# Identifying and Supporting Quantitative Skills of 21st Century Workers

## QUANTITATIVE SKILLS MAP

aamt
THE AUSTRALIAN ASSOCIATION OF MATHEMATICS TEACHERS INC.

AUSTRALIAN INDUSTRY GROUP

Identifying and Supporting Quantitative Skills of 21st Century Workers:
Quantitative Skills Map



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**Publisher**

The Australian Association of Mathematics Teachers (AAMT) Inc.
GPO Box 1729 Adelaide SA 5001
08 8363 0288
office@aamt.edu.au

The Australian Association of Mathematics Teachers Inc.
www.aamt.edu.au

Australian Industry Group
http://www.aigroup.com.au

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## Reference Group

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# 1. The Purpose and Structure of the *Quantitative Skills Map*

The *Quantitative Skills Map* has been drawn from the Case Study research and identifies some common mathematical skills that are expected for non-graduate workers.

The research identified that mathematical needs and usage in the workplace generally fall into two categories;

- *Professional occupations* - the high-end sophisticated use of mathematics by those with degrees including a substantial mathematical element in specialised workplaces, and
- *Technical and trades occupations* – who generally have taken the Apprenticeship & Workplace pathway for Trades training, or directly into work. A large proportion of these occupations require Australian Qualifications Framework (AQF) Certificate III or IV level qualifications that involve the use of mathematics by non-specialist people.

The focus of the *Quantitative Skills Map* is on this latter group – those working in roles not requiring a quantitative degree or mathematical specialism. Understanding the mathematical demands on this segment of the workforce is crucial to understanding what mathematics skills are required for the workplace. The *Skills Map* has been developed to deal with the concerns raised by peak employer bodies for better preparation of work entrants through the education and training – particularly in relation to entry-level employees such as those involved with Certificate II or III level courses.

***The Research has been used to identify and analyse a list of quantitative skills to produce a 'map' – documenting the quantitative mathematical skills in use by entry level workers in workplace contexts, including the use of mathematical skills for critical thinking, analysing situations and solving problems on-the-job***

### The Structure of the *Quantitative Skills Map*

The *Quantitative Skills Map* is based on the following four key elements:

- Mathematical Content
- Mathematical Level
- Mathematical Executive Functions
- Workplaces as Technology Rich Environments

| | |
|---|---|
| **MATHEMATICAL CONTENT** | The mathematical content used in, and appropriate to, the workplace, including specific workplace skills in:<br>▪ Measurement<br>▪ Estimation<br>▪ Number skills—undertaking calculations<br>▪ Use of formulae<br>▪ Interpreting plans, diagrams and scale drawings<br>▪ Graphs, charts and tables<br>▪ Evaluation, critique and modelling using mathematical concepts |
| **MATHEMATICAL LEVEL** | Identifies links to the Australian Core Skills Framework (ACSF) that may help describe *levels of performance* for entry-level workers in the use of the quantitative skills<br><br>The ACSF provides a comprehensive framework for identifying, measuring and reporting Language, Literacy and Numeracy (LLN) skills and clear benchmarks. It provides a common language for talking about LLN by using everyday language to describe what workers can do at particular skill levels. |
| **MATHEMATICAL EXECUTIVE FUNCTIONS** ***for supporting critical thinking, analysing situations and solving problems*** | The competent application of mathematical concepts in complex workplace contexts requires more than the use of fundamental mathematical skills and understandings. Rather, it requires a set of blended skills and capabilities that includes a mixture of:<br>▪ understanding the mathematical concepts, procedures and skills that workers need to know;<br>▪ understanding the kinds of practical tasks they need to perform; and<br>▪ understanding the processes they should be able to use in applying mathematics – recognising how mathematics might help, choosing and adapting the mathematics needed, making decisions about the accuracy required and reviewing the methods used in the context.<br><br>In addition to the mathematical content and skills, there is a set of cognitive skills that people require to deal with more complex situations. These are described as *executive functions* – a set of mental processes that can help connect past experience with present action. The competent use of mathematics in the workplace is not just about being able to do fundamental mathematics, but about knowing which mathematics to use and being able to construct appropriate models and interpret and communicate the results. Workers use *executive functions* to perform activities such as planning, organising, strategising, paying attention to and remembering details, and managing time and space. The three components of the *executive functions* are generally taken to include:<br>▪ Resisting impulses – stopping to allow time to think before taking action;<br>▪ Effective use of working memory – bearing a number of things in mind while thinking about how to do something; and<br>▪ Cognitive flexibility – capacity to think about a problem in different ways.<br><br>For mathematical contexts in the workplace, these *executive function* skills are integral to things like the worker knowing what mathematics from their 'toolkit' will be useful in the context; applying that mathematics, understanding the effects of practical constraints, recognising an unreasonable result, checking and correcting their calculations and solutions – indeed most of the processes identified as part of '*mathematical modelling*'. |
| **WORKPLACES AS TECHNOLOGY RICH ENVIRONMENTS** | Evidence from the research sites suggests that workplaces are technology rich environments with much of the mathematics people use in the workplace are embedded within ICT, particularly in the use of spreadsheets and graphical outputs. This has implications for how mathematics in taught in schools. |

# 2. Mathematical Content

The Research utilised a list of mathematical skills derived from Australian and international workplace numeracy researchsuch as *OECD PIAAC Research Numeracy: A Conceptual Framework* to identify examples of the types of tasks in which mathematical skills were used. These mathematical skills included:

