Nanotechnology and Nanofabrication Technicians

Final Report on Essential Knowledge, Skills and Attitudes

ANFF

tafeSA
Government of South Australia

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2. Executive Summary

2.1 Purpose of this Report and Data Examined

In Australia, the knowledge, skills, and attitudes required for Micro and Nanofabrication Technicians are not well-described. The Australian National Fabrication Facility (ANFF) engaged TAFE SA in March 2021, to undertake a training needs analysis to better document and describe the knowledge, skills, and attitudes requirements in this area and report back on options for curriculum development and increasing skilled workforce numbers.

The purpose of this Report is to:

1. Describe the Knowledge, Skills and Attitudes (KSAs) required for Micro and Nanofabrication Technicians in Australia
2. Map those KSAs to Australian and International vocational qualifications, higher education qualifications and non-accredited courses, in order to identify gaps in curriculum and training packages, and
3. Make recommendations to ANFF and industry regarding engagement strategies to close curriculum gaps and increase the pool of workers with transferrable or relevant skills for the industry.

TAFE SA has gathered and examined:

- International job advertisement data from the United States of America (USA), United Kingdom (UK), Canada, France, and Germany
- International and Australian qualifications which specifically include nanotechnology specialisations or from which the nanofabrication industries in different countries are targeting their recruitment, based on job advertisement data
- Standard Operating Procedures (SOPs) for a wide variety of ANFF equipment
- Interview transcripts following face-to-face and online interviews with ANFF and Industry Experts, and representatives of the Skills Service Organisation, IBSA
- Feedback from the industry Consultation Paper developed by TAFE SA and distributed by ANFF in September 2021.

This Report presents detailed findings on:

- The nature of relevant overseas Job Roles (Detailed findings at Section 5.1 International Job Advertisement Data)
- Essential knowledge, skills, and attitudes of Nanofabrication Technicians in Australia (Sections 5.4 Workplace Health and Safety (WHS) Skills – 5.17 Industry 4.0 Skills)
- Gaps in Australian and overseas qualifications (Section 6)
- Opportunities to increase training pathways for students and existing workers to acquire skills in micro and nanofabrication, together with recommendations that ANFF may adopt to facilitate those opportunities.

The key findings in the report are summarised below.

2.2 Key findings on Overseas Job roles

In countries such as the USA, UK, Canada, France, and Germany, where the nanofabrication industries are more advanced than in Australia, there are more established learning pathways into the industry at the technical level. Nanofabrication industry job roles include:

- 'Laboratory and Cleanroom Technicians'
- 'Electronics Technicians'
- 'Chemistry Technicians'
- 'Process Technicians'
- 'Mechanical Technicians'
- 'Test Technicians' and
- 'Assembly Technicians'.

Common educational pathways include Diplomas and Associate Degrees in Chemical Technician Assistance, Electronics, Nanotechnology Systems, and apprenticeships in Mechanical and Electrical Trades.

Detailed findings with respect to the nature and content of overseas job roles are contained in Section 5.1 International Job Advertisement Data of this Report.

2.3 Key findings with respect to Knowledge, Skills and Attitudes of Nanofabrication Technicians in Australia

The following essential Knowledge, Skills and Attitudes Areas (KSA Areas) were identified from Job Advertisements, Standard Operating Procedures, Interviews and Consultation Paper Feedback:

- Workplace Health and Safety
- Process Operations
- Equipment Operations and Types of Equipment
- Basic Scientific Knowledge and Mathematics
- Nanotechnology Topics
- Cleanroom Standards
- Workplace Training and Mentoring
- Reporting and Record Keeping
- Quality Standards
- Engineering Topics
- Mechanical Trade Skills, including Maintenance and Repair
- Process Improvement
- Software and Computing Skills
- Industry 4.0 Skills.

Many of these KSA Areas also had an additional, more detailed, level of 'KSA Topics' aligned to them (see Table 6). Both the KSA Areas and KSA Topics were used by TAFE SA to map KSAs to Australian and Overseas qualifications. A full discussion of these findings is contained in Sections 5.4 Workplace Health and Safety (WHS) Skills to 5.17 Industry 4.0 Skills of this Report. These findings could be used by ANFF or training providers to contextualise existing courses, develop new curriculum or develop micro-credentials or certifications in nanofabrication.

There was strong feedback that some skills and knowledge could really only be acquired by 'mentorship' or one-on-one training and supervision on the job. These KSAs included:

- Operation and maintenance of specialised and expensive equipment
- Understanding of the semiconductor industry and manufacturing
- Relevant scientific knowledge of nanofabrication processes.

It is noted that traineeships and apprenticeships are a strongly promoted form of on-job training in Australia in the vocational sector. The higher education sector also makes strong use of internships and work-integrated learning projects for undergraduate students.

2.4 Key findings with respect to qualifications that build essential and desirable Knowledge, Skills and Attitudes

The following Australian Training Packages contain qualifications that could be utilised to build micro and nanofabrication technician skills through contextualisation of learning materials and units or development of new units of competency:

- MSL Training Package (Laboratory Operations qualifications)
- MSM and MSA Training Packages (Certificate IV in Process Manufacturing (MSM40116) and Diploma of Manufacturing Technology (MSA50108))
- MEM Training Package (Certificate III in Engineering – Mechanical Trade (MEM30205).

Many existing units of competency in those packages lend themselves to contextualisation for nanofabrication skills development, including units in the MSL qualifications which cover Workplace Health and Safety; Maintenance and Calibration of Instruments and Equipment; Processing and Interpreting Data; Record-keeping; and Performing Microscopic Examination.

The following International qualifications were particularly strong with respect to identified essential KSA Areas, as well as in the topics of nanoscience and nanofabrication techniques.

- Diploma of Nanosystems Engineering Technology (Northern Alberta Institute of Technology – Canada)
- Diploma of Nanotechnology Technician (Athens Technical College – USA).

2.5 Key Recommendations on Next Steps to Support Increased Skilled Engagement

TAFE SA recommends that ANFF evaluate whether to increase engagement with what could broadly be termed the 'Key Skills Stakeholders'. These Key Skills Stakeholders include:

- The relatively recently formed National Skills Commission
- the Skills Service Organisation IBSA (in respect their MSL, MSM, MSA and MEM training packages)
- TAFE institutes in the states with reasonably high numbers of laboratory operations students and where there might be delivery in a location near ANFF nodes and micro and nanofabrication industry customers, in particular in Victoria, NSW and Queensland.

To lead this engagement, ANFF could consider engaging a national nanofabrication skills coordinator or an organisation to perform this function, and to advocate for recognition of nanotechnology and nanofabrication job roles and knowledge, skills, and attitudes in the national VET system. Examples of the type of engagement which could occur are presented below.

2.5.1 Engagement with the National Skills Commission

In engaging with the National Skills Commission, ANFF could:

- Submit selected KSA findings from this Report to the National Skills Commission for consideration in development of their national skills data base and their work on transferable skills cluster.
- Request that the National Skills Commission consider utilising USA O*NET job role data for Nanotechnology Technicians and Nanotechnology Engineers in their skills definition program of work.
- Request that ANZCO codes be updated to include relevant laboratory technician and nanofabrication technician job roles.

2.5.2 Nanofabrication Skills Leadership, Certification or Accreditation

As ANFF has strong existing short-course materials ANFF could engage with State Training and Skills Departments with a view to accrediting some of its own content as micro-credentials. Funding could also be sought from each state to offer these skills to students and graduates.

2.5.3 Engagement with IBSA

In engaging with Skills Service Organisations, such as IBSA, ANFF could:

- Provide feedback on the development of new units of competency and unit rewrites for the Laboratory Operations suite of qualifications in the MSL Training Package (IBSA is currently waiting for confirmation and approval of a program of work of around 100 units of competency).
- Provide feedback on the development of new qualifications proposed for the MEM Training Package.
- Review 2005 draft nanotechnology units of competency, obtained by TAFE SA, from IBSA consultants but never implemented. ANFF could put forward revised content for consideration in the development of new more contemporary units.

We note that there are different engagement officers at IBSA responsible for different training packages, and the national training system is currently undergoing significant reform. While this presents an opportunity for ANFF to influence developments, the mechanisms by which that could be achieved are not yet clear.

2.5.4 Engagement with TAFE Institutions and Universities

ANFF could partner with TAFE Institutes across Australia which deliver the Cert III, Cert IV, and Diploma of Laboratory Operations with an intent to explore:

- Recruitment of graduates for employment into ANFF and industry as nanofabrication technicians.
- Offering summer internships to 'test' the suitability of partially completed students to be employed full time at the completion of their qualifications. A key question is whether graduates can be rapidly inducted into ANFF policies and SOPs, given their underpinning knowledge and skills of good laboratory practice.
- Licensing ANFF courseware into existing Laboratory Operations Courses across Australia (currently, very pathology and histology-focussed), Mechanical Trade courses and Electronics courses in order to 'contextualise' or broaden existing offerings to include nanotechnology and nanofabrication topics. ANFF could provide a low / no cost licence to incentivise institutions to do this and/or additional development funding for the development of contextualised training resources.
- Selected access to ANFF equipment to support current students to study in a unit of competency, or simply as a field trip to expose students to the industry.
- Provide ANFF short courses to the wider public or transition workers to have a 'taste' of the industry and build awareness of the opportunities and underpinning science.
- Seek a university or higher education partner to develop a Higher Education Diploma or Associate Degree in Nanotechnology. This could be modelled on the Alberta, Canada course which is highly aligned to key KSA Areas. A major question here would be whether one state could support sufficient student interest and demand to run the course in a profitable way; and whether there would be sufficient employment opportunities for graduates.
- Establish a traineeship program whereby ANFF nodes and neighbouring industries take on Laboratory Operations trainees as operators, with a view to developing them into Nanotechnology Laboratory Technicians. Trainees would work part-time at ANFF and study at the nearby TAFE Institute part-time.

