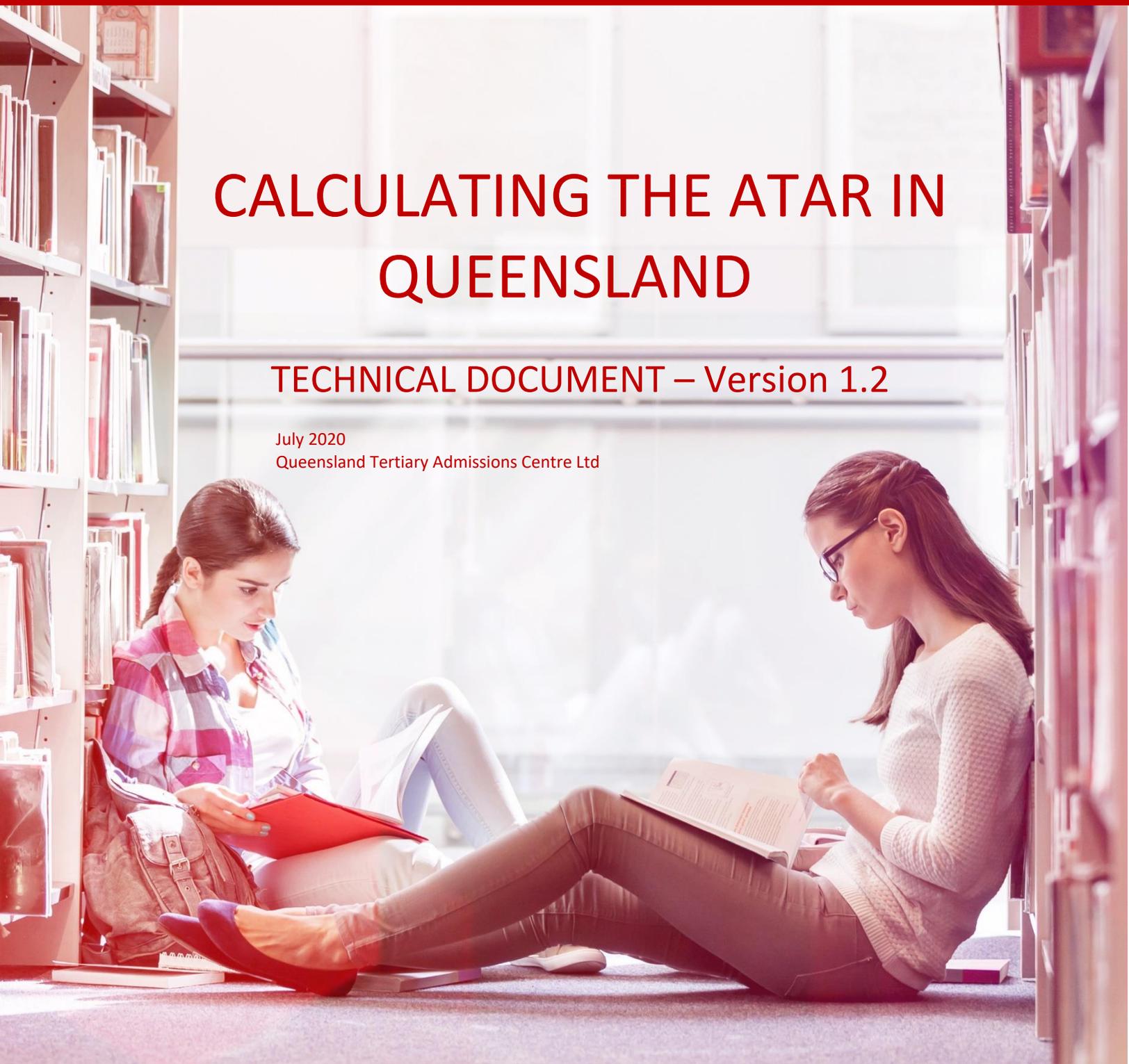


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# CALCULATING THE ATAR IN QUEENSLAND

TECHNICAL DOCUMENT – Version 1.2

July 2020  
Queensland Tertiary Admissions Centre Ltd



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# 1 Introduction

The Australian Tertiary Admission Rank (ATAR) is a measure of a student's overall achievement at school, for use in higher education admission systems in all Australian states and territories. More precisely, it is a rank indicating a student's position relative to the potential Year 12 population in a jurisdiction. The ATAR is expressed on a 2000-point scale from 99.95 (highest) to 0.00, in increments of 0.05. ATARs equal to or below 30 are reported as "30.00 or less". Queensland will move from the Overall Position (OP) to ATARs in 2020, and the new measure will become effective for students who seek entry to tertiary courses commencing in 2021.

Other than reporting students' secondary school performance on a more refined index allowing more separation between students, further changes from the OP include a different allocation model to band students, and a different subject scaling method. The Queensland Core Skills Test (QCS Test) will be discontinued<sup>1</sup>, and the ATAR in Queensland will be derived from an inter-subject scaling process in a similar way to those that are used currently in other jurisdictions.

The aim of this technical document is to provide a comprehensive description of the full end-to-end process that the Queensland Tertiary Admissions Centre (QTAC) will use to calculate the ATAR, including various methodological and technical aspects, and it is therefore aimed at an informed audience. Non-technical readers can find more accessible documents on the ATAR dedicated page of QTAC's website<sup>2</sup>.

## 2 Process overview

### 2.1 Senior assessment

Figure 1 displays a simplified description of the new senior secondary system, and highlights the separation of responsibility for senior student assessment (what happens in schools and the QCAA) from the one for selecting applicants for tertiary entrance (what happens at universities and QTAC). QCAA's quality assurance and moderation processes guarantees the validity and comparability of results, by ensuring consistency of judgements about student achievements.

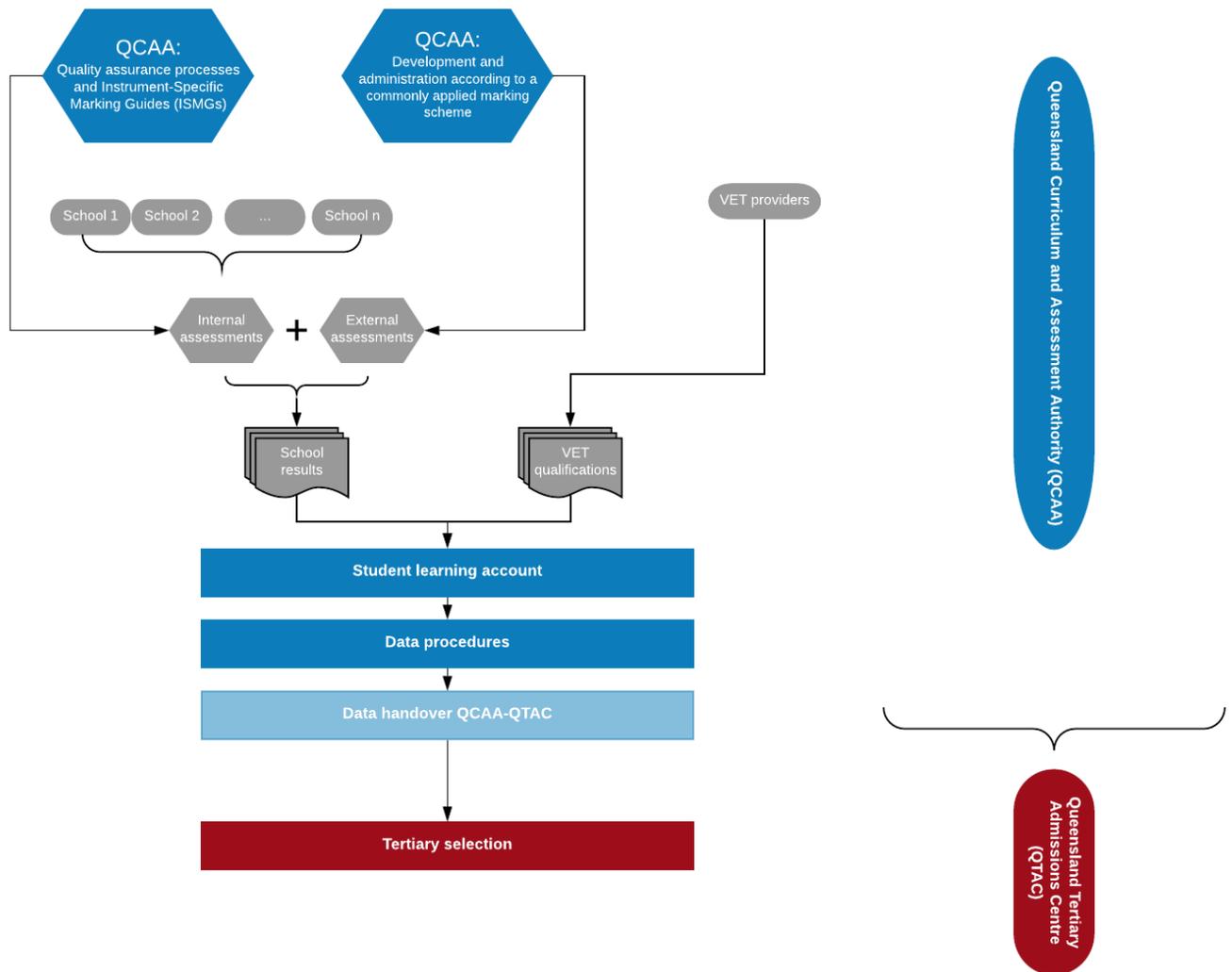
For Applied subjects, this includes the approval of study plans, a review of assessment, student responses and teacher judgements. For General subjects, quality assurance is carried out through similar assessment and review tools for Units 1 and 2, and an endorsement and confirmation process for Units 3 and 4.