**Measurement**

**Estimation**

**Number skills—undertaking calculations**

**Use of formulae**

**Interpreting plans, diagrams and scale drawings**

**Graphs, charts and tables**

**Evaluation, critique and modelling using mathematical concepts**

The use of these mathematical skills are generally activated by responses to the following instructional terms that indicate mathematics requirements

- According to signs, codes and labels
- Adjust
- Allowance
- Calculate
- Check
- Collect data
- Compare
- Computations
- Convert
- Determine value
- Estimate
- Formula
- Interpret charts and graphs
- Levels
- Measuring techniques
- Monitor
- Tolerance
- Perform
- Proportion

## Measurement

Varieties of measurements are required to be performed daily by workers. They must be accurate, appropriate to workplace needs and up to workplace standards and accuracy requirements. Workplace activities related to measurement generally include:

- Making initial estimates of measurement and performing the measurement correctly using appropriate instruments;
- Interpreting concepts and units of measure using and describing using suitable language and symbols;
- Choosing appropriate formulae and using these to calculate other measurements of common shapes (e.g. area, volume);
- Performing conversion between metric units; and
- Checking reasonableness of results and interpreting in terms of original purpose.

Measurement in many cases is a complex activity where workers might be involved in a range of activities including:

- Identifying the purpose of the measurement;
- Identifying the physical properties to be measured such as length, volume, weight, temperature, speed;
- Understanding and following sampling procedures;
- Understanding and following measurement procedures;
- Performing and/or checking calibration;
- Selecting and using measuring equipment correctly and safely;
- Checking measured results against estimated results;
- Checking measured results against standards;
- Rounding decimals;
- Using the correct units of measure;
- Converting units of measure;
- Reporting results and recording results; and
- Taking action.

There are many different measurements that may be used in the workplace and also many different ways that the required measurement may be obtained, with a wide range of measurement tools used on a daily basis, although the types of tools are particular to each site. The array of measuring and calculating tools includes calculators; laser equipment; rulers; tape measures; trundle wheels; scales; weighbridges; thermometers; timers, clocks.

Efficient workers must be able to competently use any of these tools as required to correctly complete processes or procedures related to workplace mathematics calculations. Typical workplace mathematics situations may relate to: understanding plans e.g. in constructing structures; understanding engineering drawings; following process specifications correctly e.g. in correctly following a production process ; following manufacturer specifications and instructions e.g. in using a product correctly; following instructions on material safety data sheets e.g. in correctly calculating chemical mixes

## Examples of the use of *Measurement* in the workplace

**In the *Measurement Products Factory* of a power and automation engineering company, workers use flow meters to measure fluid/gas flow length, temperature, speed. They also use measurement when cutting material, measuring overall length and thickness**

**Manufacturing a replacement bracket for a fitting on a trainer aircraft (Aircraft Maintenance) requires heat treatment of metals and *bend analysis* to calculate *bend creep* – this requires measurement of distance, angle measurement, location of a point, all to a specified degree of accuracy. The heat treatment of the metal requires careful measurement of temperature and reference to tables.**

**Drafters in the drafting service provider need to know the "underlying maths principles" involved in drafting even though CAD takes the calculations out of the user's hands. Measurement covers a broad range of variables in drawing. Factors such as weights, loads, area, volume, lengths, dimensions, are all examples of Measurement that may need to be considered in drawing. They use measurement to consider "Rise & Run" of steps in ladders and angles of platforms and in design and drawing – lengths, lines, structures, diameters, and shapes.**

**In the manufacturing of cylinders all parts of the cylinder need to fit together perfectly so measurements have to be precise. Workers need to be able to convert imperial to metric measurements and vice versa as some countries who supply parts and buy cylinders work on the imperial system. Conversions from millimetres to centimetres and so on are also needed. Workers had to calculate if a forklift could hold the pipes that it needed to move. They use tape measures often throughout the day. Converting kilowatts to horsepower is also used to gauge strength and safety.**

**There are many aspects of measurement that are important for a diesel mechanic to understand, such as:**

- **Speed of a vehicle and cycle times;**
- **Cutting lengths of steel accurately;**
- **Dogging – calculating volume, weight of objects to lift;**
- **Temperature and pressures e.g. oil, water, coolant;**
- **Speed of highway trucks (100km/h), their wheel and engine size and the impact of different gear ratios; and**
- **Using micrometres to accurately measure parts for reusability, if they meet the specifications.**

**Within air-conditioning systems technicians need to have a strong ability to recognize the required relationships between airflow and volumes – this area forms a majority of fault finding call outs.**

**Technicians use electrical measures – Voltage, Current, Power, Consumption, conversion between Kwh/mjoules**
**Use data loggers, multimeters, electrical meters, and need to access online measuring equipment**

## Estimation

Workers are often required to estimate approximate answers when exact calculations are not required. They need to know when to make a choice between calculation and estimation. This depends on their understanding of the particular process and context.

Workers are required to identify estimation requirements and select appropriate estimation methods to meet work requirements.

Workers need the ability to:

- identify whether a calculation or estimation is required to meet workplace requirements;
- use estimation techniques to check quantities, ratios, speed and other required data estimates;
- use estimation techniques to check calculated results and workplace data;
- where estimations are used, ensure estimated amounts are consistent with process or product specification and demonstrate knowledge of measurement units used in the workplace; and
- use estimation techniques to check calculated results and workplace data.