3. Background

3.1 What is a Training Needs Analysis?

A Training Needs Analysis (TNA) is a process that identifies and defines the knowledge, skills, and attitudes required by an employee to perform on the job, and then recommends the learning and development activities that are needed to be implemented, in order to ensure the employee performs at that defined level.

The process of identifying knowledge, skills and attitudes needs to be tailored to the requirements of particular employers and workplaces, but it can include the following activities:

- Examining workplace job descriptions.
- Interviewing Employees about their job roles.
- Documenting a detailed task analysis of technician-style tasks performed on the job.
- Interviewing Supervisors about employee performance, safety, and efficiencies at the worksite.
- Interviewing Managers about the broader business need and how performance in this job role contributes to broader business efficiency, reputation, and risk reduction.
- Examining SOPs and equipment manuals.
- Examining the existing qualifications of workers and the kinds of skills they have developed in formal training environments.
- Asking how a worker's 'learning journey' through formal, workplace and informal learning has helped them develop the required skills.
- Examining non-accredited short course training that workers have undertaken.
- Documenting the findings in a Skills Matrix or Competency Matrix format and then validating those findings.
- Mapping existing skills levels of the workforce or graduates to desired skills levels to define and document whether there is a skills 'gap' in current training regimes.
- Concluding where investment in training and development should be prioritised and developing strategies to 'close the gap'.

3.2 Tailoring a TNA for micro and nanotechnology in Australia

There are some unique features of micro and nanofabrication in Australia which need to be considered when tailoring a TNA for ANFF and the industry.

These include:

- The novel and experimental nature of many of the fabrication and characterisation techniques and processes at ANFF.
- The relatively high number of PhD-qualified and Engineering staff members in the workforce.
- Different specialisations of different ANFF nodes.
- The relatively large number of different capabilities (89) across the nodes and associated wide range of equipment and technologies.
- The relatively small and nascent nature of the industry in Australia (described by one Interviewee as 'boutique'), when compared with the industry in the USA, UK, Canada, France, and Germany.

- Some skills requirements at ANFF will necessarily differ from industry, with the former being a research environment and the latter, more focussed on production efficiency and avoiding downtime.

4. Research Approach and Data Sources

This Report provides a summary of essential and desirable knowledge, skills and attitudes for nanofabrication and microfabrication technicians based on data gathered so far from:

- Job advertisements for 109 technician job listings in the nanotechnology and nanofabrication industries in the USA, UK, Canada, France, and Germany.
- 21 face-to-face and online interviews with ANFF staff and key industry stakeholders in Australia.
- Standard Operating Procedures (SOPs) for 73 different pieces of equipment used by ANFF in nanofabrication / laboratories / cleanrooms.
- A variety of workplace documentation, asset and equipment lists, Kanban boards and processes kindly shared by ANFF and industry.
- USA O*NET data reports for Nanotechnology Technicians and Nanotechnology Engineers.
- Specialised nanofabrication courses in Australia and overseas included both accredited and non-accredited:
  - 59 Overseas Courses
  - 20 Australian Courses.

4.1 Research Process Map

The research methodology process map was developed to illustrate the process that TAFE SA undertook in the TNA. The methodology process map can be viewed in appendix 10.1 Research Process Map.

The keys steps in the research process included the following:

1. General Research
2. Research Overseas Jobs
3. Research – Interviews
4. Analysis of SOPs to identify Knowledge, Skills and Attitudes
5. Consultation Paper Dissemination and Feedback
6. Research and Mapping of Educational Courses
7. Final Report
8. Final Presentation

As part of the research process there were a number of reporting milestones which ensured that ANFF and industry were validating the emerging findings (see appendix 10.1 Research Process Map for all components).

Key interim reports which were delivered to ANFF included:

1. Nanotechnology and Nanofabrication Technicians – Progress Report on Data and Emerging Skills Priorities
2. Nanotechnology and Nanofabrication Technicians – Consultation Paper on Essential Knowledge and Skills
3. Nanotechnology and Nanofabrication Technicians – Essential Knowledge and Skills Mapped to Qualifications and Courses.

This process allowed for a continuous process of refinement and validation to maximise the outcomes of the project.

Additionally, the O*NET skills data for 'Nanotechnology Engineering Technologists and Technicians' was examined for comparison with primary data gathered by TAFE SA. This can be viewed in Appendix 10.10 O*NET OnLine Summary Report.

4.2 Data-gathering activities

TAFE SA has undertaken the following key data-gathering and analytical activities:

Overseas Job Advertisements

- International Job Advertisement Analysis was conducted based on 109 nanotechnology technical job listings from online job sites and employer sites. The data was collected for technician level jobs in nanotechnology and nanofabrication companies and research facilities in the USA, UK, Canada, France, and Germany.
- Job roles included:
    - Mechanical Production Technician
    - Senior Cleanroom Laboratory Technician
    - Laboratory Support Technician
    - Process Technician
    - Assembly Technician
    - Nanotechnology Technician
    - Electro-mechanical Technician
    - Research Technician
    - Cleanroom Technician, and
    - Electronics Technician.

(A more detailed list is provided within this report at Section 5.1 International Job Advertisement Data).

Industry Interviews and Onsite Tours

- Detailed interviews with 21 stakeholders – including ANFF staff, ANFF industry contacts, TAFE SA industry contacts and attendance at nine site inspections (including multiple visits to some sites).
- Job role titles of the ANFF Interviewees have included: Facility Manager, Microfabrication Engineer, Research Associate, Technical Support Officer, CNC Milling Technician; Office Manager and Cleanroom Technical Officer.
- Job roles of Interviewees from industry included: Aerospace and Defence Manager; Director of Operations; Engineering and Quality Manager; Senior Engineer; Project Manager; SMT Manager; Chief Technology and Operations Officer; and Executive Director.
- ANFF Technical and Facilities Management staff from QLD, VIC, WA, NSW, and SA.
- Industry discussions have included engineering, production, and technical experts from EM Solutions; Entech Electronics; Bosch; Micro-X; BluGlass; Axiom Precision Manufacturing; Vaxxas; and REDARC Electronics.

As far as permitted, all interviews and site visits have been recorded by audio, video, and note-taking, with assurances given that individuals will be de-identified, and company commercial confidentiality will be respected. Recording devices and photographs were not permitted in some industrial locations due to commercial and defence industry confidentiality.

TAFE SA has also taken photographs of products, equipment, cleanroom, and laboratory set ups.

Standard Operating Procedures (SOPs)

TAFE SA examined 73 SOPs for different pieces of equipment used by ANFF in nanofabrication / laboratories / cleanrooms for ANFF's Melbourne node. The SOPs covered a range of three different equipment classes, labelled by ANFF as Easy / Safe (Green); Medium (Yellow) and Advanced / Dangerous (Red) (see appendix 10.5 List of Standard Operating Procedures).

4.3 Approach to Knowledge, Skills and Attitude Classification and Clustering

TAFE SA identified the need to cluster the Knowledge, Skills and Attitudes for technicians at two levels. The clusters of key Knowledge, Skills and Attitudes are called 'Key KSA Areas' and these are further described at the second level as 'KSA Topics'.

5. Findings

5.1 International Job Advertisement Data

5.1.1 Job Role Analysis

TAFE SA has examined 109 online recruitment advertisements from the USA, UK, Canada, France, and Germany, visible during February – March 2021 in order to extract out the knowledge, skills, attitudes, and experience that nanofabrication research institutions and industry are seeking when recruiting for Nanofabrication Technicians and early career Nanotechnology Engineers.

Listed below is the range of technician job role names for which candidates were being recruited in English-speaking countries in the nanofabrication industry. TAFE SA has clustered them into groups with other job roles that have similar functionality or titles. See Table 1 – List of International technical job role names in English speaking countries.

Groupings	Advertised Job Role Name
Technician	Technician
	QC Technician
Laboratory and or Cleanroom	Lab Technician
	Assistant Lab Technician
	Laboratory Support Technician
	Lab Technician
	Senior Cleanroom Laboratory Technician
	Applications Laboratory Technician – test
	Medical Laboratory Technician – Micro
	Cleanroom Technician
	Cleanroom Coordinator
	Laboratory Maintenance Technician
	Metallography Laboratory Technician
	Cleanroom Manufacturing Process Technician
	Cleanroom Manager
	Lab Electronics Technician
	Micro Lab Tech
	Lab Tech / Dry
	Augmented Reality / Virtual Reality Clean Room Operations Planner
Electronics	Electronics Technician
	Soldering Operative Technician – Micro-Soldering
	Electro-mechanical Technician
	Micro-electronics Technician – Diamond Turning
Chemistry	Chemistry Technician
Nanotechnology	Nanotechnology Technician
Production	Production Technician
	Production Operator
Processes and/or Manufacturing	Process Technician
	Technician – Deposition
	Lead Manufacturing Technician
	Manufacturing (Fabrication and Assembly) Technician
	Manufacturing Engineering Technician
Mechanical	Mechanical Production Technician

Mechatronics	Electro-mechanical Technician
Assembly	Assembly Technician
	Nano Assembly Operative
	Optics Assembly Technician
Characterisation	CD-SEM Equipment Engineering Technician
Testing	Test Technician
	System Repair and Test Technician
	Production Technician (Testing)
QA	Quality Assurance Technician
	QC Technician
Research	Research Technician
	Research Technician, Nanotechnology (temp role)
	Research Assistant Trainee

Table 1 – List of International technical job role names in English speaking countries

TAFE SA's observations based on job role names in English-speaking countries include:

- There are a large number of different technical job titles for technician level roles in nanotechnology and nanofabrication, given the sample size.
- A large number of job role names include the word 'technician' and/or 'laboratory' or 'cleanroom'.
- There is a hierarchy in these roles from Operator / Operative to Assistant Technician; Technician; Senior Technician; and Manager.
- Some roles have generic descriptions while others are highly defined in terms of the role of the technician to perform a certain function, carry out a particular process or use a particular piece or type of equipment.

These job roles are being offered by a diverse range of institutions and industry sectors. See Table 2 – List of industry sectors offering nanofabrication job roles.