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<sup>1</sup> The last QCS Test will take place on 3 and 4 September 2019.

<sup>2</sup> <https://www.qtac.edu.au/atar-my-path/atar>.

Figure 1: Overview of the senior assessment process



In addition, student results for General subjects are based on their achievement in three internal assessment components and one external assessment component<sup>3</sup> developed and administrated by QCAA according to a commonly applied marking scheme. In General Mathematics and Science subjects, a student’s external assessment result contributes 50% to their final subject result. In all other General subjects, it contributes 25%.

A more detailed description on the quality assurance processes used in all QCAA subject types can be found in the [QCE & QCIA online handbook](#).

QTAC’s responsibility is to process results received from the QCAA to calculate an ATAR for each eligible student. As part of the ATAR calculation, a process of “inter-subject scaling” is used to

<sup>3</sup> The QCAA recognised that the [coronavirus pandemic](#) has altered teaching and learning for teachers, schools, students, and parents/carers. To mitigate this impact on 2020’s cohort of students the QCAA has removed one summative internal assessment from the assessment requirements for both General and Applied subjects.

measure the difference in the academic abilities of students enrolling in different subjects. This scaling is described in Chapter 3.

## 2.2 Data

Levels of achievement for each student in each of their subjects is reported by the QCAA in the form of a subject result, which includes letter grades and numeric grades. Each subject result indicates the level of knowledge, understanding and skill of a student in a given subject.

Completed VET qualifications are included as inputs to the ATAR, but unlike school subject results, there is no indication of a student’s level of performance. There is, in fact, a great variety of VET qualifications falling into the same category of the Australian Qualifications Framework (AQF), for example Certificates III, and different VET providers and grading systems, which cannot easily be compared.

It is the student’s responsibility to ensure that completed VET qualifications are in their QCAA learning account prior to ATARs being calculated.

The QCAA will report subject achievements from 2020 as shown in Table 1. Other related data are those included in the results file from QCAA, containing relevant personal attributes of Queensland Senior Year 12 students (name, surname, date of birth, etc.).

*Table 1: Reported results for school subjects and VET qualifications*

<b>Input</b>	<b>Input Type (T)</b>	<b>Result Reported</b>
General subject	1	Letter grade (A highest to E) and numeric grade (1-100)
General extension subject	1	Letter grade (A highest to E) and numeric grade (1-100)
Senior External Examination subject	1	Letter grade (A highest to E) and numeric grade (1-100)
Applied subject	2	Letter grade (A highest to E)
Short courses <sup>4</sup>	2	Letter grade (A highest to E)
VET qualification	3	Completion status (Y/N) and AQF level (Certificate III, Certificate IV, Diploma, Advanced Diploma)

<sup>4</sup> Short Courses are not inputs into the ATAR.

## 2.3 Terminology and definitions

Throughout this document the following terminology has been used to describe different aspects of the ATAR calculation process.

- a) **Raw result:** This term replaces the generic “Subject Result” or “Level of Achievement” mentioned in the previous paragraphs. This is aimed at breaking the concept of “Subject Result” into two components: the “Raw” (unscaled) component and the “Scaled” component.
- b) **Scaled result, or subject score:** This term refers to the subject result generated via the scaling process. A student’s raw result in a General subject might be 50 out of 100, but the scaled result might be 52.16 out of 100. Scaled results are expressed on a 100-point scale to 2 decimal places.
- c) **Subject scaling:** The process by which raw results for all subjects are adjusted to allow results to be comparable.
- d) **Polyrank:** This is the overall ability measure calculated for all students. It is a combined set of scaled results. Polyrank is expressed on a fine-grained numeric scale that enables distinction between students for tertiary selection purposes.

## 2.4 ATAR calculation process overview

Although the ATAR is a common Australia-wide measure, it is calculated differently by each jurisdiction. Eligibility criteria and scaling methods vary between jurisdictions<sup>5</sup>, and scaled results for subjects can be derived from raw subject results using linear transformations, equi-percentile mappings, or iterative methods like the one described in this document (see Chapter 3).

Raw results received from the QCAA are loaded by QTAC and checked through quality and data validation processes. Subject results and VET qualifications are loaded, and data are structured in a convenient format for the analysis. This includes combining school subjects and VET qualifications in one table, and converting letter grades used in subjects of Types 2 (as defined in Table 1) into numeric grades (A=90, B=70, C=50, D=30, E=10), to accommodate different grading systems.

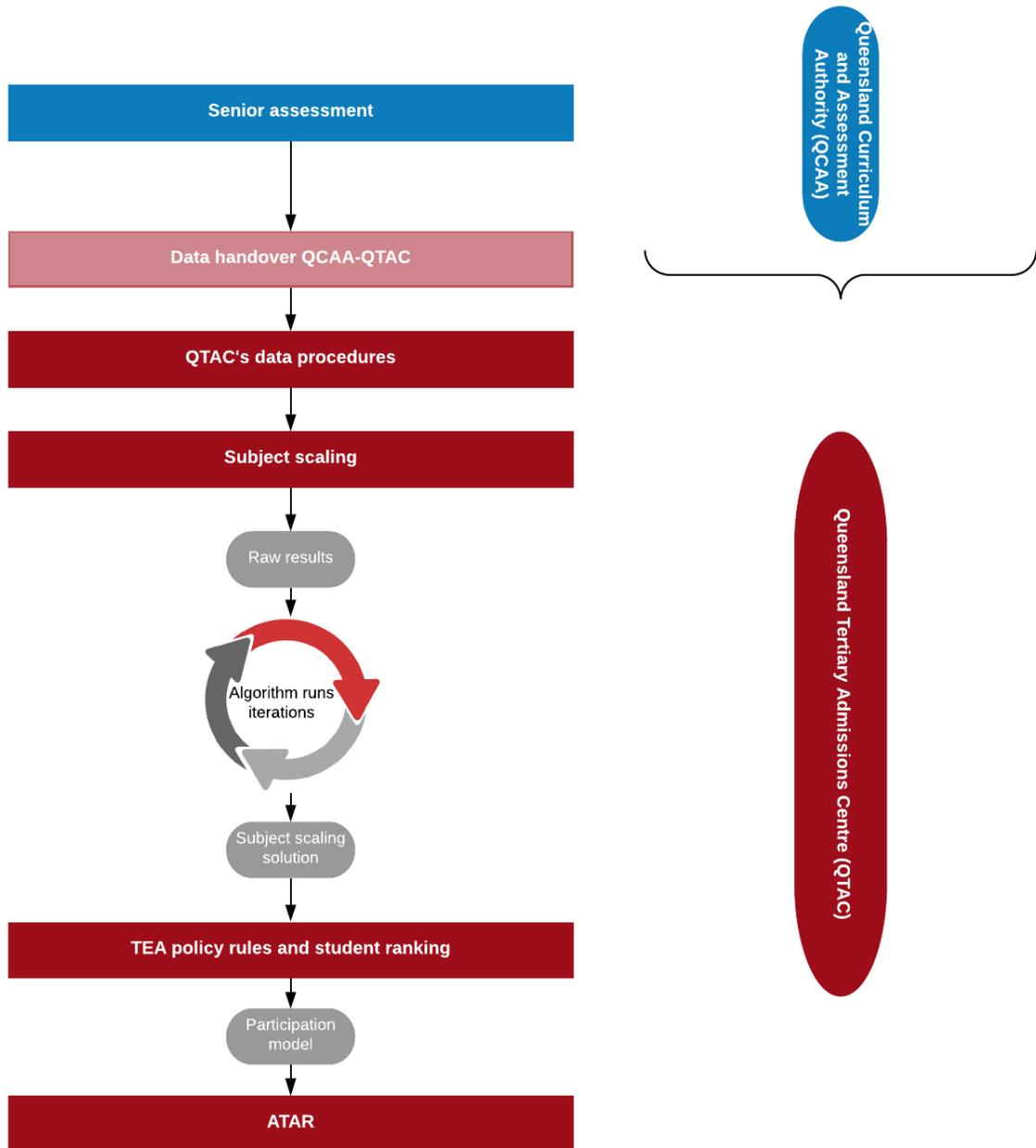
Figure 2 visually represents the end-to-end process of the calculation of the ATAR following receipt of the results from the QCAA.

Once students’ final polyrank is generated through the subject scaling process, rules over the ATAR eligibility and the composition of the Tertiary Entrance Aggregate (TEA) are applied. At this stage it is possible to order students by their overall ability and, applying the participation model, allocate them into ATAR bands (see Chapter 5).

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<sup>5</sup> Generally, all methods quantify the overall ability of students, use it to determine the subject scaled results, and *vice versa*.

Figure 2: Overview of the ATAR calculation process



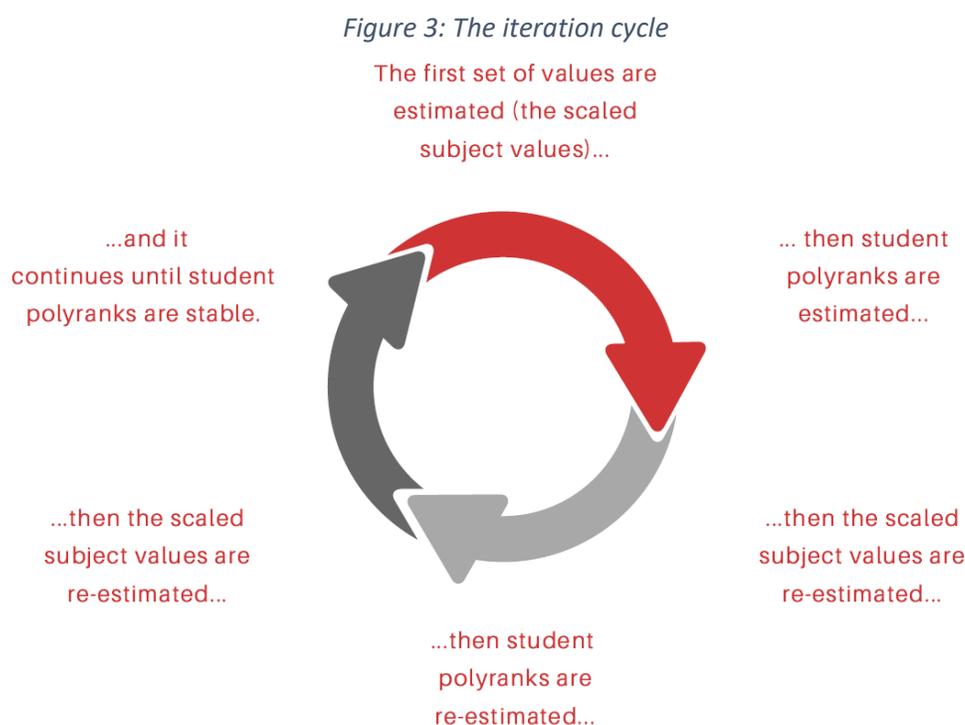
## 3 The inter-subject scaling process

### 3.1 Algorithm overview

The inter-subject scaling process is used to express subject results on the same scale, so that raw results achieved in two different subjects can be compared fairly. Scaled results are calculated for each subject and raw result, and they quantify the difficulty of achieving a particular raw result in a particular subject.

The algorithm processes all raw results from General subjects at Units 3 and 4, Applied subjects at Units 3 and 4, and completed AQF qualifications at Certificate III level and higher. At this stage, no eligibility rules relevant to the ATAR calculation are applied, therefore all Year 12 school results and completed VET qualifications are processed in the algorithm.

This subject scaling procedure belongs to a class of iterative methods, such as that outlined by Sympson (1993). The principle of this process is that it uses an initial set of scaled results and refines them, step after step, until a stable solution is found (Figure 3).



The implementation of this cycle of iterations is performed through an algorithm which estimates both the subject scaled results and the student polyranks until a convergence criterion is met. This stopping rule must be satisfied before the algorithm stops its iterations and provides the last solution of scaling outcomes.

A full description of the mathematical notation used to describe the subject scaling algorithm and formulas can be found in Appendix 1.

## 3.2 Initialisation

### 3.2.1 Subject scaled results

Subject scaled results are used by the algorithm to update student polyranks, and *vice versa*. This means that a first specification of “scaled results” must be provided to initiate the algorithm. The first step of the initialisation is to extract the counts  $N_{i,j}$  of all the students achieving a result  $j$  in a subject  $i$  (Table 2).

Table 2: Number of students achieving a result  $j$  in subject  $i$  (fictional example based on results ranging between 1 and 100)

Subject ( $i$ )	Result ( $j$ )	Students ( $N_{i,j}$ )
English	100	264
English	99	274
English	98	284
English	97	278
English	96	275
English	95	270
English	...	...
English	2	2
English	1	3

The first set of scaled results ( $r_{i,j,0}$ ) for each subject  $i$  and result  $j$  is then derived as percentile ranks:

$$r_{i,j,0} = \frac{1}{N_i} \left( \frac{N_{i,j}}{2} + \sum_{t=1}^{j-1} N_{i,t} \right) \quad (1)$$

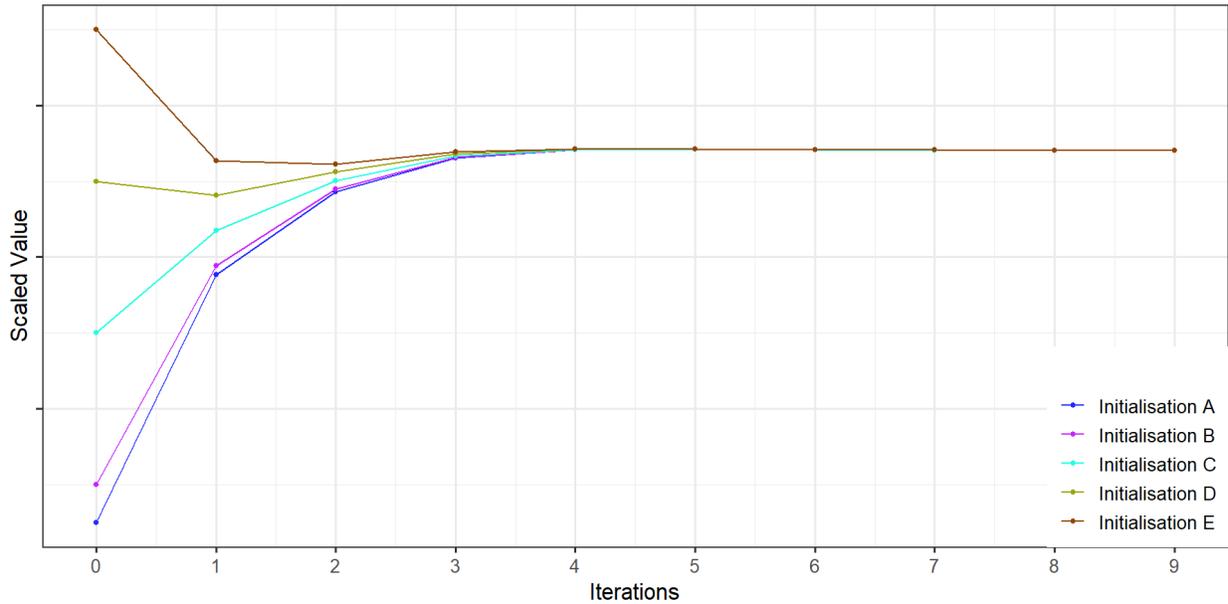
where  $N_i$  is the number of students who took subject  $i$ , and the results are ordered in every subject, so that  $j$  is always a better achievement than  $j - 1$ . Note that the first subject scores are not part of the iteration process of the algorithm, therefore they are indicated with the subscript 0 (“iteration zero”).

This generalisation can be extended to letter grades (A-E), given that they imply the order  $A > B > C > D > E$  <sup>6</sup>, however, this does not cover VET qualifications, which is treated as a binary variable, as shown in Table 1. This is because of the great variety of VET courses comprised within the same AQF levels from different VET providers and with different grading systems, which makes it difficult to compare them. For this reason, VET results are only able to be included in the calculations as a result that either exists or does not, with no indication of how well students achieved.

Consequently, VET qualifications are initialised with a default value, typically  $r_{i,0} = 0.5$ , provided that the school subject initialisation is informative (e.g. via percentile ranks). This is a safe practice, as the initial value of a VET qualification only contributes to the convergence trajectory, not the solution. A test of the assumption of this practice is shown in Figure 4, where different initial values were used in the algorithm”.

<sup>6</sup> For example, the percentile rank for  $j = A$  would be equal to:  $r_{i,A,0} = \frac{1}{N_i} \left( \frac{N_{i,A}}{2} + N_{i,B} + N_{i,C} + N_{i,D} + N_{i,E} \right)$ .

Figure 4: Convergence of a Diploma given different initialisations at  $m=0$



### 3.2.2 Student polyranks

The algorithm then uses  $r_{i,j,0}$  to get a first estimate of the students' polyranks as:

$$P_{s,0} = \frac{\sum_{i=1}^n \sum_{j \in J_i} (r_{i,j,0} I_{i,j,s})}{\sum_{i=1}^n \sum_{j \in J_i} I_{i,j,s}} \quad (2)$$

where  $J_i$  is the set of raw results for subject  $i$ , which depends on which inputs type  $i$  belongs to, as shown in Table 1, and  $I_{i,j,s}$  is an indicator function defined as:

$$I_{i,j,s} = \begin{cases} 1, & \text{if student } s \text{ achieved a result } j \text{ in subject } i \\ 0, & \text{otherwise} \end{cases}$$

In other words, the overall ability of a student is determined by the average of the scaled results of the subjects the student took. Once the set of polyranks  $P_{s,0}$  has been determined, students are ordered through an order rank  $k_{s,0}$ , which is used to generate a set of percentile ranks  $P'_{s,0}$  for students as:

$$P'_{s,0} = k_{s,0} / N, \quad (3)$$

where  $k_{s,0} = 1$  is the rank assigned to the student with the lowest polyrank, and  $k_{s,0} = N$  is the rank assigned to the student with the highest polyrank. As a result,  $P'_{s,0}$  ranges between 0 (excluded) and 1 (included), with higher values representing higher overall achievements.

Note that students with the same polyrank also have the same order rank and the same polyrank percentile rank. In case of ties, students are assigned the maximum rank between the set of competing ranks, as shown in Table 3.

Table 3: Students ordered by their polyranks

Student ( $s$ )	Polyrank ( $P_{s,0}$ )	Rank ( $k_{s,0}$ )	Percentile Rank ( $P'_{s,0}$ )
Sophie	98.72	51493	100.00 %
George	97.30	51492	99.998 %
Wei	96.65	51491 <sup>7</sup>	99.996 %
Javier	96.65		
Andrew	96.42	51489	99.992 %
Linh	96.30	51488	99.990 %
Lauren	96.26	51487	99.988 %
...	...	...	...
Anna	0.11	2	0.004 %
Nathan	0.08	1	0.002 %

### 3.3 Update process

Iterative algorithms, such as this, recalculate the estimates based on the previous iteration, progressively improving the estimates. In this case, student percentile ranks are estimated from the scaled subject results, then scaled subject results are used to estimate student polyranks<sup>8</sup>.

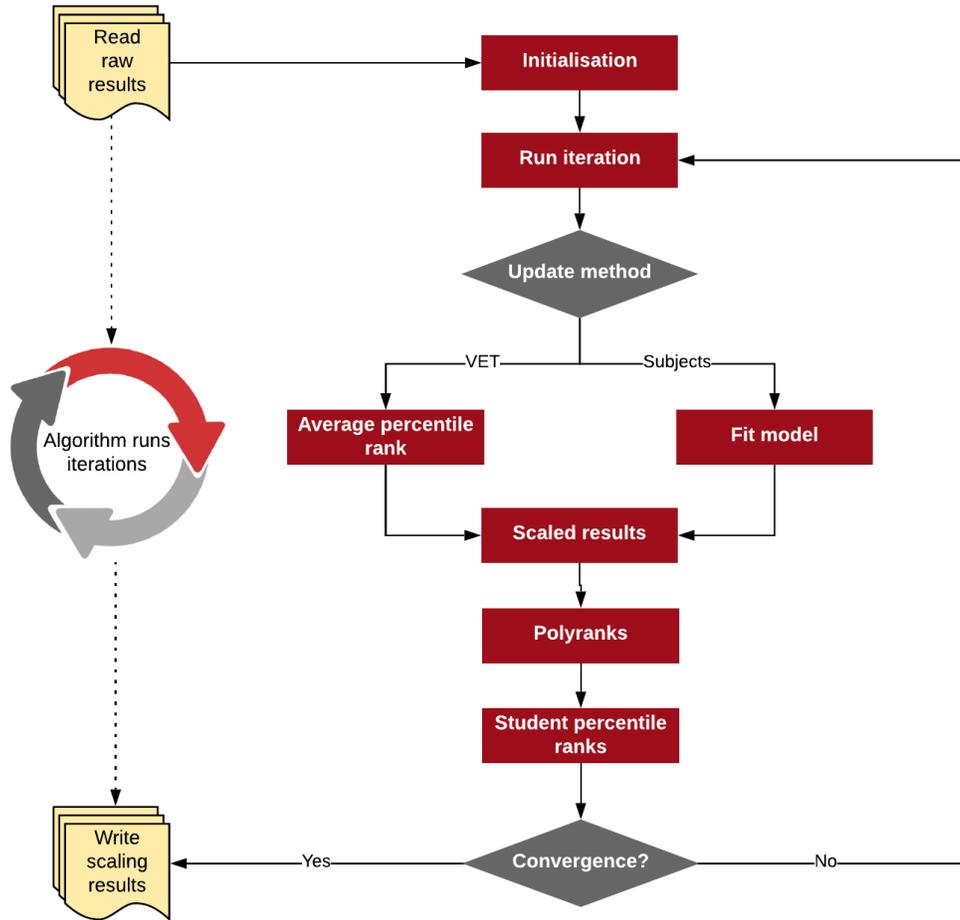
Figure 5 outlines the basic functioning of the algorithm. After initialising subjects studied at school and VET qualifications, student results are used to generate a new set of subject scores. The general principle is that the polyrank percentile ranks at a given step  $m$  of the algorithm ( $P'_{s,m}$ ) are used to determine the subjects scaled results for the next step ( $r_{i,j,(m+1)}$ ), via either a regression model (subjects), or a plain average (VET qualifications). Once scaled results are updated, they are used to derive a new set of polyrank percentile ranks ( $P'_{s,(m+1)}$ ).

After each iteration a decision rule is used to determine whether the algorithm should run another iteration or stop (at convergence). This is based on the change occurring in student polyranks from one iteration and the next (see 3.4).

<sup>7</sup> Maximum rank, in this example, is between 51491 and 51490.

<sup>8</sup> This calibration procedure has been referred to by various names including “reciprocal averages scaling” (Horst, 1935), “optimal scaling” (Bock, 1960), and “dual scaling” (Nishisato, 1980).

Figure 5: Algorithm Diagram



### 3.3.1 Updating the scaled results

A regression model is used for each school subject  $i$  and iteration  $m$ , to trace the relationship between raw results  $j$  and students' percentile ranks  $P'_{s,m}$ , and update the scaled results accordingly. The basic assumption is that a logit transformation of percentile ranks of students taking a subject  $i$  has a normal distribution, with  $\mu_{i,m}$  mean and  $\sigma_{i,m}$  standard deviation:

$$\text{logit}(P'_{s,m} I_{i,s}) \sim \text{Normal}(\mu_{i,m}, \sigma_{i,m}) \quad (4)$$

where  $I_{i,s}$  is an indicator function, defined as:

$$I_{i,s} = \begin{cases} 1, & \text{if student } s \text{ took subject } i \\ 0, & \text{otherwise} \end{cases}$$

Thus, a model for the mean  $\mu_{i,m}$  can be represented linearly as:

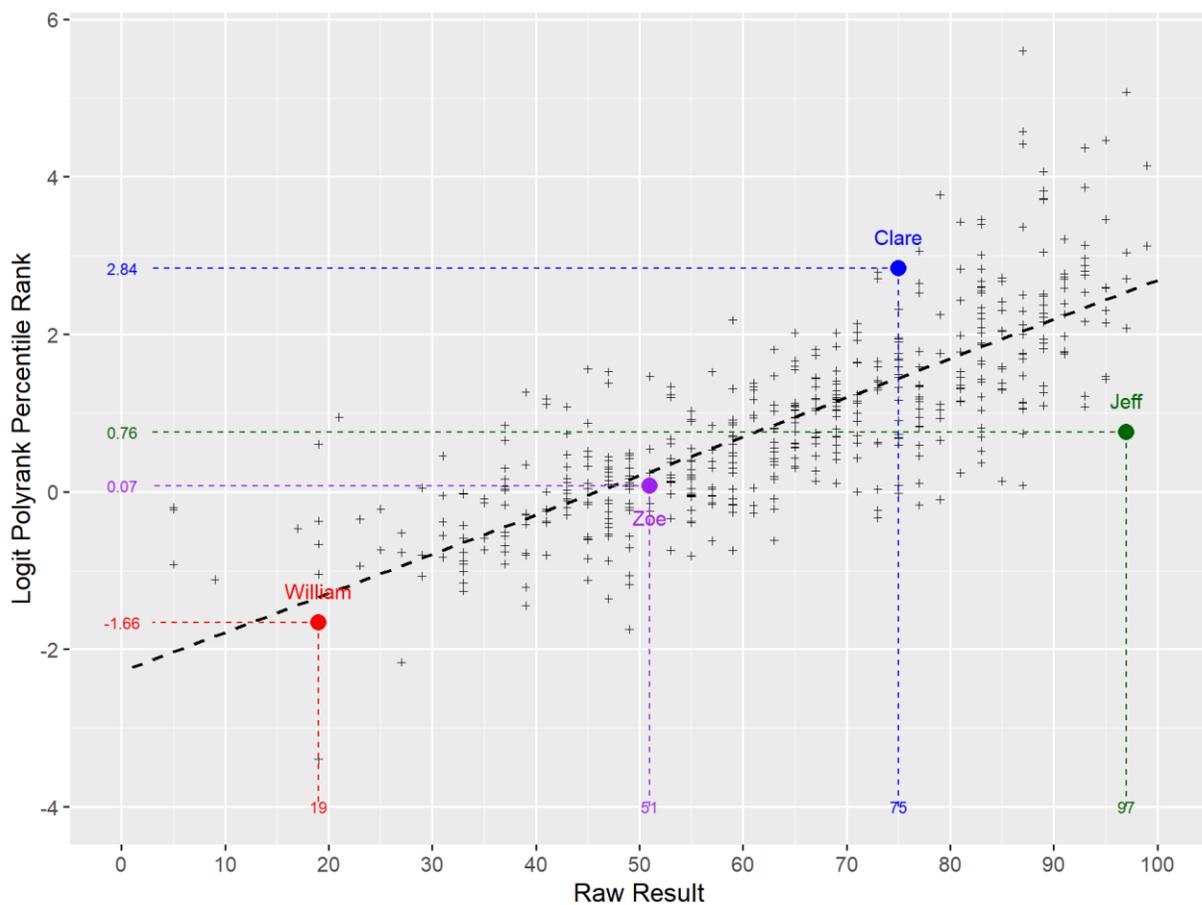
$$E[\mu_{i,m} | j] \approx \beta_{i,m,0} + \beta_{i,m,1} \times j = \eta_{i,j,m} \quad (5)$$

The coefficients  $\beta_{i,m,0}$  and  $\beta_{i,m,1}$  are estimated with the ordinary least squares (OLS) method, for each subject  $i$  and iteration  $m$  of the algorithm:

$$\hat{\beta}_{i,m} = \underset{\beta_{i,m}}{\operatorname{argmin}} \left( \sum_{s \in S} \sum_{j \in J_i} (\operatorname{logit}(P'_{s,m} I_{i,j,s}) - \eta_{i,j,m} I_{i,j,s})^2 \right) \quad (6)$$

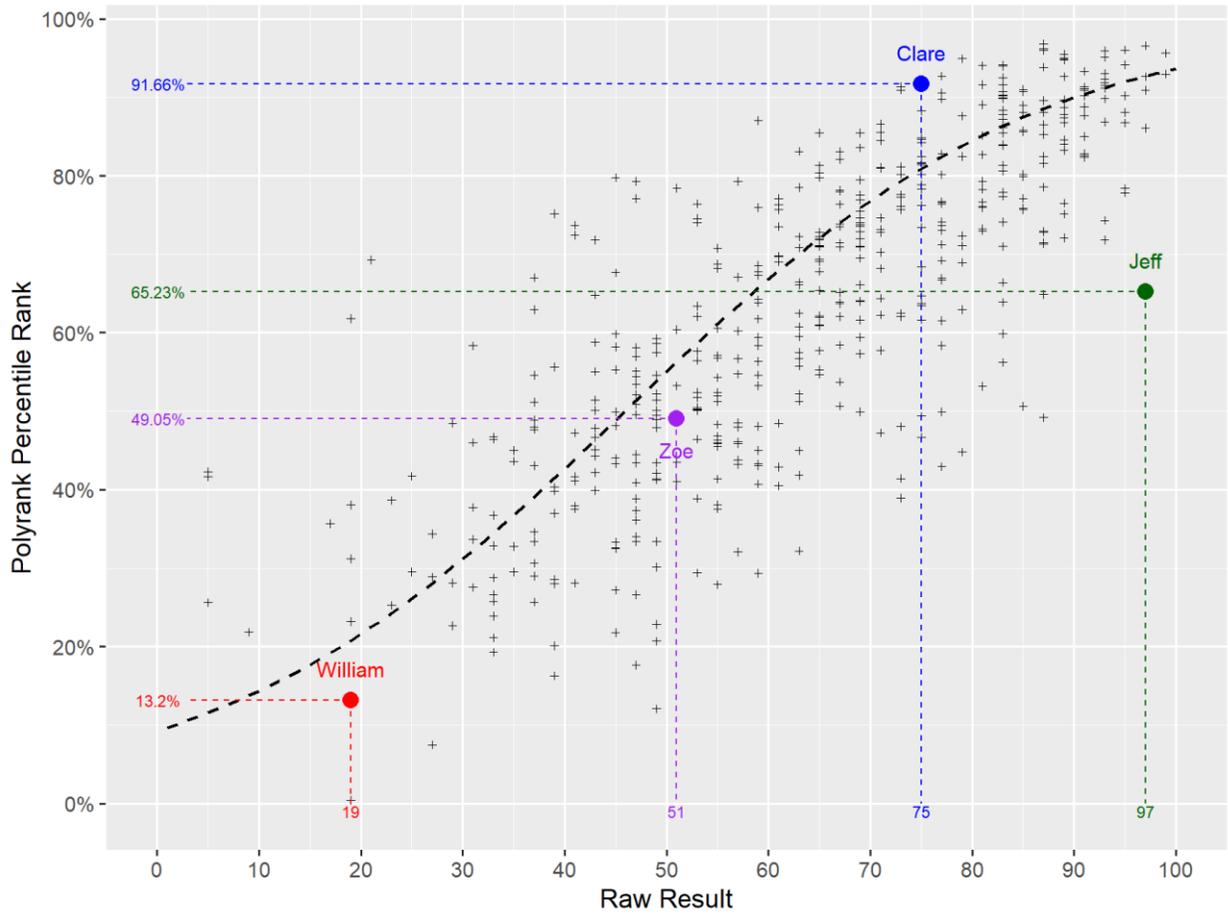
where  $S$  is the set of all  $s$  students with at least one valid result and  $I_{i,j,s}$  is the same indicator function defined for (2).

Figure 6: Linear model for a fictional subject  $i$  at a random iteration  $m$



A visual representation of (5) is given by Figure 6, where the logit-transformed percentile ranks  $P'_{s,m}$  of different students, and among those of the four highlighted fictional students, contribute to estimate the coefficients  $\hat{\beta}_{i,m}$ , used to derive the linear model fit  $\eta_{i,j,m}$ , represented by the dashed line. Scaled scores can then be updated using the inverse transformation  $\operatorname{logit}^{-1}(\eta_{i,j,m})$ . An example of this is provided in Figure 7.

Figure 7: Scaled result update at iteration  $m + 1$  for a fictional subject  $i$



When  $i$  is a VET qualification there is no model fit and the updated scaled results are just derived from an average of  $P'_{i,s,m}$ . Therefore, the solution at step  $m + 1$  is given by:

$$r_{i,j,(m+1)} = \begin{cases} e^{\eta_{i,j,m}} / (1 + e^{\eta_{i,j,m}}), & \forall i: T_i = 1 \vee T_i = 2 \\ \sum_{s \in S} (P'_{i,s,m} I_{i,s}) / \sum_{s \in S} I_{i,s}, & \forall i: T_i = 3 \end{cases} \quad (7)$$

### 3.3.2 Updating student percentile ranks

Updating students' percentile ranks requires applying (2) and (3) again using the updated scaled results  $r_{i,j,(m+1)}$  derived in 3.3.1:

$$P_{s,(m+1)} = \sum_i^n \sum_{j \in J_i} (r_{i,j,(m+1)} I_{i,j,s}) / \sum_i^n \sum_{j \in J_i} I_{i,j,s} \quad (8)$$

$$P'_{s,(m+1)} = k_{s,(m+1)} / N \quad (9)$$

where  $k_{s,(m+1)}$  is the order of students by ascending order at step  $(m + 1)$ , as described in 3.2.2.

### 3.4 Convergence criterion

The algorithm iterates, refining subject scaled results and student rankings. The convergence criterion (or stopping rule) is based on a minimax-style criterion (widely used in decision theory). In this case, the convergence is evaluated through the maximum change of polyrank percentile ranks between two consecutive steps  $m$  and  $m + 1$ :

$$\max |P'_{s,m} - P'_{s,(m+1)}| < \varepsilon_{(m+1)} \quad (10)$$

where  $\varepsilon_{(m+1)}$  is a small positive quantity which can be seen as a tolerance value, used to set a threshold for convergence. Usually, after a sufficient number of iterations  $M$ , this difference becomes equal to zero, meaning that the solution is fully calibrated.

The number of iterations  $M$ , needed to reach a convergence might vary based on the number of students, subject combinations, and other factors.

The change in polyrank percentile ranks between iterations can be monitored to determine a cut off level, in case a full convergence cannot be reached. Since  $P'_{s,m}$  and  $P'_{s,(m+1)}$  are determined from the student ranks  $k_{s,m}$  and  $k_{s,(m+1)}$ , the threshold can be expressed in terms of swing of positions<sup>9</sup>, as shown in Table 4.

Table 4: Fictional example based on 50,000 students

Maximum swing	$\varepsilon_{(m+1)}$
±1	± 0.002%
±2	± 0.004%
±3	± 0.006%
±4	± 0.008%
±5	± 0.01%

When the convergence criterion is met, the iteration process ceases, and a final set of scaled scores  $r_{i,j,M}$  and student percentile ranks  $P'_{s,M}$  are returned.

<sup>9</sup> The maximum swing of positions is equal to  $\max |k_{s,m} - k_{s,(m+1)}|$ , or simply  $N \times \varepsilon_{(m+1)}$ .

## 4 Eligibility and Aggregate Composition

When calculating a final percentile rank polyrank  $P'_{s,M}$  for each student  $s$  we must consider which students are eligible for an ATAR and how a Tertiary Entrance Aggregate (TEA) should be composed for them.

A full description of the mathematical notation used to describe the composition of the TEA and the ATAR allocation (chapter 5) can be found in Appendix 2.

### 4.1 Eligibility Criteria

To be eligible for an ATAR, a Queensland student must comply with the following ATAR eligibility criteria.

#### 4.1.1 English Subject Requirement

Successful completion of an English subject is a mandatory requirement for the award of an ATAR. Students are required to successfully complete (i.e. be awarded a raw letter grade of “C” or better) in one of the following QCAA English subject offerings:

- English
- English as an Additional Language
- Literature
- English & Literature Extension
- Essential English

While successful completion of an English subject is a mandatory requirement for ATAR eligibility, there are no mandatory subject inclusions for the ATAR. For example, a student with English, two mathematics subjects and three science subjects, may have their ATAR calculated exclusively from the two mathematics subjects and three science subjects if this provides for their highest possible ATAR.

#### 4.1.2 Subject Inclusion and Eligibility Schemes

The ATAR can be calculated on the basis of three different schemes:

- 5 General subjects at Units 3&4; or
- 4 General subjects at Units 3&4 and 1 Applied subject at Units 3 and 4; or
- 4 General subjects at Units 3&4 and 1 completed VET qualification at AQF Certificate III level or higher.

Students who might be eligible with more than one scheme, or students who might be eligible for the same scheme with more than one combination of subjects<sup>10</sup>, will be awarded ATARs on the basis of the combination ensuring the maximum final percentile rank  $P'_{s,M}$ , or TEA (see 4.2).

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<sup>10</sup> E.g. students with an attainment in 6 General subjects, or 4 General subjects and 2 Applied subjects, etc.

Subjects that will not feature in the ATAR calculations include:

- short course subjects (e.g. Short Course in Literacy, Short Course in Numeracy)
- subjects from the International Baccalaureate Diploma
- secondary subjects from interstate or overseas jurisdictions
- VET qualifications at Certificate I or II level
- Incomplete VET qualifications
- Single unit tertiary subjects
- Music, dance and other performing arts qualifications

### 4.1.3 Accumulating Results

Most students are expected to follow a traditional pattern of accumulating their results over two years of study in Grades 11 and 12. However, ATARs can be calculated based on results attained from within five consecutive years. At the extreme, one eligible subject per year, over five years, would qualify a student for an ATAR<sup>11</sup>.

Inclusion of previous years' results are banked by QCAA, for the 4-year period prior to 2020, and by QTAC from 2020. Where a student has repeated a subject, the most recent scaled result will be used in the calculation of the ATAR.

### 4.1.4 Precluded Subject Combinations

Study patterns and subject combinations will be monitored by QTAC each year. Although generally there are no restrictions on the combinations of subjects that a student might choose to undertake, some exceptions are made for the following combinations of subject results:

- a) Only General English subjects or Applied English subjects can be included in a student's ATAR, but not both (e.g. English and Essential English);
- b) Only General Mathematics subjects or Applied Mathematics subjects can be included in a student's ATAR, but not both (e.g. Mathematical Methods and Essential Mathematics);
- c) Only one result for the same subject taken as a General subject or via the Senior External Examination can be included in a student's ATAR (e.g. it is not possible to include results from both the General subject Chinese and the Senior External Examination subject Chinese in a student's ATAR. Similarly, it is not possible to include results from both the General subject Biology and the Senior External Examination subject Biology in a student's ATAR).

There are no other restrictions on the inclusion of the subjects in the ATAR. For example, a student may include both English and Literature, or both Mathematical Methods and Specialist Mathematics, or both Chinese and Chinese Extension.

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<sup>11</sup> These rules are particularly relevant for the calculation of ATARs for Repeat and Variable Progression Rate (VPR) students.

## 4.2 TEA Composition

The Tertiary Entrance Aggregate (TEA) is composed of the best five scaled results per student, after all the eligibility criteria outlined in 4.1 have been applied. This is the final score used for the allocation of students into ATAR bands. Since a student might have more than one allowed combination of subjects to generate a TEA, before calculating an aggregate  $R_s$  for all ATAR eligible students  $S^*$ , we must determine their best combination out of the  $n_s$  results they achieved.

Let  $U_{z_s}$  be the  $z$ -th set of five allowed inputs  $i$  for a student  $s$ , where  $z_s \in [1, \dots, Z_s]$  and  $Z_s$  is the number of allowed combinations each student has. Any potential TEA for each of these combinations is equal to:

$$R_{U_{z_s}} = \sum_{i=1}^n \sum_{j \in J_i} r_{i,j,M} I_{i,j,S} I_{i \in U_{z_s}} \quad (11)$$

where

$$I_{i \in U_{z_s}} = \begin{cases} 1, & \text{if } i \in U_{z_s} \\ 0, & \text{otherwise} \end{cases}$$

The best TEA for each ATAR eligible student  $s \in S^*$  is then given by:

$$R_s = R_{\tilde{U}_{z_s}} = \sum_{i=1}^n \sum_{j \in J_i} r_{i,j,M} I_{i,j,S} I_{i \in \tilde{U}_{z_s}} \quad (12)$$

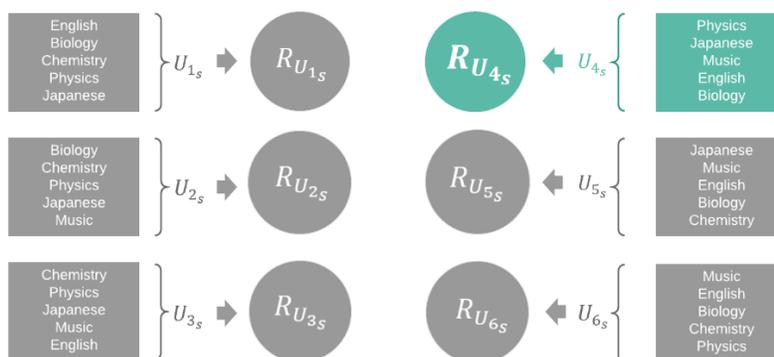
where

$$\tilde{U}_{z_s} = \operatorname{argmax}_{U_{z_s}} (R_{U_{1_s}}, R_{U_{2_s}}, \dots, R_{U_{z_s}})$$

$$I_{i \in \tilde{U}_{z_s}} = \begin{cases} 1, & \text{if } i \in \tilde{U}_{z_s} \\ 0, & \text{otherwise} \end{cases}$$

For students having only five valid results (11) and (12) are equivalent. When more results are available, all the permitted combinations must be looked at, in order to choose the combination generating the highest TEA. Seven results would generate up to 21 combinations, eight results would generate up to 56 combinations, and so on<sup>12</sup>. Figure 8 shows a visual example for a student with six General subjects, and the six possible combinations that should be compared.

Figure 8: Example for a student with six results (English, Biology, Chemistry, Japanese, Music and Physics), showing all the possible combinations ( $U_{1_s}, U_{2_s}, U_{3_s}, U_{4_s}, U_{5_s}, U_{6_s}$ ) and TEAs  $R_{U_{1_s}}, R_{U_{2_s}}, R_{U_{3_s}}, R_{U_{4_s}}, R_{U_{5_s}}, R_{U_{6_s}}$ . In this fictional case, the combination generating the maximum TEA is highlighted in green ( $\tilde{U}_{z_s} = U_{4_s}$ ).



<sup>12</sup> The number of allowed combinations for student  $s$  is  $Z_s \leq \binom{n_s}{5} = \frac{n_s!}{(n_s-5)! 5!}$ .

From a practical point of view, sorting all the results achieved by each student in descending order in most cases results in the best five results, although the presence of other rules may overturn the selection of some inputs. For this reason, the determination of the best five results for each student is not always straightforward<sup>13</sup>.

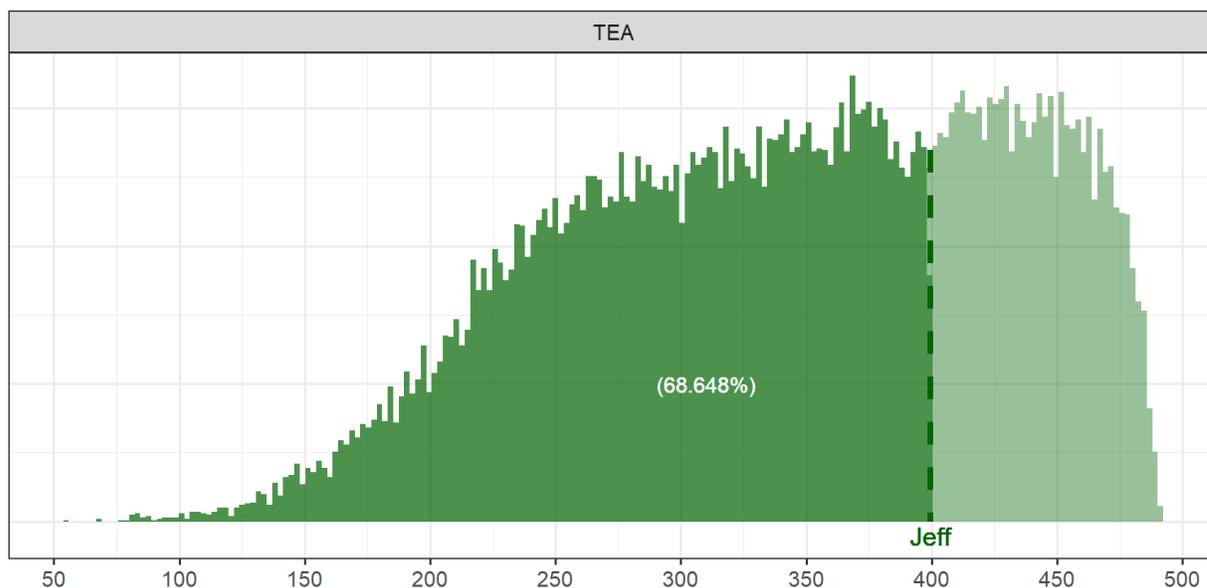
The TEA is finally reported in its 500-point scale format to two decimal places, as shown in Table 5.

Table 5: Students ordered by their percentile rank and TEA

Student (s)	Percentile rank ( $P'_{s,M}$ )	TEA ( $R_s$ )
Sophie	100.00 %	491.51
George	99.998 %	491.30
Wei	99.996 %	490.77
Javier	99.992 %	490.74
Andrew	99.992 %	490.74
...	...	...
Jeff	68.648 %	399.56
...	...	...
Anna	0.004 %	68.72
Nathan	0.002 %	55.11

A visual representation of the relationship between  $P'_{s,M}$  and  $R_s$  is given in Figure 9.

Figure 9: TEA and Percentile rank of student Jeff



<sup>13</sup> For example, a rule based on the count of General subjects can prevent from choosing an Applied subject over a General subject, in case of a precluded subject combination (4.1.4), when the remaining General subjects for a student is less than four.

## 5 ATAR Allocation

The subject scaling outputs are used to determine a measure of “overall performance” of students and an order rank, something which can be achieved by averaging the best five scaled results, or summing them into an aggregate, as described in 4.2. Allocating students into ATAR bands involves assigning all TEAs into bands, according to specified criteria.

As each jurisdiction uses different eligibility rules and subject scaling methods, Queensland’s scaled scores and TEAs cannot be compared directly to those of other jurisdictions. The ATAR however, is designed to be an Australian standard rank for tertiary admissions, and ATAR bands form a basis of comparison of overall student achievement across different states. In order to achieve this, ATARs are calculated using the entire potential Year 12 population as a base (see 5.1).

In terms of allocation, this means distributing the appropriate number of students in each band, including those who did not qualify for an ATAR, and students who were not captured in the Year 12 data. But rather than expanding the number of students at a constant rate across the ATAR bands, the number of places to be allocated are reshaped through a model using the assumption that “the higher the band, the higher the probability that a student is ATAR eligible” (see 5.2).

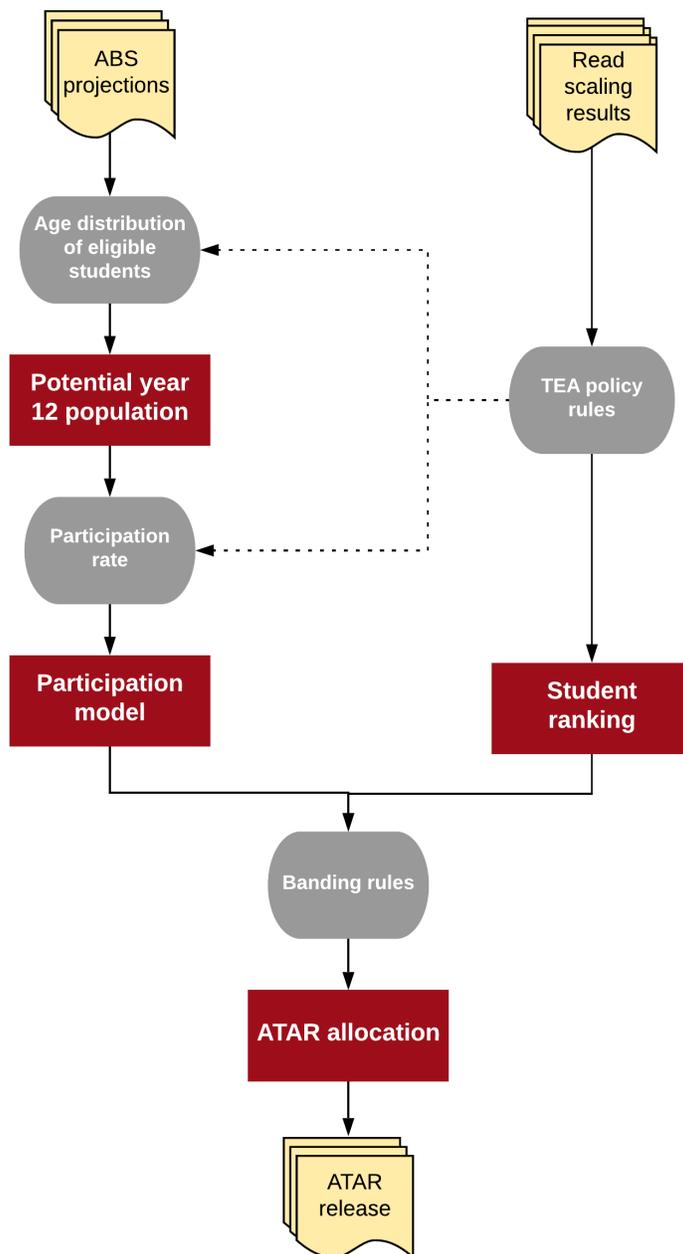
The final part of the process is the allocation of students into bands. A defined procedural rule is used to allocate students. The number of places that should theoretically be allocated is never exceeded using a decision rule referred to as “cumulative constraint” (see 5.3). The implementation of the cumulative constraint is particularly helpful to guide the allocation when the number of theoretical places include decimal points, and especially when there are students achieving the same TEA. This situation occurs when more than one student has a TEA composed from the same combination of subjects and raw results, or when the combination is substantially equivalent<sup>14</sup>.

A visual representation of the process is given by Figure 10. The inter-subject scaling results (Chapter 3) and the auxiliary data of Queensland projected population are both inputs to the ATAR allocation. The definition of the TEA policy rules (Chapter 4) dictates how the scaled results are combined (as indicated by the solid line) but it also defines some parameters used to derive the potential Year 12 population and the participation model (as indicated by the dash lines).

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<sup>14</sup> TEAs are rounded to two decimal places. Any difference at a lower order is not used to discriminate students.

Figure 10: Overview of the ATAR allocation process



## 5.1 Potential Year 12 Population

While TEAs or students' overall ability scores are not directly comparable across different states, each jurisdiction's distribution of their "students' ability" is assumed to be the same. Under this construct, the top 5% of students in Queensland, for example, are considered equally able to the top 5% students in any other jurisdiction. This assumption makes it possible to compare ATARs from different states, provided they use the Year 12s as their base population to allocate students into ATAR bands.

The potential Year 12 population for Queensland ( $Y$ ), is derived from Queensland's Year 12 residents ( $Q$ ) according to the Australian Bureau of Statistics' (ABS) population projections<sup>15</sup>, and the age distribution of the ATAR eligible students ( $E$ ).

As the ABS reports, "the projections are not predictions or forecasts, but are simply illustrations of the growth and change in population which would occur if certain assumptions about future levels of fertility, mortality, overseas migration and internal migration were to prevail over the projection period. The assumptions are formulated on the basis of demographic trends seen in past data".

The ABS projections of a given year are provided as counts of residents per age and gender composition. The age distribution of the ATAR eligible students is used to derive a weighted average of the ABS projected residents aged 16-20 as:

$$Y = \sum_{g=16}^{20} Q_g \left( \frac{E_g}{\sum_{g=16}^{20} E_g} \right) \quad (13)$$

where  $Q_g$  is the number of Queensland's projected population of age  $g$ , and  $E_g$  is the number of Queensland's ATAR eligible students of age  $g$ . Therefore, the weighted population  $Y$  is mostly influenced by the ABS projections relative to the most observed ages  $g$  in the ATAR eligible population (currently 16-17). The potential Year 12 population is designed in such a way to include people who:

- qualified for an ATAR;
- continued at school, but were not eligible for an ATAR;
- completed their senior years through TAFE or another VET provider; or
- left school before the end of Year 12, for example, to enter the workforce.

## 5.2 Participation Model

The participation model provides an estimate of the achievement of the senior student population within the state-wide population. In other words, it estimates the achievement of students at school compared to the overall population, including those not at school, and ranks them within this population.

To determine a participation model, various data sources can be used, including historical data or results from tests sat by students in early secondary school. Previously, Queensland used a model derived from NSW school performance data, providing an achievement score for Year 10 students, and whether they continued to Year 12 or not. This is the same model that other jurisdictions have also used in the past<sup>16</sup>.

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<sup>15</sup> E.g. ABS Catalogue Number [3222.0](#) "Population Projections, Australia, 2017 (base) – 2066".

<sup>16</sup> Most states in the last 18 years have modelled the participation curve using a two-parameter logistic function proposed by Professor Tim Brown. This is the model used in Queensland under the OP system, and it is parametrised by a participation rate and a 50% participation mark representing the rank at which approximately half of the population is participating in senior schooling, from the NSW Year 10 student scores distribution.

In 2014 the Australasian Conference of Tertiary Admission Centres (ACTAC) advocated to change this model. Among ACTAC’s reasons was that the logistic model had been used with subjectivity and lack of uniformity, and that in some jurisdictions, annual data used for calculating the Interstate Transfer Index (ITI) became unavailable.

The participation model that will be used in Queensland from 2020 is the model introduced by Harrison and Hyndman (2015), based on a one-parameter family of cubic splines (see 5.2.2). As the name suggests, the model is shaped by only one parameter (the participation rate), which defines the curve to be used.

This is also the model currently used by all other jurisdictions in Australia. The participation rate is calculated annually using a standard procedure (see 5.2.1).

### 5.2.1 Participation Rate

The participation rate varies substantially between states for historical and demographical reasons. For example, Western Australia’s participation rate is traditionally low compared to rates in Victoria and New South Wales. The Overall Participation Rate (*OPR*) is defined in each jurisdiction as the ratio between the total number of ATAR eligible candidates and the total weighted population previously calculated in (13):

$$OPR = \frac{\sum_{g=16}^{20} E_g}{Y} = \frac{E}{Y} \quad (14)$$

where,  $E$  is the sum of all ATAR eligible students aged 16-20 ( $E_{16}, \dots, E_{20}$ ), and  $Y$  is the potential Year 12 population defined in 5.1.

### 5.2.2 Participation Curve

Within the context of the one-parameter cubic splines family model, participation rates account for the ability of students to be ATAR eligible, over the potential Year 12 population. This proportion dictates how sharp is the increase of the participation curve, and ultimately, how many places should be allocated (ie reserved) to ATAR eligible students in each band.

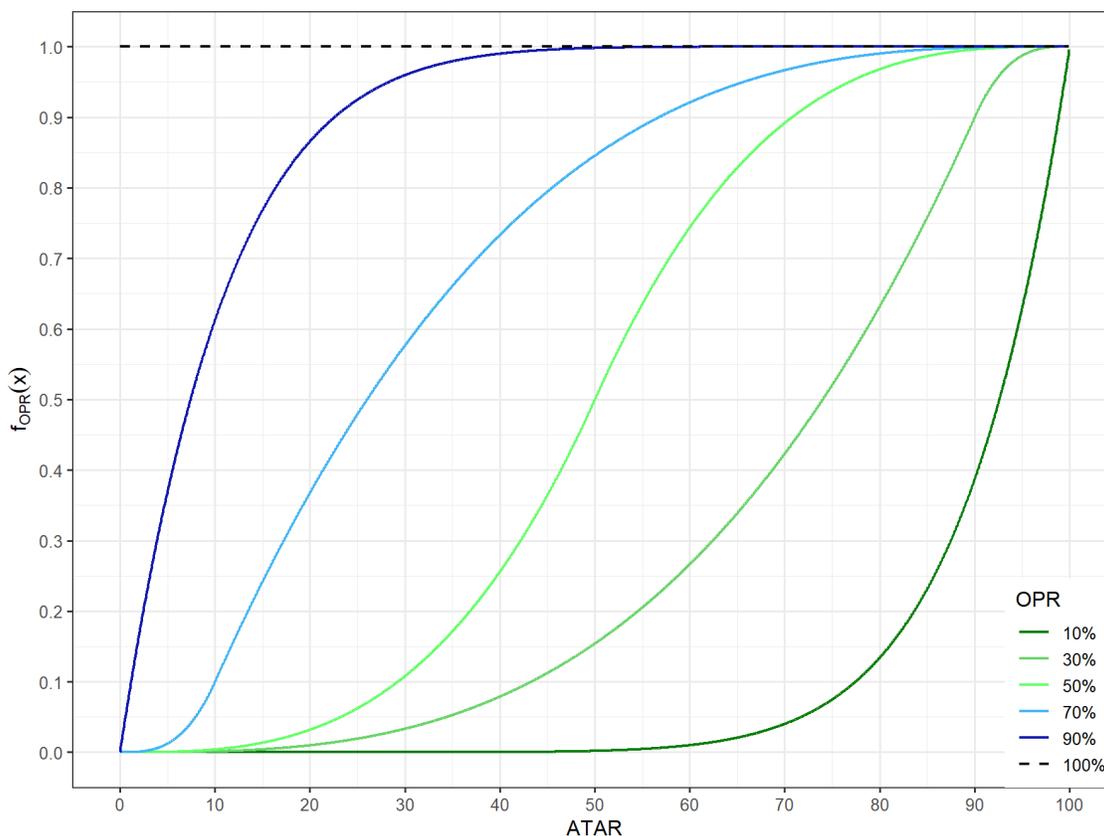
The main assumption is that the probability that a student is ATAR eligible increases with the student’s ability. Therefore, the model reserves more high-ATAR places to eligible students, while reserving low-ATAR places mostly to non-eligible students. The participation curve is defined as:

$$f_{OPR}(x) = \begin{cases} x^{(1-OPR)/OPR}, & OPR < 0.25 \\ 1 - (1 - x)^{OPR/(1-OPR)}, & OPR > 0.75 \\ x^3 / \alpha^2, & (0.25 \leq OPR \leq 0.75) \wedge (0 \leq x \leq \alpha) \\ 1 - (1 - x)^3 / (1 - \alpha)^2, & (0.25 \leq OPR \leq 0.75) \wedge (\alpha \leq x \leq 1) \end{cases} \quad (15)$$

where  $\alpha = 1.5 - 2 OPR$ , and  $x$  is the proportion ranking of a student within the ATAR eligible population, which can be seen as  $x = ATAR/100$ . On the other hand,  $f_{OPR}(x)$  is the proportion ranking of a student within the total cohort of potential Year 12s, and from a practical point of view, it can be seen as the probability of being ATAR eligible at any given  $x$ .

Figure 11 shows a visual sample of such family of curves, whose shape depends on the *OPR*.

Figure 11: Participation curve at different overall participation rates



Overall, the curves are continuous and monotonically increasing, and the area under each of them is equal to the participation rate:  $\int_0^1 f_{OPR}(x) dx = OPR$ . The value of the participation curves is equal to zero for  $x = 0$ , and equal to one for  $x = 1$ . Practically, this means that all places at an ATAR band of 99.95 will be reserved to ATAR eligible students, and all places at an ATAR band of 0 will be reserved entirely to ineligible students, while leaving a number of places available to a mix of eligible and ineligible students in all other bands. The number of places to be allocated to either one or the other set of students is ultimately determined by the participation rate.

For example, if the participation rate was 100%, the proportion of allocations to be reserved to eligible students would be equal to 1 for all ATAR bands. Under this scenario, all the potential Year 12 population is also ATAR eligible, therefore all  $Y/2000$  places per band<sup>17</sup> are reserved to ATAR eligible students, because there are no other persons to consider (school leavers, ATAR ineligible students, etc). Conversely, if the participation rate was 0%, this would mean that there are no ATAR eligible students at all, therefore their allocation should be equal to 0 for all bands.

<sup>17</sup> The number of places to be allocated to either eligible or ineligible students is equal to the size of the potential Year 12 population on the number of ATAR bands. This fraction is referred to as ATAR Band Constraint.

For mid-range participation rates ( $25\% \leq OPR \leq 75\%$ ), the curves are cubic spline functions, with a single knot at  $x = \alpha$ , and a sigmoid shape. Similarly to the logistic participation curve, values of participation tend to be very similar for values of  $x$  in the proximity of  $x = 1$  ( $f_{OPR}(x) = 1$ ) and values in the proximity of  $x = 0$  ( $f_{OPR}(x) = 0$ )<sup>18</sup>. For very low or very high participation rates ( $OPR < 25\%$  or  $OPR > 75\%$ ) the model assumes other functional forms.

### 5.3 Cumulative Constraint and Allocation to Bands

The total number of students to be theoretically allocated in each ATAR band ( $A_b$ ) can now be calculated by multiplying  $f_{OPR}(x)$  and the ATAR Band Constraint ( $h$ ):

$$A^*_b = f_{OPR}(x) \times h = f_{OPR}(x) \times \frac{Y}{2000} \quad (16)$$

where  $f_{OPR}(x)$  is the value of participation model for each ATAR band defined in 5.2.2, and  $Y$  is the potential Year 12 population defined in 5.1.

When allocating students into ATAR bands,  $h$  is converted into a cumulative constraint. This means that the cumulative number of places that can be allocated between 99.95 and any given band  $b$ , can never exceed the theoretical cumulative number of places available:

$$\sum_b^{99.95} A_b \leq \sum_b^{99.95} A^*_b, \quad (17)$$

where  $A^*_b$  is the theoretical allocation according to (16) and  $A_b$  is the actual allocation of students at each ATAR band, based on their aggregates and the cumulative constraint.

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<sup>18</sup> For  $0.25 \leq \alpha \leq 0.75$  the derivative function  $f_{OPR}(x)$  for both  $x = 0$  and  $x = 1$  tends to zero:  
 $\lim_{x \rightarrow 0 \vee x \rightarrow 1} \frac{\delta f_{OPR}(x)}{\delta(x)} = 0.$

## 6 Appendices

### APPENDIX 1: Inter-subject Scaling Notation

Notation	Description	Domain
$i$	School Subject or VET index	$i \in [1, \dots, n]$
$j$	Raw Result	$j \in J_i$
$n$	Total number of school subjects or VET qualifications	$n \in \mathbb{N}$
$n_s$	Number of school subjects or VET qualifications taken by a student $s$	$n_s \in n$
$T_i$	Result Type of subject $i$	$T_i \in [1, 2, 3]$
$J_i$	Set of possible raw results $j$ , given subject $i$	$J_i = \begin{cases} 1, \dots, 100, & \text{if } T_i = 1 \\ A, B, C, D, E, & \text{if } T_i = 2 \\ \emptyset, & \text{if } T_i = 3 \end{cases}$
$s$	Student index	$s \in S$
$S$	Set of all students with at least one valid result	$N$ categorical modes
$S^*$	Set of all ATAR eligible students	$S^* \in S$
$N$	Total number of students with at least one valid result	$N \in \mathbb{N}$
$N_i$	Total number of students with a valid result in subject $i$	$N_i \in \mathbb{N}$
$N_{i,j}$	Total number of students with a result $j$ in a subject $i$	$N_{i,j} \in \mathbb{N}$

<b>Notation</b>	<b>Description</b>	<b>Domain</b>
$m$	Iteration index	$m \in \{1, \dots, M\}$
$M$	Number of iterations required for convergence	$M \in \mathbb{N}$
$P_{s,m}$	Score of student $s$ at the $m$ -th iteration	$P_{s,m} \in \mathbb{R}^+$
$k_{s,m}$	Rank of student $s$ at the $m$ -th iteration	$k_{s,m} \in \{1, \dots, N\}$
$P'_{s,m}$	Polyrank Percentile Rank of student $s$ at the $m$ -th iteration	$P'_{m,s} \in (0,1]$
$r_{i,j,m}$	Scaled score of $(i, j)$ at the $m$ -th iteration	$r_{i,j,m} \in \mathbb{R}^+$
$\beta_{i,m}$	Model Coefficients for subject $i$ at the $m$ -th iteration	$\beta_{i,m} \in \mathbb{R}$
$\eta_{i,m}$	Linear model prediction for subject $i$ at the $m$ -th iteration	$\eta_{i,m} \in \mathbb{R}$

## APPENDIX 2: TEA and ATAR Allocation Notation

Notation	Description	Domain
$i$	School results or VET index	$i \in [1, \dots, n]$
$n$	Total number of school subjects or VET qualifications	$n \in \mathbb{N}$
$n_s$	Number of school subjects or VET qualifications taken by a student $s$	$n_s \in n$
$z_s$	$z$ -th valid combination of subjects for student $s$	$z_s \in [1, 2, \dots, Z_s]$
$Z_s$	Number of valid combinations for student $s$	$Z_s \in \mathbb{N}$
$U_{z_s}$	Set of subjects included in the $z$ -th combination for student $s$	$U_{z_s} \in [i^{(1)}, \dots, i^{(5)}]$
$\tilde{U}_s$	Best combination of five inputs for student $s$	$\tilde{U}_s \in [i^{(1)}, \dots, i^{(5)}]$
$R_{U_{z_s}}$	Potential TEA for combination $U_{z_s}$	$R_{U_{z_s}} \in \mathbb{R}^+$
$R_s$	Actual TEA of student $s$	$R_s \in \mathbb{R}^+$
$g$	Age	$g \in \{16, 17, 18, 19, 20\}$
$E$	Number of ATAR Eligible Students	$E \in \mathbb{N}$
$E_g$	Number of ATAR Eligible Students of age $g$	$E_g \in \mathbb{N}$
$Q_g$	ABS projected Queensland residents of age $g$	$Q_g \in \mathbb{N}$
$Y$	Potential Year 12 Population	$Y \in \mathbb{N}$

Notation	Description	Domain
$OPR$	Overall Participation Rate	$OPR \in (0,1] \in \mathbb{Q}^+$
$x$	Proportion rank of ATAR-eligible students	$x \in (0,1]$
$f_{OPR}$	Participation Model	$f_{OPR} \in \mathbb{R}^+$
$\alpha$	Scale parameter and knot of $f_{OPR}$ for $25\% \leq OPR \leq 75\%$	$\alpha \in \mathbb{Q}^+$
$h$	ATAR Band Constraint	$h \in \mathbb{Q}^+$
$b$	ATAR band	$b \in [0, 0.05, \dots, 99.95]$
$A^*_b$	Theoretical Number of ATAR eligible students to be allocated in band $b$ according to the participation model	$A^*_b \in \mathbb{N}$
$A_b$	Number of ATAR eligible students allocated in band $b$	$A_b \in \mathbb{N}$

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# CALCULATING THE ATAR IN QUEENSLAND – TECHNICAL DOCUMENT

Version 1.2

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