In many cases workers are required to perform mental calculations and estimations quickly and often automatically without using a calculator or writing anything down. Estimations can take the place of a precise calculation where precision is not required, or can be used to mentally check whether an error has been made. Rounding is also a form of estimation.

## Examples of the use of – *estimation* - in the workplace

**Estimation in Energy Management System is quite important – need to be able to estimate likely outcomes and 'to read/confirm' what data will say or show. They need to be able to tell if some value is not where it should be.**

**For Air Conditioning Service Technicians it is important for all technicians to not rely on a calculator, and therefore have a good idea of what an answer to a particular problem might look like first, whether on call out after hours or during normal work hours. Technicians need to have the ability to use pen and paper, mental calculations and use calculators depending on the given situation.**

**For Design Drafter estimation is important when assessing drawings or checking dimensions and for *"mental estimation"* where the worker should have or develop the ability to "estimate and calculate closely to the final accurate measurement."**

**In Manufacturing areas the degree of accuracy for measurements was highly dependent on purpose, ranging from standard tolerance levels of 0.05 or 1.00 mm in manufacturing small parts, to frequent visual estimation of load weights in relation to packing, lifting and storage or even numbers of parts off the line per minute. Workers said that the ability to estimate these types of measures is developed from years of experience handling particular products or performing similar functions in a variety of workplaces.**

## Number Skills—Undertaking Calculations

Calculation is used by most workers who are required to apply basic mathematical concepts to calculate information in the workplace.

Calculations may be performed manually or using a calculator, mobile phone or a computer and may involve whole numbers, decimals or fractions. Even when using technology such as calculators and computers, workers often have to think through a problem first to work out the right calculations to perform according to the situation. They also need to know how to use the technology.

Calculations involving *multiplication*, *addition* and *subtraction* are performed on whole numbers (for product quantities) and *decimals* (associated with measurements and money) on a daily basis, with workers selecting, as they felt appropriate, from a variety of pen-and-paper techniques, idiosyncratic in-the-head strategies and use of a calculator.

Workers need to have the ability to:

- identify whether a calculation or estimation is required to meet workplace requirements
- application of calculation techniques to meet work requirements;
- carry out calculations involving basic addition, subtraction, division and multiplication to support work role (this may involve use conversion tables where required);
- record calculations and measurement information accurately according to company procedures; and
- interpret units of measurement used in the workplace, including whole numbers, fractions and decimals

*Percentages* are calculated by workers and apply to many functions in the workplace. Workers need to understand what they mean and how to work with them. Workplaces use percentages to communicate workplace information such as productivity and performance data.

*Ratio and Proportion* - many workers need to be able to use ratios and proportions such as when mixing ingredients.  Workers need to be able to work comfortably with fractions, decimals and ratios.

## Examples of the use of *Number skills – undertaking calculations* in the workplace

***Percentages*** **are calculated by many workers and recording and calculating with** ***decimals*** **is very important, for example:**

- **In the** ***Measurement Products Factory*** **of an engineering company error factors are calculated using ratio and proportion and percentages.**
- **The manufacture of a replacement bracket for fitting on a trainer aircraft needs workers to calculate percentage growth when bending**

**In the Floatation Process used in the Mining Company process technicians use Ratio for mixing between chemicals, water and product.**

**Number skills are essential as a Drafter. Most of the calculations are done by CAD. However checking and Quality Control can require all calculations to be checked manually. Being able to** ***add, subtract, divide & multiply*** **is essential even though the CAD package does the "hard work". Workers need to understand and be able to complete basic mathematical computations. In the Office, Drafters calculate measurements of lines, lengths, weights, loads, angles, distances, percentages, ratios, volumes, areas and trigonometry to check whether an appliance will fit into a certain space. The undertaking of calculations in drawing and drafting is paramount to the quality of the document that is produced. They need to "check and correct dimensions and identify any fault in a line. Calculations can be made prior to beginning the drawing; during the drawing phase; through the checking process (own, peer & Quality assurance) and on-site where Drafters can move around structures and calculate "in the field" where needed to replace or build new structures as required.**

**In the company that sells and rents heavy equipment, parts and service support used in the mining, construction, forestry, agricultural, materials handling and government sectors calculations are also used in;**

- **the transport of structures - transporters can only take certain weights, lengths, widths of structures calculations need to be made about whether a structure needs to be transported in sections or "the best way" to transport the structure.**
- **in the workshop, where** ***dogging i*****s used a lot to move different weighted machinery, therefore calculations are required for this.**
- **to accurately set the position of a gear in a differential and to set bearing preloads, This is done by following the procedure, collecting all measurements and calculating the result. In the case of the differential, there are factory measurements stamped on the case and the shaft, that have to be used in the calculations to set the crown wheel at the prescribed position in the housing**

**Along with square roots, mental calculations and pen & paper mathematical skills like long division. However, the younger generation of diesel fitter are relying more on technology devices such as a mobile phone**

**Basic number skills are used all the time in manufacture of cylinders – workers need to know how to do addition, subtraction, division and multiplication. They need to know fractions, decimals and percentages. The mathematics is not hard the employees just need to have a comprehensive understanding of it and relate to allow them to deal with anomalies, variances and comparisons.**

**In a power and automation engineering company addition and subtraction is undertaken to make sure parts fit together accurately, in the design process. These operations are also used to adjust speed and feed rates. The operations of dividing and multiplying are used for conversions.**

**Technicians in the company specialising in energy management need to have mastered the 4 basic operations. They also need to use percentages (drives all accounting, quotes and technicians need to know if an error has occurred), proportion (input/output PIC) and pattern recognition**

## Use of Formulae

A diverse range of simple mathematical formulae are used effectively by workers in the course of their jobs. They often use formulas such as when calculating areas, volumes, dimensions and flow rates. They also need to select and use appropriate formulae to calculate the measurement properties of common shapes

In general workers use simple mathematical formulae to:

- Generalise straightforward number patterns or relationships;
- Translate simple worded problems involving unknown quantities into simple equations;
- Use substitution to find particular values and to check effectiveness ;
- Use verbal generalisations using informal and symbolic notation and representation of mathematical expressions; and
- Solve simple equations using informal techniques.