Universities	Technology Products	Instruments and Services
Micromechanical Systems Applications	Smart Glass	Transparent Conductive Films
Bioelectric Medicine	Nanobubbles	Microelectromechanical systems (MEMS)
Photonic circuits, sensors, and biochips	Wholesale water soluble CBD (cannabidiol)	Skin cells
Microplastics	Optical communications systems	Space
Biopharmaceutical industry	Manufacture electronic materials in aerospace industry	Defence
Quantum technology	Material engineering	Nano implants for chronic care
Pharmaceuticals	Gene therapies	Batteries
Energy	Solar	Textiles
Skin care / Makeup	Tissue	

Table 2 – List of industry sectors offering nanofabrication job roles

The large number of companies with different commercial applications of nanotechnology also demonstrates the breadth and depth of the nanofabrication industry in the USA, UK, Canada, France and Germany. These countries have more diverse nanofabrication industries than currently exist in Australia.

The following table (Table 3) shows a range of job role names targeted for recruitment in France and Germany (some of which have been translated into English where the job was not advertised in English):

Technician	Quality Control Laboratory Technician
	Physics Laboratory Technician
	Laboratory Technician
	Metrology Technician, electron microscopy
	Production Technician in Nano
	Synthesis Technician of colloidal / inorganic particles
	Measurement and Testing Technician
	Technician developing functional materials based on biopolymers
	Technician in Medical Characterisation
	Chemical Laboratory Technician
	Chemical Technician
Technical Assistant	Chemical Technical Assistant
	Medical Technical Assistant
	Pharmaceutical Technical Assistant
	Biological Technical Assistant
Student or Researcher	Junior Researcher – Nanobiotechnology
	Student Assistant / Internship
	Student Assistant / Internship or Masters' Thesis
	Chemistry / Biology Laboratory or Bachelor
	Masters Student Project
	Chemical Manufacturing Manager

Table 3 – List of International Job role names based on advertisements in France and Germany

The majority of international job advertisements for technicians in nanotechnology and nanofabrication were not targeting graduates of Bachelor or post-graduate qualifications. Instead, many employers were looking for candidates with Diploma or Associate degree (sub-bachelor level) qualifications plus some experience (see Figure 1 – International Job Roles Findings – Education).

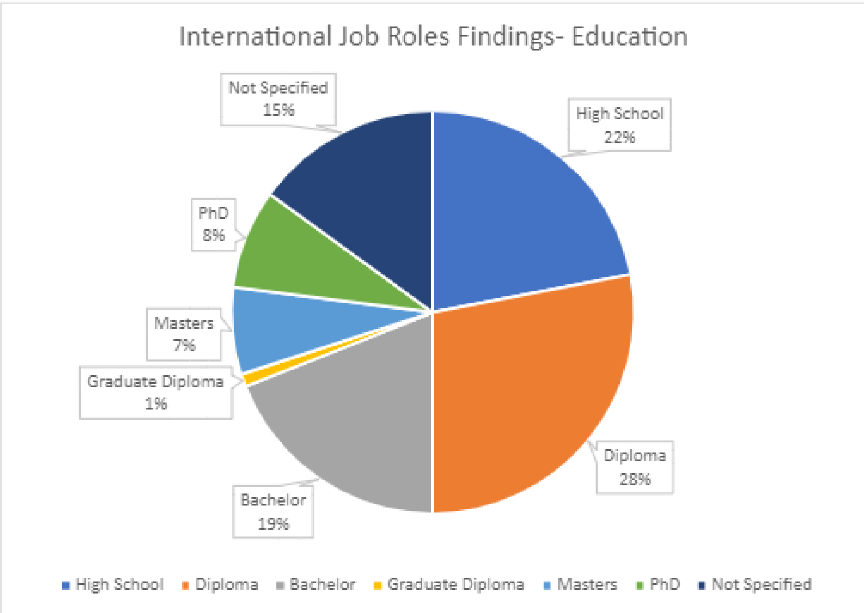


Figure 1 – International Job Roles Findings – Education

The levels of education required in the 109 international job advertisements examined were:

- Diploma / Associate degree 28%
- High School 22%
- Bachelor Degree 19%
- Not Specified 15%
- PhD 8%
- Masters' Degree 7%; and
- Graduate Diploma 1%.

5.1.2 Qualifications sought in Diploma Level Applicants

In Germany, there are a number of job roles that align directly with training at the Diploma level. These roles are Chemical Technical Assistant (CTA); Pharmaceutical Technical Assistant (PTA); Biological Technical Assistant (BTA) and Medical Technical Assistant (MTA). In addition to graduates of these technical assistant courses, German Research Institutes such as Fraunhofer, are also making strong use of student internships from Bachelor students or students wishing to undertake a Masters' degree in the laboratory.

In the USA there was strong demand for applicants with Technical Diplomas and Associate Degrees. However, there was also a strong preference that Diploma and Associate Degree level graduates have experience. Specific examples of the way which the qualifications and experience requirements were expressed in the USA include:

- Technical Diploma – Electronics
- Associate Degree – Micro-electronics
- 2 years College plus 8 years' experience
- 2 years Electrical or Technical Degree plus completion of Electrical Apprenticeship
- 2 years Electronics Technology, Electronics or Computer Engineering Technology Associate Degree + 5 years' experience.

In Canada, employers seeking Diploma level qualifications were requiring, for example:

- Technical Diploma in Nanotechnology Systems
- Diploma in Science
- Engineering Laboratory Assistant Diploma plus 'OSMT / CMSLS' preferred.

In Canada, the 'OSMT / CSMLS' is the certification provided by the Canadian Society for Medical Laboratory Science and is the preferred entry level for jobs as Medical Laboratory Technologists and Medical Laboratory Assistants.

In the UK, examples of the qualifications and certifications that employers were specifically seeking included:

- Time served in Mechanical Apprenticeships
- City and Guilds Part 3
- HND, HNC or BTech Level 3
- NQV in relevant subject area
- Advanced Diploma in a relevant subject area
- HNC or equivalent, Electrical / Mechanical discipline

- Associate Degree and GLP
- Soldering for space: ESA Qualified to ECSS-Q-ST-70-38C / 70-08C and IPC-A-610.

To decode the abbreviations that are being used in the UK advertisements, it is important to note that the UK had National Vocational Qualifications (NQVs) based on workplace assessments up until 2015; and employers are still using that terminology in advertisements.

In the UK, Higher National Diplomas (HNDs) and Higher National Certificates (HNCs) are sub-bachelor level qualifications. An HND is generally considered equivalent to the first 2 years for a bachelor level qualification.

The use of the term 'GLP' or 'Good Laboratory Practice' stems from OECD guidelines, USA FDA Rules and European Union Directives on quality systems for non-clinical health and environmental safety studies.

The 'soldering for space' reference relates to the European Space Agency standards for space project assurance regarding 'Manual soldering of high reliability electrical connections'.

The IPC-A-610 is a reference to the widely used inspection standard for printed circuit board assemblies from the IPC (Institute of Printed Circuits)

In France, recruiters were seeking:

- Two years of higher education or equivalent; or
- Two years plus experience in an OECD Good Laboratories Practice (GLP) environment.
- DUT or BTS Professional Licence in Biology, Biotechnology or Materials Sciences.
- Baccalaureate, BP, BT - Training in physiochemistry or chemistry or materials science.
- Bac + 2 level diploma (DUT, BTS) in physics, materials, or microelectronics.
- Level 5 of the national framework of professional certifications or BAC + 2 in the field of physical and chemical sciences, geology, life and earth or materials chemistry.
- BTS / DUT level diploma or equivalent in theoretical mechanics or physical measurements.

In France it is common to speak of a 'Bac +2' level qualification. This means 2 years of study following completion of secondary education. The DUT Diplôme universitaire de technologie / Diploma in Technological Studies, or BTS licences are a reference to licences that are issued for completion of 2-year Diploma courses from universities.

5.1.3 High School Level Applicants

The main countries where high-school level qualifications were mentioned as relevant to entry level were the USA and the UK.

In the USA these requirements were described as:

- High School Diploma or GED plus 2 years' experience
- High School + Wet Chemistry Experience
- High School + 6 months cleanroom experience
- High School + completion of a vocational training course or formal apprenticeship in machine shop.

In the UK high school entry was described as:

- minimum of 4 GCSEs at grades A* - C (incl. English and Maths), or,
- NVQ level 1 in a relevant subject area and have previous experience of working in a similar laboratory.

In the UK, GCSE stands for General Certificate of Secondary Education. An NVQ level 1 is a very basic level vocational award.

5.1.4 Bachelor Degree-qualified Applicants

For the USA job descriptions where bachelor level qualification was sought, the following are examples of the requirements:

- Bachelors + 5 years' experience in semiconductor cleanroom
- BS Physical Sciences or Engineering with 5+ years' experience
- BA or BS Degree plus 8 years relevant experience
- Bachelor's Degree Engineering.

It is interesting to note that where USA recruiters were seeking candidates with bachelor's degrees, they were also seeking a considerable amount of experience, compared to the average experience being sought internationally.

Canadians were seeking:

- Degree in Science or Engineering
- Bachelor's in Nanotechnology or Engineering
- Bachelor of Science Electrical Engineering.

In the French advertisements, there were suggestions that their BTS and BAC+2 qualifications i.e. qualifications that involve 2 years of post-secondary study may be equivalent to USA Bachelor qualification.

In Germany the main qualifications targeted were Bachelor degrees in Chemistry, Chemical Engineering, Materials Science or Minerology.

5.1.5 Key observations on years of experience

The international job advertisement data shows that where recruiters specify the number of years of experience that they require, they are targeting applicants on average with a relatively low level of experience (see Figure 2).

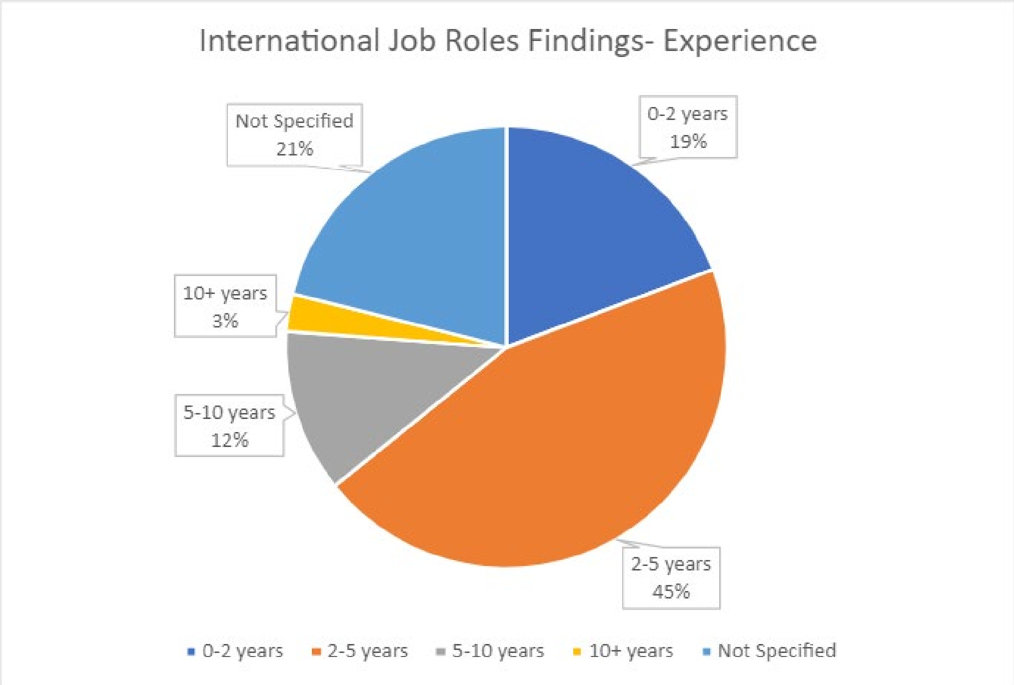


Figure 2 – International Job Role Findings – Experience

In 19% of cases, between 0-2 years' worth of experience is indicated. In 45% of advertisements 2–5 years of experience is desired. In 21% of cases the years of experience were not specified.

In only 15% of cases was more than 5 years' experience desired. And in only 3% of cases was someone with 10 years plus experience being sought.

5.1.6 Key observations on Knowledge, Skills and Attitudes from International Job Advertisements

The International Job Advertisements show there are 22 commonly sought-after knowledge, skills, and attitudes that 30% or more of employers of nanotechnology technicians are searching for (See Figure 3).

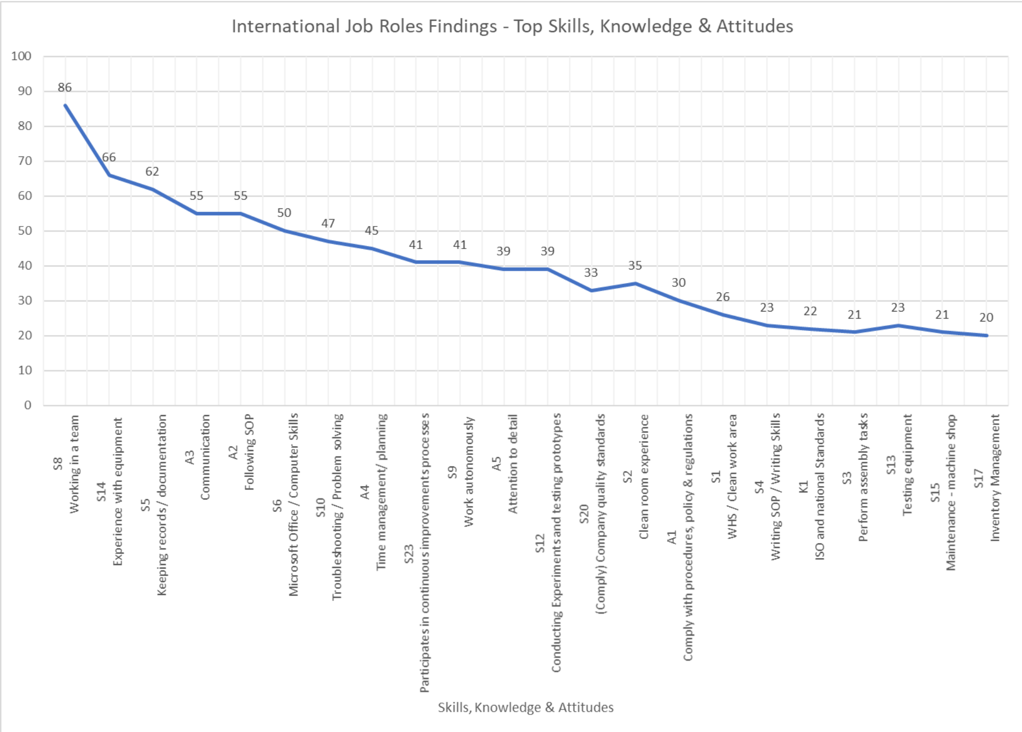


Figure 3 – International Job Roles Findings – Top Knowledge, Skills and Attitudes

The key (top 22) attitudes employers in nanotechnology and nanofabrication are searching for are shown in Table 4.

Working in a team	Time Management / Planning	Comply with procedures, policy, and regulations
Experience with equipment	Participating in Continuous Improvement Processes	WHS / Clean Work Areas
Recordkeeping / documentation	Working autonomously	ISO and National Standards
Communication	Attention to detail	Perform Assembly Tasks
Following Standard Operating Procedures (SOPs)	Conducting experiments and testing prototypes	Testing equipment
Microsoft Office / Computer Skills	Complying with company quality standards	Maintenance – Machine Shop
Troubleshooting / Problem Solving	Cleanroom Experience	Inventory Management

Table 4 – Top Attitudes outlined by employers

TAFE SA has compared the main skills and attitudes sought from international job role data to the ANFF Technician and Senior Technician job roles data supplied by ANFF. This assists in determining whether the main skills and attitudes being targeted internationally are also important to ANFF. (see Table 5).

International Technical Job Advertisements in Nanotechnology Research and Industry	ANFF Technician Role Extract Provided	ANFF Senior Technician Role Extract Provided
Working in a team	Teamwork not specifically mentioned but could be implied.	Ability to work … collaboratively with others. An ability to establish effective relationships and to represent and promote ANFF … Node.
Experience with laboratory equipment	Provide technical and user support for equipment. Maintain and operate a range of equipment (e.g. CNC Machining, cleanroom fabrication equipment). Under general direction, design and fabricate components and devices using computer software for experiments within project scope.	Expert hands-on knowledge of electronics / electrical / mechanical pneumatic equipment repair. Demonstrated practical knowledge of semiconductor equipment. Demonstrated experience with equipment preventative maintenance. Utilise technical expertise, provide a high level of operational, scientific, and technical support … for frequent users.
Recordkeeping / documentation	Prepare inspection reports. Provide technical information to support the preparation of capital equipment acquisition grants.	Ability to keep detailed records and produce high quality technical reports. (Also expected to supervise the Technician's preparation of inspection reports)
Communication	Prepare inspection reports. Provide technical support and information on ANFF facilities and capabilities to users accessing equipment. Train and oversee students, staff, and approved users.	High level communication and interpersonal skills.
Following Standard Operating Procedures (SOPs)	Maintain and operate equipment… in accordance with the University's WHS and ANFF procedures and processes.	Oversee the development and maintenance of relevant policies and procedures. Ensure correct WHS / OHS procedures are maintained for NCRIS ANFF-Q users.
Microsoft Office / Computer Skills	Design and fabricate components using computer software for experiments.	Provide training in designing and testing of devices by utilising software programs such as Intellisense and Layouteditor
Troubleshooting / Problem Solving	Proactively identifying and resolving problems to avoid delays.	Excellent organisational and problem-solving skills.

Time Management / Planning	Support projects to ensure they are successfully delivered on time. This includes monitoring project milestones, managing conflicting timelines and proactively identifying and resolving problems to avoid delay.	Ability to work within deadlines. Proactive management to maximise uptimes and quality.
Participating in Continuous improvement Processes	Prepare inspection reports under supervision of Facility Manager or delegate.	Ensure compliance with ANFF quality.
Working autonomously	Works 'under general direction'.	Implied but not explicit.
Attention to detail	Implied but not explicit.	Implied but not explicit.
Conducting experiments and testing prototypes	Train and oversee students, staff, and other approved users in the operation of relevant instrumentation and characterisation of manufactured components and devices.	Activities enable Researchers to do this.
Complying with company quality standards	Maintains and operates equipment in accordance with …University and ANFF … Node procedures and processes.	Ensure compliance with existing ANFF-Q procedures, including managing and administering access and logging use to equipment capability within the ANFF-Q, this includes providing processing and analysis. Ensure correct WHS / OHS procedure are maintained for NCRIS ANFF-Q users.
Cleanroom Experience	Maintain and operate a range of equipment (including cleanroom fabrication equipment).	Manage and maintain class 10,000, 1,000 and 100 clean rooms (or ISO 7,6 and 5). Demonstrated practical knowledge of semiconductor equipment and processing.
Comply with procedures, policy, and regulations	… operate… in accordance with the University's Workplace Health and Safety and ANFF … Node procedures and processes.	Experience in developing and maintaining Standard Operation Procedures (desirable).
WHS / Clean Work Areas	… operate… in accordance with the University's Workplace Health and Safety and ANFF … Node procedures and processes.	Experience in developing and maintaining Standard Operation Procedures (desirable). Ensure correct WHS / OHS procedures are maintained for NCRIS ANFF-Q users.
ISO and National Standards	Implied in maintaining and operating a range of cleanroom fabrication equipment.	Manage and maintain class 10,000, 1,000 and 100 clean rooms (or ISO 7,6 and 5).
Perform Assembly Tasks	Implied if relevant components and devices are manufactured that require assembly.	May plan for this or train others to do this
Testing equipment	Implied in maintaining a range of equipment.	Implied in maintenance and repair of testing equipment.
Maintenance – Machine Shop	Maintain and operate a range of equipment (CNC and cleanroom).	Manage, maintain, and operate a range of advanced micro / nanofabrication and testing equipment to enable them to operate to the full extent of the equipment capability and to allow

		research at the cutting edge of technology. Manage facility-specific procurement, distribution, equipment repair and maintenance processes. Demonstrated experience with equipment preventative maintenance.
Inventory Management		Manage facility-specific procurement, distribution, equipment repair and maintenance processes. Ensure cleanroom consumables are maintained at user levels.

Table 5 – International Technical Job Advertisements in Nanotechnology Research and Industry compared to the extracts in ANFF Technician and Senior Technician Role

There are a number of ANFF Senior Technician requirements that appear to be above and beyond those reflected in the international job advertisements for nanofabrication technicians. These include:

- Proven track record in effectively training clients in equipment operations and scientific techniques.
- Providing training in designing and testing of devices by utilising software programs.
- Keep up to date with new advances in techniques and research by literature searching and other relevant sources of information.

ANFF Technician requirements exceeding those commonly reflected in international job advertisements are:

- Providing technical information to support the preparation of capital equipment acquisition and reports to ANFF, government, and other funding bodies.
- Working very closely with ANFF users to support their projects. This includes 'developing a comprehensive knowledge of the user's science and specific project goals'. This degree of support for customer requirements and new manufacturing processes is very high and not reflected in the international jobs data.

5.2 Interviews

Stakeholder Interview and Site Visit Data Summaries and Findings

TAFE SA conducted detailed face-to-face and online interviews with 21 stakeholders – including ANFF staff, ANFF industry contacts, TAFE SA industry contacts and attended nine site inspections (including multiple visits to some sites).

Job role titles of the ANFF Interviewees have included:

Facility Manager	Microfabrication Engineer
Senior Research Associate	Technical Support Officer
CNC Milling Technician	Office Manager
Cleanroom Technical Officer	Polymer Fibre Facility Manager
Cleanroom Equipment Engineer	Engineering and Quality Manager
Manager (Workshops Engineering)	Technical Support Officer – Electronics

Job roles of Interviewees from industry included:

Aerospace and Defence Manager	Director of Operations
Engineering and Quality Manager	Senior Engineer
Project Manager	SMT Manager
Chief Technology and Operations Officer	Executive Director
Senior Medical Device Engineer	

Interviews have been fully transcribed, edited and analysed for inclusion in developing detailed knowledge, skills, and attitude matrices. The process of transcribing interviews required careful editing, as there are a multitude of highly technical terms that are not automatically recognised by the assistive software.

Stakeholder interview data and analysis is extracted below under the following headings:

- Knowledge of Micro and Nanofabrication Technicians
- Skills of Micro and Nanofabrication Technicians
- Attitudes of Micro and Nanofabrication Technicians.

Knowledge of Micro and Nanofabrication Technicians

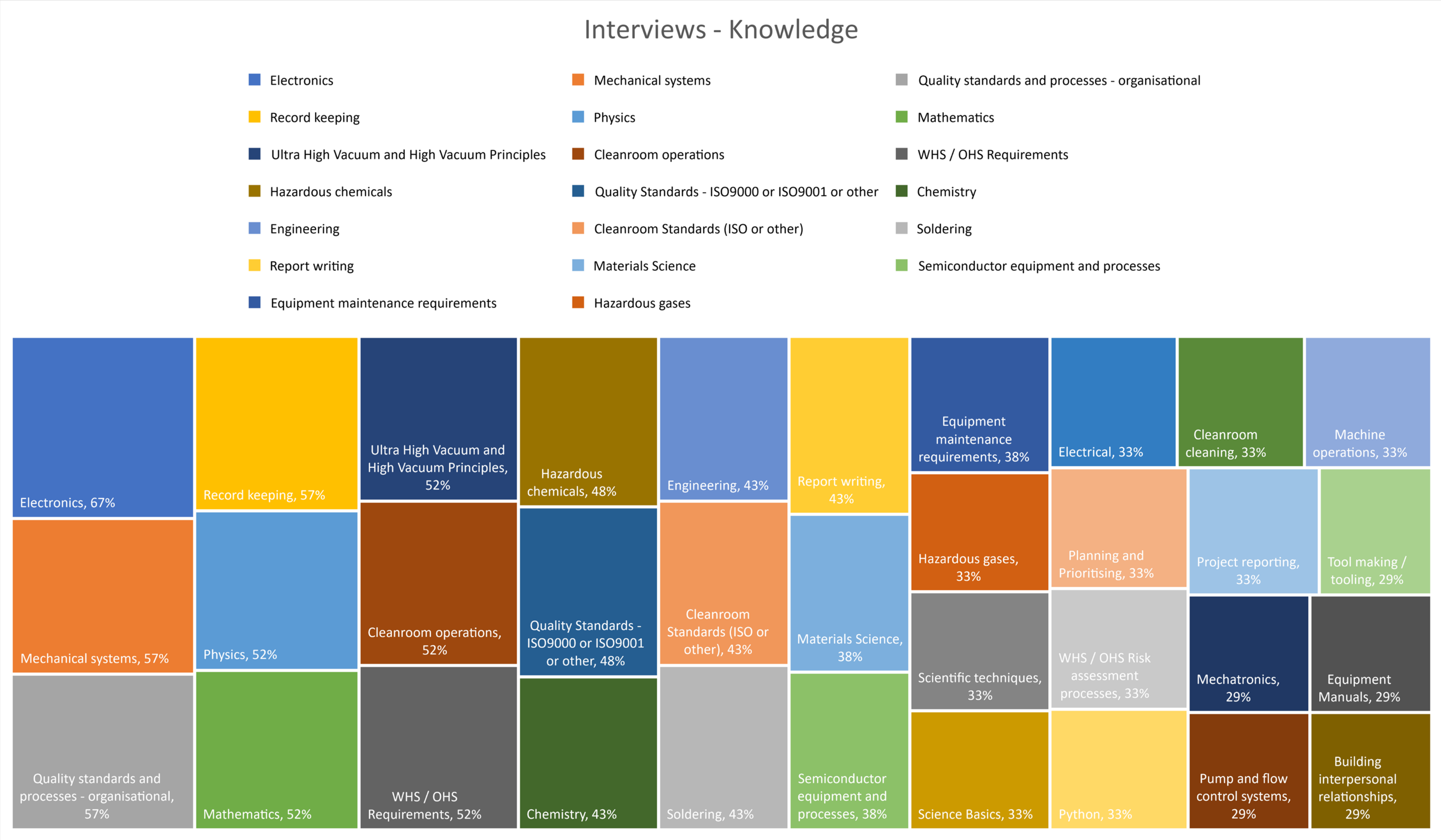


Figure 4 – Knowledge of Micro and Nanofabrication Technicians from Interviews

As per Figure 4, shows that Interviewees have provided many examples of the types of ideal and assumed knowledge that technicians would bring to their roles.

There is a strong consensus that the depth of knowledge does vary between technicians and senior technicians. Key knowledge areas are:

- Electronics, together with or with a particular focus on semi-conductor manufacturing equipment and processes
- Mechanical systems. Technicians spend a lot of time ensuring mechanical systems are maintained and operate well
- Record keeping and Report writing
- Physics
- Mathematics
- Ultra-High Vacuum and High Vacuum Principles
- Cleanroom operations, ISO, and Quality Standards
- WHS / OHS Requirements
- Chemistry, in particular hazardous Chemicals and Gases
- Engineering
- Soldering.

Additionally, Interviewees raised a number of areas of desirable knowledge which may be included in the above or cross-over. These are:

- Materials Science
- Cleanroom cleaning
- Electrical, including basic electrical systems and circuits
- Skills from tool-making trades and tooling
- Scientific principles or knowledge applicable to specific nanofabrication equipment e.g. pneumatics, pump and flow control systems, chemical vapour deposition, photolithography, x-rays, plasmas, etching, thermocouples, injection moulding, plumbing basics, radio, and laser technologies
- Scientific Method
- Mechatronics.

Skills of Micro and Nanofabrication Technicians

Based on the volume of skills material and responses, TAFE SA has divided skills requirements into skills required for Facilities Operations and skills required for Process Operations. While there is some cross-over, it is conceptually helpful to make a distinction between the different contexts for the application of the two sets of skills.

Skills for Facilities Operations and Project Management

Figure 5 – Skills, Facility Operations of Micro and Nanofabrication Technicians from Interviews

There are a number of areas where Interviewees placed a high level of skills for facilities operation and management of projects and work (see Figure 5). In particular, skills which were referred to by 50% or more of the Interviewees include:

- Implement maintenance for equipment, machines, and instruments
- Develop and maintain SOPs for facility
- Read, interpret and apply engineering drawings, schematics, and technical documents to plan use of facilities and projects
- Implement maintenance required for facility.

Skills that were referred to by 43% to 49% of Interviewees and may also be essential are:

- Work safely with equipment machines and instruments
- Read and interpret ISO Standards, IPC standards and other standards to facility and projects
- Ensure compliance with safe operating procedures
- Participate in one-on-one work activities (mentor, buddy, work shadow etc)
- Read, interpret, and apply quality standard for organisation and other quality standards, ISO Standards, IPC standards and other standards to facility and projects
- Develop preventative maintenance plan for the facility
- Liaise with original equipment manufacturer (OEM) for equipment maintenance and fault plan.

Skills for Process Operations

Figure 6 – Skills, Process Operations of Micro and Nanofabrication Technicians from Interviews

There are a number of areas in process operations where Interviewees recorded a high level of agreement (see Figure 6). These include routine and planned maintenance, troubleshooting faults, repairs and following SOPs.

Skills which were referred to by 50% or more of the Interviewees include:

- Troubleshoot issues if these arise during operations
- Troubleshoot equipment faults when issues arise
- Perform routine and planned maintenance for equipment and machinery
- Rectify and repair equipment and machinery faults within capabilities
- Follow work instructions
- Conduct tests to evaluate components, part, or product
- Assemble components to outcomes required
- Interpret work / project objectives and requirements to achieve outcomes
- Report information for projects and work activities
- Follow standard operating procedure to perform task
- Perform operations to complete task.

Skills that were referred to by 43% to 49% of Interviewees that are also likely to be essential are:

- Identify issues and take corrective actions
- Comply with WHS and standard operating procedures prior to entering a cleanroom
- Provide technical support and information to facility users
- Design component using software or by hand
- Microscopes
- Cleanrooms
- Set up equipment and machine to achieve outcome
- Follow standard operating procedures when contacting tasks in a cleanroom
- Use equipment in a cleanroom follow standard operating procedures
- Contact training for equipment, machines, and instrumental users.

TAFE SA has developed a list of key software and equipment, (refer to findings in Figure 7 and Figure 8 below) in order to inform recommendations. Based on interview data to date, illustrations of key software and equipment / machinery are extracted:

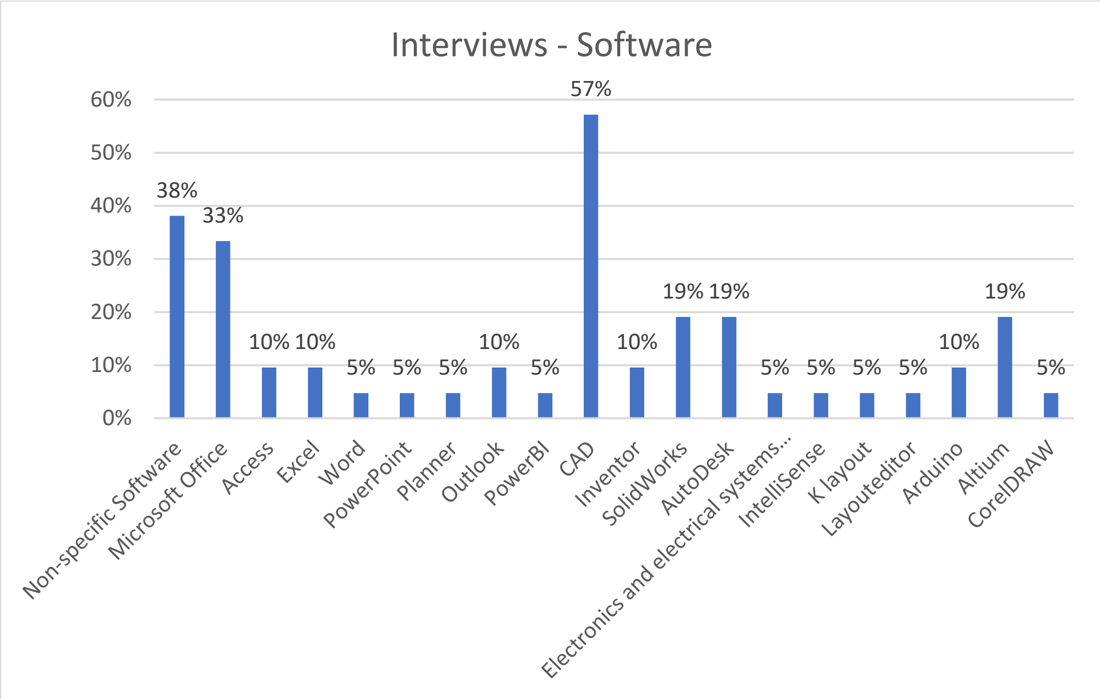


Figure 7 – Software identified in interviews

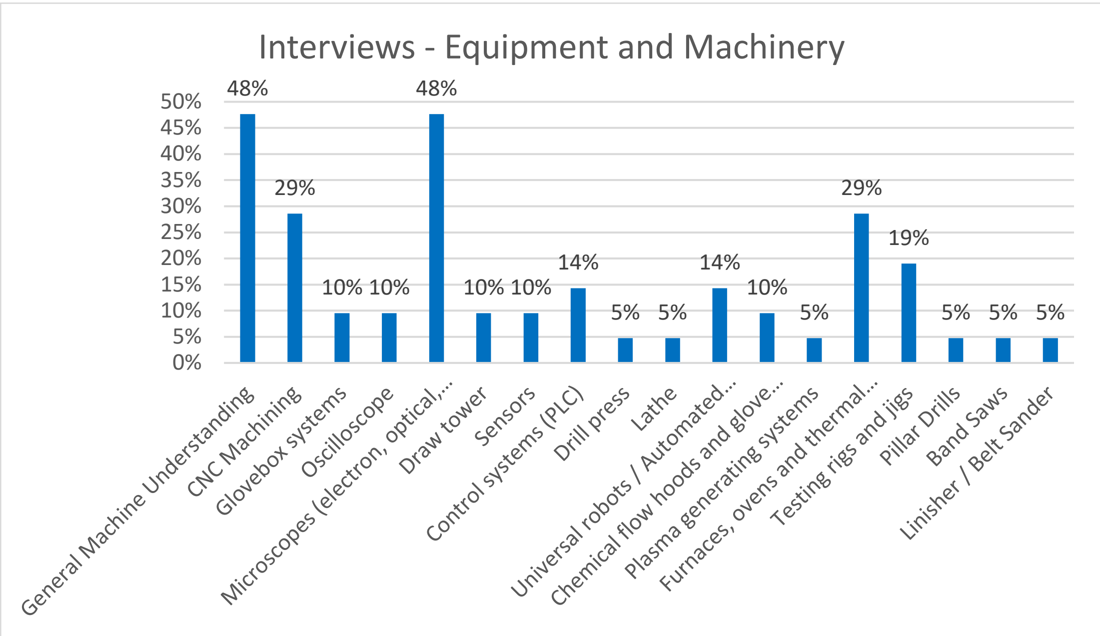


Figure 8 – Equipment and Machinery identified from interviews

Attitudes

Additionally, Interviewees placed heavy importance on the need to recruit people with the right attitude. Attitudes such as Problem solving; Work as part of a team; Communication; Attention to detail; and Time management all rated highly. In the interviews some industry experts prioritised attitudes above knowledge. The rationale for this approach seemed to be that it is easier to expand people's skills through training or mentoring than it is to shape their attitudes (Refer to Figure 9 for key attitudes).

Feedback from our Interviews in relation to Attitudes included:

> *Generally, we just try to find people with the right aptitude and attitude. People that are willing to learn [and] show some, I guess, interest and passion for it and then you can develop them. We've got the in-house skills to be able to train them up, so it obviously takes time to be able to build them up to that level. But it is hard to find people at the moment, that's the only option we've got. We'd love to get people straight off the street and with minimal training, get them up and running, but that's extremely difficult in the current climate.*

> *I think a lot of it is just the attitude. You can have someone who's knows everything, but unless they can communicate and work within a team and…the attention to detail and stuff that you can't just read in a book. I think that's just as equally important as the technical side of things.*

> *Obviously, one is dedicated to culture. We see if they fit within the business. But I think yeah, making sure you get the right people with the right attitude is critical to the success of any project or any manufacturing process you're doing.*

During the interviews there was consistently strong feedback from industry and ANFF, that Problem Solving, Communication and Time Management skills were very important. These attitudes determine how an employee approaches challenges, finds solutions and adapts to change, especially in a manufacturing environment. This was echoed by a number of Interviewees:

> *Problem solving skills and communication are important, they don't have to be the world's best conversationalist, they just need to be being able to communicate clearly.*

> *I think communication is really important. We have people from a lot of different backgrounds. Communication, critical thinking, and problem solving, this would be core. Not everybody can attend to the same problem at the same time, so being able to critically think and try to attempt to solve the problem would be important.*

> *In terms of soft skills [and] communicating with the right stakeholders, we need the people who can really communicate across the board in terms of relaying what the problem is and trying to find solutions that would be really important.*

> *The other skill I think would be time management. That's really important because when we have problems, we want it to be solved in a timely manner and that would be critical to their role as well.*

Figure 9 – Attitudes from interviews

Distinctions between ANFF Technicians and Industry Technicians

The interviews revealed differences between KSAs required for ANFF Technicians compared to Industry Technicians. ANFF Technicians develop expertise across a wider variety of processes, as they work closely with researchers to innovate, have broad areas of responsibility, and operate with a high degree of autonomy. ANFF Technicians have highly developed networks within their universities and can draw on the expertise of academics, engineering services and trade staff to problem-solve and seek guidance for solutions.

Industry Technicians ensure production processes run smoothly and repair and maintain commercial-scale equipment to produce, test, or modify products. Operations and modifications to advanced equipment take place under the supervision of process and mechanical engineering staff. Industry makes clearer distinctions than ANFF between job roles such as Operator, Technician and Engineer. Both ANFF and industry encourage technicians to problem-solve and troubleshoot but Industry Technicians adhere to strict manufacturing guidance and do not make changes without a sign off from the process engineer or supervising engineer.

Distinctions between the Technician Role and an Operator Role

It was generally agreed by Interviewees, that an Operator would perform a more basic role than a technician. Responses in the interviews indicated that it was important to distinguish between Operators and Technicians and the types of tasks and responsibilities undertaken by them. In the industrial environment there were particular questions about whether it would be Operators or Technicians who would assemble components:

> *Yes, usually, [for] the assembly [of] components, we call them Operators. Yes, it's slightly lower than a technician. We ask a technician to assemble. The advantage of having a technician do the assembly, is that he can also do fault-finding at the point of assembly. He will have a bit more knowledge about how the process is flowing and he will be able to interpret and make a call as the process is happening. An operator will have a list of instructions to do, and they will just go through till the outcome.*

A strong preference was expressed for technicians to undertake the work.

> *We would prefer a technician to do that kind of work because it's a low volume but high value product, so you want someone to identify the issue immediately, not at the end of the whole batch being manufactured.*

In some industrial settings the term ‘Machine Setter’ was used for a Technician and their role was distinguished from that of an Operator:

> *We don't call them technicians, but we could. We call them ‘machine setters’ so they basically deal only with setting up the machine to make sure its production worthy to run the products. And then they step away. Operators are called operators, they just run the operation aspect of the production line.*
>
> *The operator’s job is just to flag the machine and stop it from running the products, and then if there is a deviation in the process, that gets attended to by the machine setters.*

Model Technicians

ANFF had a number of technical staff who appeared to be model technicians and employees with a multitude of complex technical skill and knowledge.

ANFF employees are ‘masters of all trades’ in their jobs compared with a number of industry related technician roles. One technician had an extensive level of skill, knowledge, and attitude, unlikely to be readily achievable for other technicians. This employee had:

- A broad range of skills such as fabrication, planning, project management, WHS, SOPs, compliance and standards, CAD design, maintenance and repair, continuous improvement, training, testing of prototyping and fault finding.
- A deep bank of knowledge that included, mechanical, nanotechnology, mathematics, physics, cleanrooms, vacuums, and project management techniques.
- Very strong positive attitudes and behaviours which included exemplary communication, customer service skills, problem solving, and time management skills.

After leaving school he spent between 7 and 8 years undertaking further education, while working, which included completing a tool making apprenticeship and Bachelor of Technology degree. During and after this education, this individual also worked across numerous engineering companies gaining experience in procurement, scoping customer requirements, project management, and designing and machining components. The projects also gave the staff member exposure to a variety of industries that include Oil and Gas, Water, Rail and Defence and the standards, WHS and quality control requirements in those industries.

5.3 Standard Operating Procedures (SOPs)

Through our research TAFE SA examined 73 SOPs for different pieces of equipment used by ANFF. Additionally, the 10 most commonly identified Knowledge in the SOPs Knowledge Matrix (see Figure 10) includes:

- Emergency shutdown procedures 93%
- Red EMO button 93%
- Safety glasses (e.g. Polycarbonate, googles, laser safety glasses) 93%
- Booking of equipment 90%
- Logbook procedures 88%
- Dangerous goods waste management training 86%
- Training assessment, checklist, signoff to occur 85%
- induction-site and local area 84%
- Participate in one-on-one learning activities (mentor, buddy, work shadow etc.) 74%
- How to fill out logbook 73%.

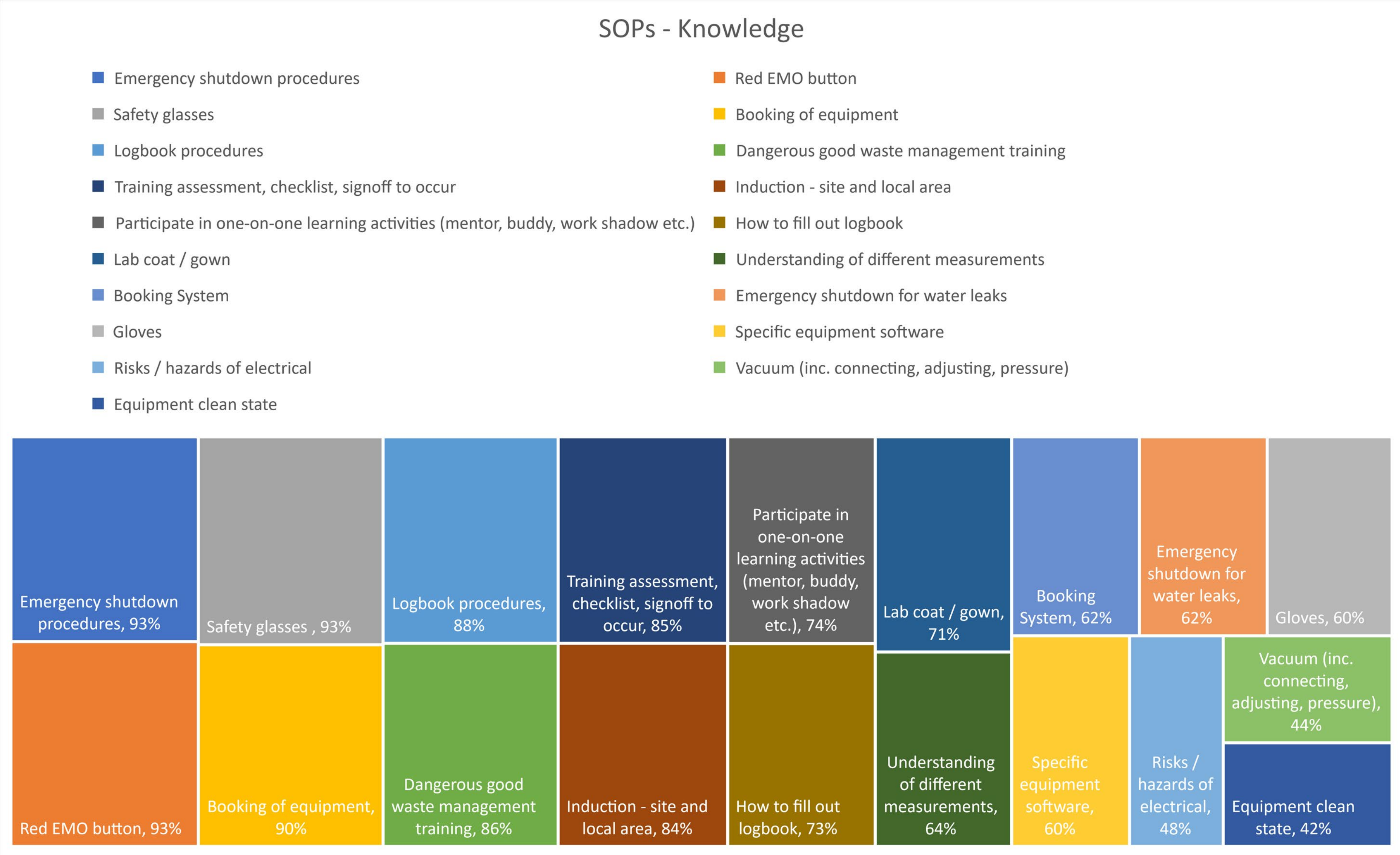


Figure 10 - Knowledge from Standard Operating Procedures (SOPs)

The key most frequent skills identified in the SOPs Skills Process Operations Matrix (see Figure 11) included:

- Follow work instructions 100%
- Work safely with equipment machines and instruments 93%
- Follow standard operating procedures to perform task 92%
- Set up equipment and machines to achieve outcome 89%
- Uphold safety and cleanliness 88%
- Use appropriate PPE, based on the procedures or process 86%
- Follow standard operating procedures when conducting tasks in cleanroom / laboratory (inc. PC2 lab) 85%
- Check parameters 81%
- Load sample / wafer / substrate appropriately 81%
- Perform operations to complete task 74%.

Skills for Process Operations from our interviews research aligned with the SOPs findings for those needed to operate equipment and machinery (refer to Figure 6 and Figure 11) which include:

- Troubleshoot issues if these arise during Operations
- Troubleshoot equipment faults when issues arise
- Follow work instructions
- Follow standard operating procedures
- cleanroom operations
- Ultra-High Vacuum and High Vacuum Principles.

Figure 11 - Skills from Standard Operating Procedures (SOPs)

The skills at a facilities operation level were also identified in the SOPs Skills Facilities Operations diagram (see Figure 12) but rated low. This is due to the high level of skills identified which are suited to a role above a technician level. The low rating of SOPs tasks relates directly to the operation of machinery compared to the wholistic skills, needed in facility operations. In the SOPs Skills Diagram: Participate in one in one learning activities (mentor, buddy, work shadow) rated the highest, followed by: Liaise with Original Equipment Manufacturer. Both directly aligned to the operation of machinery.

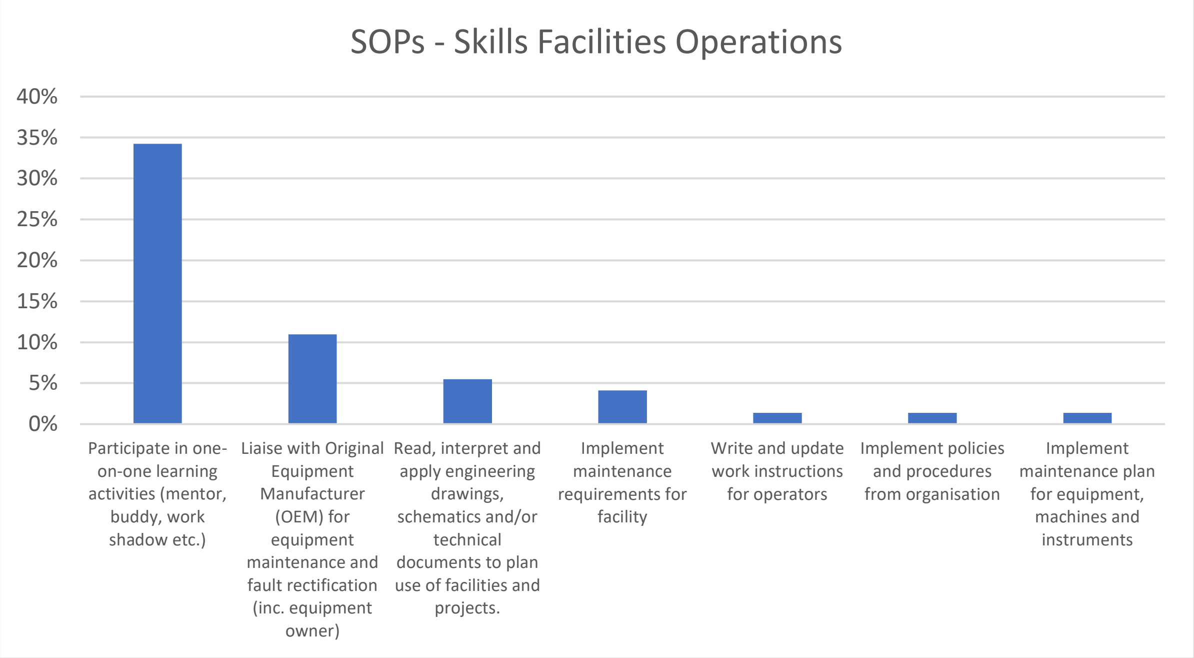


Figure 12 – Skills Facilities Operations from Standard Operating Procedure

The highest rated attitudes, based on the SOPs (see Figure 13) were:

- Respect User Etiquette 100%
- Attention to detail 91%
- Disciplined / Follows rules 92%
- Work autonomously 86%
- Written communication 79%
- Verbal communication 78%
- Work to deadlines 62%
- Work as part of team 63%.

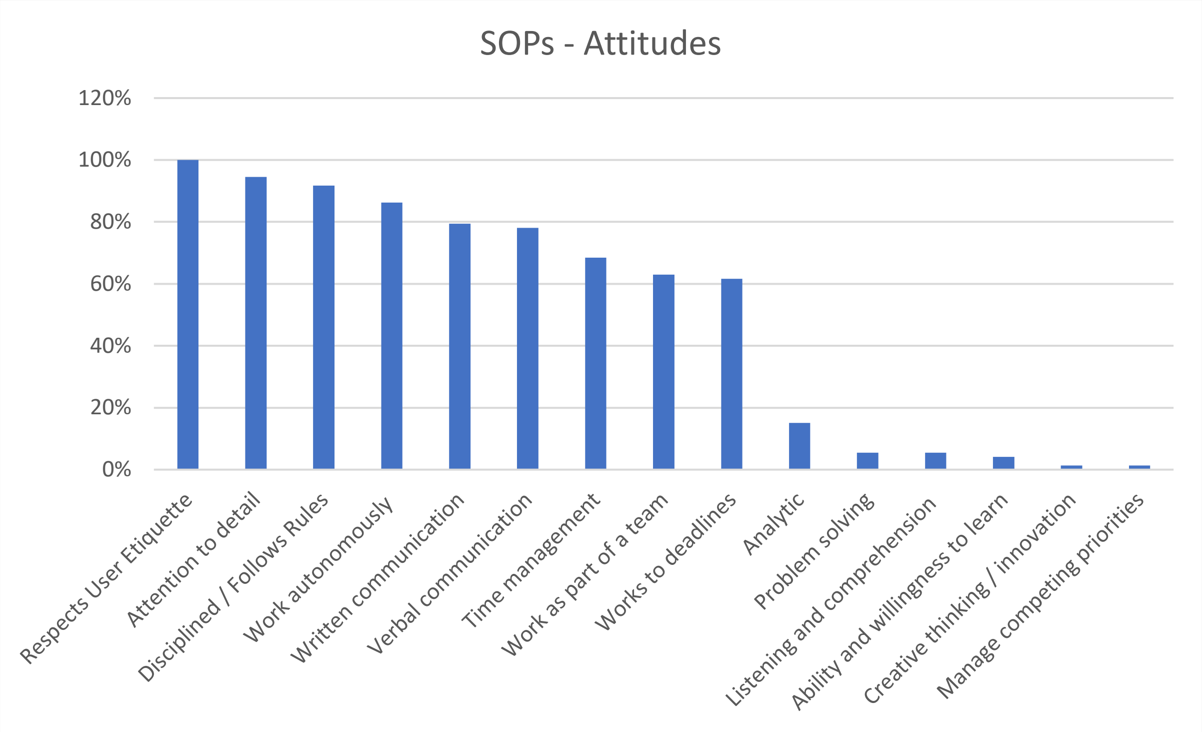


Figure 13 – Attitudes from Standard Operating Procedures

Attitudes in the international Job Role findings that most strongly aligned with attitudes in the SOPs were:

- Work in a team
- Attention to detail
- Troubleshooting / Problem solving
- Comply with procedures, policies, and regulations
- Communication
- Work autonomously
- Time management / Planning.

5.4 Workplace Health and Safety (WHS) Skills

Workplace Health and Safety (WHS) skills rated highly across all data sources. Workers who use nanotechnology in research or production processes may be exposed to nanomaterials through inhalation, skin contact, or ingestion.

The WHS skills that rated highly were:

- Follow work instructions
- Work safely with equipment, machines, and instruments
- Follow standard operating procedures to perform task
- Uphold safety and cleanliness
- Use appropriate PPE based on the procedure or process undertaken
- Comply with WHS and standard operating procedures prior to entering a cleanroom
- Comply with WHS requirements to perform tasks
- Ensure WHS controls are followed.

At a Senior Technician or Facilities Management Level additional WHS skills included:

- Implement WHS requirements for facility from organisational policies and procedures
- Apply WHS policies and procedures
- Conduct risk assessments
- Write and review standard operating procedures.

In performing WHS knowledge and skills, of common hazards, risks, controls, and particular PPE included:

Common Hazards and Risks

Electrical	Hazardous Chemicals IPA, Photoresist, Hydrofluoric Acid (HF), Solvents, Acetone, Nitric Acid, KOH	Hazardous Gases HF, O_2, N_2, CH_4, Ar, N_2O, SF_6, SiH_4, CF_4, NH_3, BCl_3, Cl_2, He
UV rays from gas plasma or UV light source	Pinching from equipment (doors, lids, tools)	Hazardous substances including nanoparticles and fine powders.
Radiation (X-rays)	Lasers	Hot surfaces

Controls

Elimination	Substitution	Standard Operating Procedures
Training	Buddy and Mentoring systems	Fume hoods and glove boxes
Preventative Maintenance	Reporting	Logbooks
Different authority levels for equipment users.	PPE	Emergency Procedures including showers, eye wash, first aid, shut down buttons and evacuation.
Cleaning, Wiping and Waste Disposal protocols	Chemical Labelling Rules	MSDSs

PPE

Gowning and de-gowning procedures	Types of common PPE: Safety glasses, lab coats / gowns, gloves, face masks	Additional PPE for specific processes: nitrile gloves, over-boots / overshoes, face shields, aprons

One respondent to the Consultation Paper identified additional PPE training requirements where arsenic, mercury or cadmium are in use:

> *Respirator training courses should be included for technicians, both of the cartridge filter kind and the closed breathing apparatus kind.*

5.5 Process Operations

The following skills, relevant to different stages of process operations, rated highly:

Preparation
- Ensure equipment is booked and free before using
- Check materials, consumables and other resources required to perform task are available
- Turn on equipment and log in to associated software programs
- Check equipment parameters (see equipment section).

During Operations
- Perform operations to complete set tasks
- Select, input and/or adapt recipe according to required process
- Select chuck or clamp / mount sample / substrate / work piece / stub / transfer shuttle
- Load samples
- Apply scientific knowledge to process operations
- Run process / start scan / initialise / align
- Read and interpret monitoring systems and sensor outputs to ensure conformance to requirements
- Log errors
- Remove wafer or samples as per procedures (inc. using correct tool).

Shut down and clean up
- Complete shutdown procedures
- Complete clean up requirements
- Follow waste disposal and labelling protocols for equipment in use or process undertaken.

Assembly and Packaging
For manufacturing environments, the following skills were also desirable:

- Assemble components to outcome required
- Conduct tests to evaluate component, part, or product.

The following Process Operations skills, were also identified but sit at Senior Technician or Process Engineer level:

- Oversee equipment, machines, and instrumentation users
- Provide technical support and information to facility users
- Produce and test a prototype
- Read and interpret monitoring systems and sensor outputs and data to identify faults
- Conduct experiments and test prototypes
- Read and interpret technical manuals to perform work
- Use technical knowledge to perform work activities, provide supervision and advice to others.

As one Senior Technician indicated in our interviews:

> *Equipment training is like your Ps and Ls [Driver Licence]; you need to do so many hours. Yes, obviously it depends on the person as well.*

Feedback from our Consultation Paper captured the level at which a Technician should understand and operate the system:

> *Technicians should be able to understand the system to the component level in a general way and should be trained to identify likely failure models based on the mode of operation of the tool. At the technician level, they do not necessarily need to guide and document this procedure but should be able to execute it 'intuitively' at least, to track their changes, change one thing at a time, test their work, and to report. They should also be able to work within a team guided by an engineer engaging in…that intuitive process.*

5.6 Equipment Operations and Types of Equipment

Essential skills in relation to equipment operations were:

- Use equipment in cleanroom following standard operating procedures
- Set up equipment and machinery to achieve outcome
- Calibrate equipment and machinery
- Check and select equipment parameters
- Load sample / wafer / substrate appropriately. This may be into drawers; receiver cassettes; sample holders; baths; and including with metal or plastic tweezers or other tools.

Common parameters that technicians should understand, (based on ANFF SOPs) may include selecting the appropriate: Recipe; Deposition Time; Gas Flow Rate; Target Material; Exposure Time; Pressure; Coordinates; Room Temperature; Rise Program; RPM; and Beam Current.

A number of ANFF Senior Technicians made mention of the expensive nature of equipment that is being used. One comment that reflected this is:

> *The easiest way of explaining it is like a fleet of cars. They are exotic cars, they are temperamental, they are not Corollas or anything. This is a fleet of Maseratis and Ferraris.*

Due to the expensive and complex nature of equipment, it is difficult for technicians to be trained on this type of equipment prior to entering the workplace. For this reason, many Interviewees confirmed the need for entry level technicians to have what amounted to a level of 'transferable skill'. Interviewees indicated this would enable technicians to be trained by them more readily on in-house processes and equipment once they commence in the workplace.

The range of prior experience or training on equipment on which to build transferable skills was suggested to include:

Vacuums, High Vacuums and Ultra High Vacuum*	Furnaces and Ovens	Optical microscopes and general characterisation skills / taking standard images
Loading cassettes and sample holders	Balances	CNC programming
Metal and plastic tweezers	Fume cupboards	Wet benches and wet chemistry
Pipettes	General laboratory procedures	Laboratory application software and control screens and interfaces
Flow meters	Thermocouples	

* Particular **Vacuum system knowledge** included:

Classification of Vacuums and pressure ranges for: Low Vacuum; Medium Vacuum; High Vacuum; Ultra-High Vacuum; Extreme High Vacuum. Units of pressure – Pa and Torr	Achieving ultra-high vacuum pressure: - Small chambers - Multiple pumps in series - