university entry. Broadly speaking, the content of these two subjects can be grouped into several areas:

- Functions and Graphs, which is broken up primarily into families of functions, with some extra concepts thown into some generalist topics:
  - Polynomials and Rational Functions (MMu1t1, SMu3t2),
  - Exponentials and Logarithms (MMu2t1, MMu4t1)
  - Trigonometric Functions (MMu1t2, SMu2t1)
- Calculus, which is largely structured similarly to the Functions and Graphs: breaking it up by the type of function you are doing calculus on, splitting up differentiation from integration, and throwing in rules of differentiation and approaches to integration with a few extra concepts along the way (MMu2t3, MMu3t1, MMu3t2, SMu4t1, SM4t2).
- Geometry and Linear Algebra: Mostly vectors, with some matrices, systems of equations, and even circle theorems. This is the topic in which the concept of proof is primarily attempted to be introduced, and perhaps that is the reason why it is entirely contained within the Specialist Mathematics curriculum (SMu1t2, SMu1t3, SMu2t2, SMu3t3),
- Complex Numbers, as well as rational/ irrational numbers, etc. (SMu2t3, SMu3t1), and finally

- Probability and Statistics, with some combinatorics thrown in for good measure (MMu1t3, MMu3t3, MMu4t2, MMu4t3, SMu1t1, SMu4t3)

Although there are a couple of topics (MMu2t2 for example) which although they relate to these broader areas, also contain a substantial amount of other content.

More detailed discussion of the specific key concepts of interest will follow in Section 3.2 as a natural part of comparisons between curriculums, as that is where the specifics will be important. These sections are intended to give a broader overview of the structure of the content in these curriculums

3.1.4 SACE Stage 1 Mathematics, Stage 2 Mathematical Methods and Specialist Mathematics

SACE follows the AC fairly well at a broad level (although there are differences in the details, which will be discussed in Section 3.2. Broadly though the topics in the three SACE subjects here, although split into three subjects instead of two, can be broadly grouped into areas much the same as the AC:

- Functions and Graphs, which is broken roughy as:
  - General Concepts (S1M1, S2SM3),
  - Polynomials and Rational Functions (S1M2, S2SM3),
  - Exponentials and Logarithms (S1M5, S2MM4, S1M7)
  - Trigonometric Functions (S1M3, S1M10)
- Calculus, which similarly split up by the type of function you are doing calculus on, differentiation vs integration, and throwing in rules of differentiation and approaches to integration with a few extra concepts along the way (S1M6, S2MM1, S2MM3, S2MM4, S2SM5, S2SM6).
- Geometry and Linear Algebra: Mostly vectors, with some matrices, systems of equations, and even circle theorems. This is the topic in which the concept of proof is primarily attempted to be introduced, and perhaps that is the reason why it is entirely contained within the Specialist Mathematics curriculum (S1M8, S1M9, S1M11, S2SM4),
- Complex Numbers, as well as rational/ irrational numbers, etc. (S1M12, S2SM2), and finally
- Probability and Statistics, with some combinatorics thrown in for good measure is included almost exclusively in Stage 2 Mathematical Methods (S1M4, S2MM2, S2MM5, S2MM6)

Although there are a couple of topics (S1M7,for example — very similarly to MMu2t2) which although they relate to these broader areas, also contain a substantial amount of other content. This grouping also leaves one topic out in the SACE context: S2SM1 which is essentially just the concept of mathematical induction.

3.1.5 MathsStart and MathsTrack

MathsStart can be seen as essentially an introduction to functions, MathsTrack then takes this, and extends it primarily to calculus, taking a little detour along the way to cover some vector and matrix geometry/ systems of linear equations concepts. So broadly grouping the topics in a way analogous to above:

- Functions and Graphs, roughly broken up into:
  - General Concepts (MS1, MS2),
  - Polynomials and Rational Functions (MS3, MS4, MT1),
  - Exponentials and Logarithms (MS7, MS8), and
  - Trigonometry (MS5, MS6)
- Calculus, similarly first introducing differentiation on polynomials with various other general concepts (MT6, MT7) and then exponentials and logarithms (MT8) and finally also integration (MT9).
- Geometry and Linear Algebra (MT2, MT3, MT4).

Note the missing topic 5 in MathsTrack, this used to be part of the course some time ago but is currently no longer included in the content of the course, and so is not included here.

3.2 Curriculum Mapping

Figure 3.1 shows the topic-level alignment between the AC (senior mathematical methods and specialist mathematics), SACE (stage 1 mathematics, stage 2 mathematical methods and stage 2 specialist mathematics), MathsStart and MathsTrack. This is the broad, eagle-eye, view of the alignment between the content in these topics.

Although key concept level alignment between topics connected with lines in Figure 3.1 is not always perfect, it is fairly strong in most cases. Individual cases with any misalignment will be discussed in the remainder of this chapter.

3.2.1 AC to SACE

At a glance, there appears to be a very good one-to-one alignment at the topic level between the AC and SACE. Broadly speaking the biggest difference between these two curriculums is their structure. The AC content is structured into two subjects (mathematical methods and specialist mathematics) which span "senior highschool", which most commonly would equate to both years 11 and 12 in Australia. Each of these two subjects contains 12 topics. The SACE content on the other hand is split into stage 1 (commonly year 11 in Australia) and stage 2 (commonly year 12), stage 1 consists of a single subject "mathematics" with 12 topics, and stage 2 is split into two (mathematical methods and specialist mathematics) each with 6 topics. So the total number of topics is actually the same accross the board between the AC and SACE, and they seem to match almost exactly with a pattern in which the first 6 topics of both the AC mathematical methods and speciaist mathematics constitute

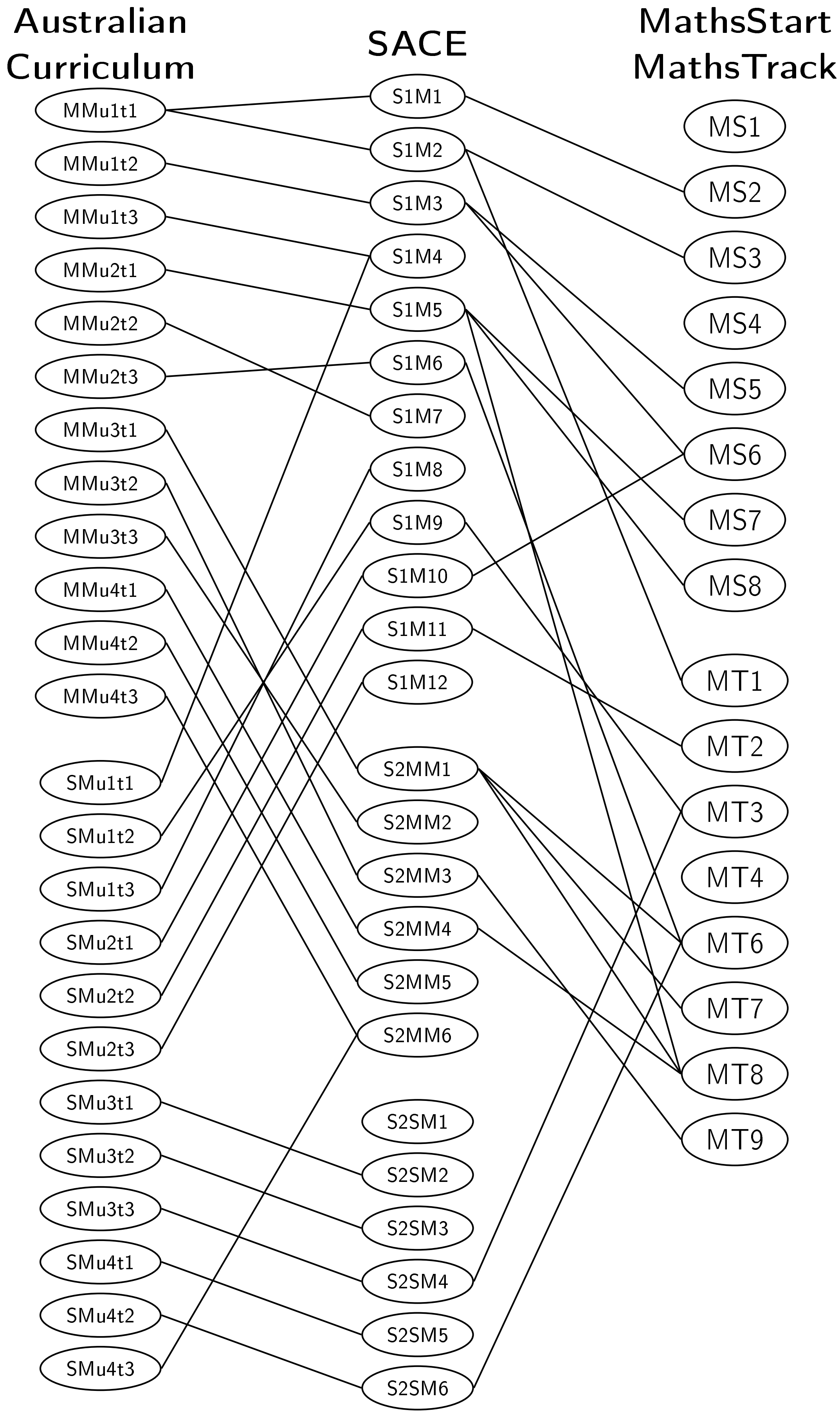

Figure 3.1: Curriculum Mapping

SACE stage 1 mathematics and the remaining 6 topics in each of the AC subjects align to the corresponding SACE stage 2 subject.

As usual however, the devil is in the details:

- Hello

Note: Cumulative Distribution Function not mentioned in SACE

3.2.2 AC and SACE to MathsStart and MathsTrack

MS4: Note the link to S2SM3

- MS1: Maybe Introduce Interval Notation along with Intervals?
- MT2: Gauss-Jordan is used to introduce the concept of a Matrix Inverse, altough very relevant to first year maths, not in the AC/ SACE at all.
- MT6: Note that the concept of the normal to a curve is introduced, but is not in any curriculum (or first year maths course that I know of?)
- MT8: There are many ways to introduce $e = 2.718\ldots$, but the way it is introduced in MathsTrack is (perhaps coincidentally), precisely the same as the way it is introduced in SACE (and AC?).
- MT8: Surge Models are introduced which are not used anywhere else.
- MT8: Logistic Models are introduced, but not as a DE just as a model.

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Chapter 4

Moving Forward: Improvements

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4.1 Current Strengths of MathsStart and MathsTrack

Moving foward is a two-part process:

- Recognise what is being done well, encourage and recognise it, and continue to support its ongoing excellence.
- Recognise what can be improved on, gaps that may exist, and address them with specific actionable changes.

4.1.1 SQUIGGLES

4.1.2 Staff Culture at the Maths Learning Center

4.1.3 Self-Paced Assessment and Content Speed (!!!)

Link to Maths Anxiety literature review.

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Conclusions and Reccomendations

With respect to the bridging courses run through the university of adelaide's maths learning centre: MathsStart and MathsTrack,

- The self-paced and feedback focused approach to assessment is certainly the highlight of the programs, should be continued, encouraged, potentially further resourced, expanded, and reccomended to other bridging course facilitators.
- The role of bridging courses as what is often student's first experience at university implies that potentially students wellbeing and retention could be improved by structuring the programs to provide more opportunities for students to meet each other and work together: either in the maths learning center drop-in area, or a seperate area, but potentially assigning a certain time on a certain day perhaps weekly or fortnightly during which students are encouraged to come and work together, could allow them to make freinds, build social networks, and better aclimitise them to the university environment in order to better prepare them for success in their studies.
- The smallest but perhaps easiest to implement improvement could be to better align the course content with curriculum, both the highschool curriculum (AC/ SACE) in the case of students doing the bridging course to then comence study interstate or overseas, or with specific first year entry level courses, to better match the potential gaps in knowledge students may encounter.

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