## Examples of the use of *Using formulas* in the workplace

**Workers responsible for manufacturing replacement body parts for trainer aircraft use formulae (substitution) to calculate the bend creep – the amount the metal stretches when the metal is bent.**

**Drafters use formulae:**

- **when working out angles associated with structures out on-site & in designing drawings;**
- **when calculating Ladders and Platforms as examples that may be built with certain angles in them; and**
- **to calculate Stresses & Displacement of Energy including the distance over where the Energy is displaced.**

**In the heavy machinery company there are a lot of formulas that are used in dogging (Dogging work is the use of slinging techniques, including the selection and inspection of lifting gear, to safely sling a load, or the directing of a plant operator in the movement of a load when the load is out of the operator's view) These include:**

- **Angle factors;**
- **Weight of steel per metre; and**
- **Max weight possible to lift to calculate the safe working load.**

**Formulas are used to set specifics for the programming that is needed to manufacture cylinder components. Formulas are used to gauge the strength of materials. Formulas are also needed for size specifics. Trigonometry is used regularly too in the design process and when setting up the programs. Other formula includes Euler formula; area of a circle; circumference of a circle; milling, drilling, boring and tapping speed and feed rates.**

**The building of *Energy Management Services* is reliant on the use of formulas in the design, construction and operation of complex systems. This includes formulae for the measure of electricity, power consumption, conversion from kilowatt hours to mega-joules, cable sizing over length, valve sizing, electrical capacity, pressure drop, controller programming(PID).**

## Interpreting plans, diagrams and scale drawings

Many workers use drawings, plans and diagrams in their day-to-day jobs and are involved in reading some aspects of plans and diagrams - particularly with an array of symbols and measurements.

Workers require the ability to:

- Interpret all relevant information on plans, drawings and diagrams to complete a work plan or method statement or to complete a project;
- Calculate dimensions and measure accurately; and
- Understand
  - the features of plans, drawings and diagrams.
  - symbols and abbreviations used on plans, drawings and diagrams.
  - scale on plans, drawings and diagrams.

Generally workers need to interpret key features of plans, drawings and diagrams, including interpreting;

- Different types of plans, drawings and diagrams and their purposes;
- The scale, dimensions and tolerances; and
- Symbols and abbreviations.

Workers solve problems using plans, drawings and diagrams including:

- Applying scale to calculate actual dimensions from the plan, drawing or diagram;
- Calculate missing dimensions from the plan, drawing or diagram; and
- Interpreting different views from the plan, drawing or diagram.

Workers are required to create shapes and their representation, including:

- Representing two-dimensional shapes and three-dimensional objects by scale drawings, simple plans and models using appropriate symbols and conventions;
- Using ratio to create scale drawings, simple plans and models; and
- Estimating, drawing and measuring angles.

Workers investigate shapes and their representation:

- Using ratio to interpret scale drawings, simple plans and models;
- Reading and interpreting scale drawings, simple plans and models to see if they are representative of the original object and vice versa;
- Using the features and language of shape to describe objects and their representation.

## Examples of the use of *Interpreting plans, diagrams and scale drawings* in the workplace

**Integral to the operation of the Energy Management Services Company through scale drawings, schematics, diagrams, plans, control layouts that are all used frequently throughout the business. This includes the use of scale drawings and schematics of client locations and the ability to read symbols of systems to do analysis.**

**The fault finding process for Building Management Services technicians requires the interpretation of information in many forms including scale flow charts and building and floor plans (scaled and unscaled).**

**Interpreting plans, diagrams and scaled drawings is very important in relation to the design component of manufacturing cylinders. The draftsman uses these skills daily as do the machinists when they complete the programming process**

**These skills are used regularly by diesel fitters, with the need for swift and accurate analysis of the plans/drawings/ diagrams being imperative for the safety of all the workers involved and the effectiveness of the machine. New equipment is either assembled in the workshops in full or in part and then completed at the mine site. Technical drawings are used, as well as exploded views of parts and schematics of hydraulics and electric/electronic wiring, hosing and parts.**

**Drafters need to be able to read, understand and interpret data associated with plans, diagrams and scale drawings. Drafters must be able to design and interpret plans, diagrams and scale drawings such as those used in mechanical, electrical, special projects and any structure that needs to be designed. Understanding the design of a structure through interpreting plans, diagrams and scale drawings is a necessity in this job. As an example, they may get plans back from an architect and there may be modifications that need to be made. They have to be able to read and understand what the architect wants to be modified and then from the diagram/drawing, be able to make the modifications successfully. Any modifications must be able to "work" and be able to be practical once made hence when understanding the drawing and making the modifications, the Drafter needs to understand how the modifications will work within the structure. Maths skills in measurement, approximating, estimating, drawing accurate dimensions and making corrections are all important skills in this area.**

## Graphs, charts and tables

Mathematical use was noticeable with respect to graphs, charts and tables. Workers used tables of product sizes, specifications, costs etc. on a daily basis. The ability to interpret mathematical data is essential to the workplace particularly in problem solving and quality improvement.

A worker needs to be able to look at mathematical data and recognise patterns and anomalies, including the ability to:

- Read and extract numerical information embedded in a range of texts;
- Undertake a range of mathematical calculations with numbers, make initial estimates of results and interpret the results;
- Collect data and organise the data into tables and to construct graphs using appropriate scales and axes;
- Use key features and conventions of tables and graphs and of measures of central tendency (means, medians, modes) and simple measures of spread to investigate and interpret familiar and routine statistical information;
- Use both informal and formal language of numbers, graphs and tables to interpret and convey the numerical and statistical information and results;
- Use the descriptive language of numbers and numerical information; and
- Interpret the results in terms of their reasonableness against the initial estimates and in terms of any work consequences.

Workers Investigate and create statistical data, tables and graphs, including:

- Collecting and representing data in tables and in graphical form, using appropriate scales and axes;
- Calculating measures of central tendency and simple measures of spread for sets of ungrouped data;
- Using the descriptive language of graphs, tables and averages; and
- Interpreting the results of the investigation in terms of the meaning of the data and/ or accompanying texts, tables and graphs and in terms of work consequences.

## Examples of the use of G*raphs, charts and tables* in the workplace

**The power and automation engineering business widely uses graphical analysis in its administration area - Excel is a commonly used tool and is used to manage and track the business and its performance. Workers need the ability to customise and analyse Excel programs**

**It is important for Drafters to be able to interpret graphs, read charts and understand and apply data from tables. Examples of this may include:**

- **Flow rates associated with *piping* that are presented in graph form or that graphs need to be constructed to represent this data.**
- **Charts that contain specifications that a Drafter may need to adhere to or utilise when designing a particular structure. The Charts may refer to loads, weights, heights, etc.**
- **Certain Tables/Charts relating to Australian Standards that need to be considered prior to & during drafting.**
- **Being able to read & interpret charts / Specification tables needed to get part sizes from standardized information.**
- **When interpreting or understanding stress in loads.**

**A Store person receiving coded orders needs to match, sort and record large numbers.**

**In the *Grinding Process* undertaken in the Mining Company - process technicians monitor all operations using computer-aided devices and systems for any faults/breakdowns as well as maximise productivity. This involves reading graphs; analysing system charts; reading power rates; understanding decibels understanding ratios (as there are 3 different types of rocks requiring 3 different ratios); understanding statistics for 'wear and tear' on balls which operate conveyor belts.**

**In the *Floatation Process* undertaken in the Mining Company - process technicians work with Engineers to maximise amount of copper/gold extracted. This involves watching computer screens for data/statistics and any faults/breakdowns; Reading and analysing trend graphs of efficiency of machinery; Recording of data regularly - Rates (e.g.: % per hour; cubic metres/hour) Collecting and analysing data (e.g.: frothing, flow of water & chemicals in cubic metres/hour).**

**Graphs, charts and tables are all used regularly, through crane use (dogging), information collected from the data loggers (ECM's), use of equipment and safety. All of these are displayed numerously around the workshop.**

**Graphs are used to show output in a clear visible format so that all staff can access them. Employees use tables regularly for conversions and item connections.**

**The fault finding process, for BMS technicians, requires the interpretation of information in many forms including tabular input/output charts and graphical representations of the system at work. Line graphs used to interpret temperature data (logged temperature valve every 15 minutes tracking over particular time interval). Continuum software uses graphical and tabular representation in fault finding. Workers in this area use spreadsheets to read remote data; undertake online meter reading to compare and validate values; read ordered data Identifying location codes and symbolic representation; number/order revision and analysis of information;<br>design circuit diagrams; link information to spreadsheets from geographical locations**

**Information is frequently presented in the form of graphs and charts, especially for customers to show consumption, and the results of efficiency measures. A lot of data is recorded electronically at client locations and sent to central servers for analysis. Workers need to be able to recognize errors in data, especially irregular spikes due to transmission error. Different monitors may have different rates of reporting; every 15 minutes, reports only every 12 hours as a total, giving a measure spike in the system. They need to be able to see this, and adjust as needed**

## Evaluation, critique and modelling using mathematical concepts

Many tasks in the workplace involve problem solving and decision making using mathematical skills. Workers use mathematical problem-solving techniques to investigate and solve relevant workplace problems, including:

- Using appropriate techniques to interpret and extract relevant information from a job activity;
- Selecting and using a range of appropriate problem-solving techniques:
- Assessing the reasonableness of the result and select an alternative problem-solving technique, if necessary; and
- Using the language and terminology of problem-solving to communicate the procedures and outcomes of the activity.

Workers are required to:

- Apply mathematical knowledge and skills in familiar and unfamiliar situations requiring investigation, modeling, or problem-solving;
- Use problem-solving strategies used to interpret, clarify, and analyse problems, identification of any assumptions and their associated effects, analysis of the results in the context of the problem, and understanding the strengths and limitations of the model; and
- Reflect on the reasonableness and accuracy of their results and possible alternative methods and solutions.

## Examples of the use of *Evaluation, critique and modelling using mathematical concepts* in the workplace

**BMS technicians are continually using all these concepts, as they form an integral part of their problem solving processes when looking to analyse and solve systems that are working incorrectly. Technicians need to be able to recognise anomalies, evaluating data identifying underlying changes in temp, air flows etc.**

**This is an important part of the designing and programming processes in the manufacture of cylinders especially if a customer wants a cylinder that does not meet standard or typical norms. Designing this cylinder requires trial and error on the draftsman behalf and modifying for the programming.**

**In the heavy machinery dealership vehicles are fitted with various ECMs (Electronic Control Modules) and these mathematical skills are used to analyse the data that is produced and problem solve to come up with solutions as to how various issues can be rectified. The information and graphs that are produced from the ECM's is analysed to look for 'trending'. Interpreting and analyzing this information is imperative for the safe running and efficiency of all machinery. For example, if the temperature of the oil fluctuates, does it happen when the truck is driving uphill? This analysis and feedback can then be passed back to the design team at CAT, which helps them change their design process for the next series of vehicles or producing a new OS for the ECM's.**

**Drafters need to evaluate how structures can be best drawn; why they would be best suited in or as a part of a structure; how will the structure be used; including angles, weights, loads, lengths & all measurements. The appraisal and critiquing of drawings is essential in ensuring that the drawing will be viable once it has been handed to the Engineers so that they can move forward with the structure. 3D Modelling was crucial in understanding the processes needed for design drawing Drafters need to have a strong working knowledge of 3D Modelling to understand how drawings take shape. Computer software handles the 3D Modelling however Drafters need to have the understanding of how this Program works and how it is best utilised in the workplace and how a structure would work on-site.**

**Problem solving techniques employed by workers in aircraft maintenance technicians include**

- **Using systematic lists.**
- **Draw a diagram or make a model.**
- **Look for a pattern.**
- **Compare to a similar problem that they have already solved.**

# 3. Mathematical Level

The Australian Core Skills Framework (ACSF) provides a consistent national approach to the identification of language, literacy and numeracy skills requirements in diverse work, training, personal and community contexts. It is a common reference point for describing and discussing performance within the five core skill areas of Learning, Reading, Writing, Oral Communication and Numeracy.

The ACSF has been developed to assist practioners understand the essentials of performance in the core skills in different contexts. It provides a standard approach for describing the 5 core skills as part of workplace competence within training programmes and enables them to identify and discuss core skills issues with others in the workplace.

The Framework describes *5 levels of performance* in each of the core skills. A key feature is that it takes into account the factors that influence a person's performance:

- The degree and nature of support available;
- The familiarity with the context;
- The complexity of text, including written, diagrammatic, visual and oral; and
- The complexity of the task.

At each level within a core skill there are statements, called *Indicators* that describe achievement at this level.

The level of performance of Entry Level Workers generally equates to Level *3 Numeracy Performance:*

- Selects and interprets mathematical information that may be partly embedded in a range of familiar and some less familiar tasks and texts.
- Selects from and uses a variety of developing mathematical and problem-solving strategies in a range of familiar and some less familiar contexts.
- Uses a combination of both informal and formal oral and written mathematical language and representation to communicate mathematically.

The following table provides detail of the variables at *Level 3 performance*.

| Support | Context | Text | Task Complexity |
| --- | --- | --- | --- |
| **Moderate support**<br>**Advice and modelling available** | **Range of familiar contexts**<br>**Some less familiar/routine contexts**<br>**Some specialisation in routine contexts** | **Routine texts**<br>**May include some unfamiliar elements and embedded information**<br>**Includes some specialised vocabulary** | **Tasks include a number of steps within the one task, e.g. sequencing, basic inference, extrapolation and integration** |

Based on the indicators and performance features described above, the following outlines the skills and knowledge that might be required by entry – level workers, across the Performance Indicators

| ***Selects and interprets mathematical information that may be partly embedded in a range of familiar and some less familiar tasks and texts*** |
|---|
| ▪ can interpret and comprehend a range of everyday mathematical information that is embedded in familiar and routine texts<br>▪ can interpret and comprehend whole numbers and familiar or routine fractions, decimals and percentages<br>▪ can interpret and comprehend time including 24 hour times and dates<br>▪ can interpret and comprehend familiar and routine 2D and 3D shapes (including pyramids and cylinders)<br>▪ can interpret and comprehend familiar and routine length, mass, volume/capacity, temperature, simple area measures<br>▪ can interpret and comprehend familiar and routine maps and plans<br>▪ can interpret and comprehend familiar and routine data, tables, graphs and charts, and common, everyday chance events<br>▪ can draw on a combination of hands-on, in-context materials, personal experience, mathematical and other prior knowledge to select appropriate methods of solution from a limited range of mathematical processes |
| ***Selects from and uses a variety of developing mathematical and problem-solving strategies in a range of familiar and some less familiar contexts*** |
| ▪ can draw on a combination of hands-on, in-context materials, personal experience, mathematical and other prior knowledge to use developing estimation and other assessment skills to check and reflect on the outcome and its appropriateness to the context and task<br>▪ can use a blend of personal 'in-the-head' methods and formal pen and paper methods to calculate<br>▪ can use calculator/technological processes and tools to undertake the problem-solving process<br>▪ can select and use appropriate tools, hand held devices, computers and technological processes e.g. use a tape measure to measure the dimensions of a window in mm, create a personal weekly budget in a spreadsheet<br>▪ can calculate with whole numbers and every day or routine fractions, decimals and percentages, linking equivalent values and using these appropriate to a range of everyday or routine contexts<br>▪ can use and apply order of arithmetical operations to solve multi-process calculations<br>▪ can use and apply rates in familiar or routine situations, e.g. km/hr, $/kg, $/m<br>▪ can apply knowledge of properties of 2D and 3D shapes to describe and draw everyday objects, including constructing common 3D shapes<br>▪ can measure , estimate and calculate length, perimeter, simple area (for rectangular areas only using A = L x W), mass, capacity/volume, times, temperature using every day or routine measuring instruments |
| ***Uses a combination of both informal and formal oral and written mathematical language and representation to communicate mathematically*** |
| ▪ can convert between routine metric units by applying understanding of common prefixes such as milli, centi and kilo<br>▪ can use distance, direction, coordinates, simple scales, labels, symbols and keys to read and use everyday maps and plans<br>▪ can collect and organise familiar data and construct tables, graphs and charts, manually or with spreadsheets, using simple and familiar or routine scales and axes<br>▪ can describe, compare and interpret the likelihood of everyday chance events using qualitative terms such as certain, likely, impossible and relate this to everyday or routine fractions, decimals and percentages<br>▪ can use a combination of both informal and formal written mathematical and general language and representation to document and report the mathematical and problem-solving process and results<br>▪ can use a combination of both informal and formal oral mathematical and general language to present and discuss the mathematical and problem-solving process and results<br>▪ can use a combination of both formal and informal symbolism, diagrams, graphs and conventions relevant to the mathematical knowledge of the level, e.g. 1/100, 12.25%, km/hr, $/kg, 1.25 m = 1250 mm |

The level of mathematics generally used by the workers observed, and required by employers, can be described as *'core'* or *'fundamental'* mathematical techniques and processes. Although the mathematical content required differs from workplace to workplace, the level of the mathematics required is almost wholly covered within the *Essential* or *General* subjects of the new Australian Curriculum. Although the skills observed can appear to be quite fundamental - such as how to calculate and estimate and having a feel for numbers, percentages and proportions – it is the *application* of mathematical skills to the workplace that is not straightforward. The mathematics used is never required in isolation. Mathematical knowledge and skills are always operationalised with real data/information and with an appreciation of what the data/information means.

# 4. Mathematical Executive Functions

The competent application of mathematical concepts in complex workplace contexts requires more than the use of fundamental mathematical skills and understandings. Rather, it requires a set of blended skills and capabilities that includes a mixture of:

- understanding the mathematical concepts, procedures and skills that workers need to know;
- understanding the kinds of practical tasks they need to perform; and
- understanding the processes they should be able to use in applying mathematics – recognising how mathematics might help, choosing and adapting the mathematics needed, making decisions about the accuracy required and reviewing the methods used in the context.

In addition to the mathematical content and skills which will continue to be a key part of the total skills required of today's workforce, there is a set of cognitive skills that people require to deal with more complex situations. These are described as *executive functions* – a set of mental processes that can help connect past experience with present action. The competent use of mathematics in the workplace is not just about being able to do fundamental mathematics, but about knowing which mathematics to use and being able to construct appropriate models and interpret and communicate the results. Workers use *executive functions* to perform activities such as planning, organising, strategising, paying attention to and remembering details, and managing time and space. The three components of the *executive functions* are generally taken to include:

- Resisting impulses – stopping to allow time to think before taking action;
- Effective use of working memory – bearing a number of things in mind while thinking about how to do something; and
- Cognitive flexibility – capacity to think about a problem in different ways.

For mathematical contexts in the workplace, these *executive functions* will be integral to things such as the worker knowing what mathematics from their 'toolkit' will be useful in the context; applying that mathematics, understanding the effects of practical constraints, recognising an unreasonable result, checking and correcting their calculations and solutions; communicating the mathematics to others in appropriate ways; and enhancing the ability to think and problem-solve rather than working with isolated tasks and problems. *Executive functions* are not only skills that should be used in combination with the mathematical content but also as the basis for strategies that all teachers should consider using to enhance the learning capacity of their students. Students need to develop the ability to explore, to make and test conjectures, to reason logically, and to use a variety of mathematical methods to solve problems. Indeed most of the processes identified as part of '*mathematical modelling*'.

This will require insight into the relationship between thinking skills, executive functions, and mathematics concepts, procedures and skills. This requires consideration of -a *'readiness for thought and action'* (the capacity to appreciate the purpose of mathematical-related tasks and to use mathematical skills for critical thinking, analysing situations and solving problems) which has been identified as important in workplaces. This relates to a personal confidence to use mathematics in appropriate situations.

The following table is a tentative guide to this connection.

| | |
|---|---|
| **Resisting Impulses** – *stopping to allow time to think before any action;* | Sustaining attention to the task, not getting distracted in the middle of completing a problem, setting goals and working to meet them.<br>Thinking ahead about what kind of problem this is, and what options you have for solving it, planning the steps you will use to solve the problem.<br>Organizing the work so that it is clear, organizing images/notes on page, organising information and distilling the mathematical information in written text<br>Being able to sustain attention long enough to grasp a difficult concept without giving up.<br>Not rushing to get a solution problem just to finish, but really thinking it through to help ensure confidence in the solution. |
| **Working Memory** – *bearing a number of things in mind while thinking about how to do something;* | Keeping different steps to solving a problem in mind, recalling which formulas to use to solve which problems and keeping parts of a multistep problem in mind.<br>Keeping all of the different components to a problem in mind while solving it, thinking about previous steps while doing the current one, retrieving previously learned information to apply it to the current problem or task and applying mathematical rules.<br>Recalling prior knowledge and relating it to new ideas and situations. |
| **Cognitive Flexibility –** *capacity to think about a problem in different ways* | Thinking about whether or not their reasoning makes sense as they work to solve a problem.<br>Thinking about the steps used to solve previous problems and using that to self-correct and check.<br>Shifting between different representations written in sentences, symbols and graphics and being able to switch between representations when needed.<br>Being able to explain and communicate their reasoning in writing or to others, being able to think about and explain the steps used to solve different kinds of problems, being able to explain the reasoning behind completing a mathematical problem in a certain way |

Developing the relationship between thinking skills, executive functions, and mathematics concepts, procedures and skills is considered critical to enhance a worker's:

- ability to relate to mathematics to others; and
- ability to think and problem-solve rather than working with isolated tasks and problems.

Students therefore need to develop the ability to explore, to make and test conjectures, to reason logically, and to use a variety of mathematical methods to solve problems

The relationship between thinking skills, executive functions, and mathematics concepts, procedures and skills can be developed through:

*Mathematical Modelling* which will enhance entry levels workers ability to:

- demonstrate an understanding of mathematical concepts and relationships;
- identify, collect, and organise mathematical information relevant to investigating and solving problems;
- recognise and apply the mathematical techniques needed when analysing and solving a problem in context;
- interpret results and reflect on the reasonableness of the conclusions in context;

- communicate mathematical reasoning and ideas by using appropriate language and representations.

Through *Communicating Mathematics Information* which will enhance entry levels workers' ability to:

- communicate mathematical reasoning and ideas using appropriate language and representations, such as symbols, equations, tables, and graphs;
- interpret and use appropriate mathematical terminology, symbols, and conventions;
- analyse information displayed in a variety of representations and translating information from one representation to another;
- justify the reasonableness of the results obtained through technology or other means using everyday language; and
- interpret, apply, and communicate mathematical skills in commonly encountered situations.

The specific features of *Communicating Mathematics Information* in the workplace include;

- interpretation, translation, and communication of mathematical ideas and reasoning;
- making appropriate use of mathematical terminology and conventions; and
- conveying meaning through various oral, written, and visual forms.

In their preparation for work, students should have opportunities to read about, represent, view, listen to and discuss mathematical ideas. These opportunities should allow them to create links between their own language and ideas and the formal language and symbols of mathematics. Communication is important in clarifying, reinforcing, and modifying ideas, attitudes and beliefs about mathematics. They should be encouraged to use a variety of forms of communication while learning mathematics. Communication enables them to make connections between concrete, pictorial, symbolic, verbal, written, and mental representations of mathematical ideas. The table below outlines the performance required for entry level workers across these key areas

| Mathematical Knowledge and Skills and Their Application | Mathematical Modelling and Problem-solving | Communication of Mathematical Information |
|---|---|---|
| **Adequate knowledge of content and understanding of concepts** | **Competent analysis of the tasks using a variety of methods to investigate, model, and interpret** | **Competent communication of solutions and mathematical arguments** |
| **Use of mathematical ideas and processes that produced correct results for routine problems with and without technology** | **Effective use of problem-solving strategies to solve problems** | **Adequate use of correct notation, representations, and terminology** |
| **Application of knowledge and skills in different contexts** | **Understanding of the reasonableness and possible limitation of the results** | |

# 5. Use of Technology in the Workplace

Changes taking place in work practices which are driven by cost-efficiency measures and technological ‘advances’ mean changing, and possibly increasing, demands on workers’ numeracy levels and skills. From key stakeholders’ observations it is clear that technological advances are driving workplace changes, particularly in relation to computerisation, and that workers need to be able to deal with these changes

This increase in technology has changed the mathematical practices in which people in the workplace are required to engage. For some entry – level workers, they are now required to be ‘*more mathematically competent* - and are - *required to undertake higher cognitive tasks such as interpreting the meaning of the computer generated results of calculations’* – and - *understand the significance of the numerical output, as calculations move from manuals and charts to spreadsheets and calculators*.’

Through technology change the mathematics has become more embedded in working life - however, the impacts of technological change may be dependent on the skill level of employees. For example, employees initially tended to make very little use of ICT or used it as a supporting tool rather than to change traditional ways of working. For example the introduction of computer aided design (CAD) has substantially increased technology, reducing development costs and wastage, and changing the required types of mathematical engagement.

A significant increase in Technology is visible in the production and use of spreadsheets across many sectors. Mathematical understanding of the principles underlying the spreadsheet is essential in order to make sense of the output. However, a mathematical understanding is not sufficient.

An important consideration in the structuring of curriculum and teaching approaches is to embed digital technologies so that they are not seen as optional tools. Digital technologies allow new approaches to explaining and presenting mathematics, as well as assisting in connecting representations and thus deepening understanding. The continuing evolution of digital technologies is progressively changing the work of mathematicians and school mathematics and the curriculum must continue to adapt.

Digital technologies can make previously inaccessible mathematics accessible, and enhance the potential for teachers to make mathematics interesting to more students, including the use of realistic data and examples.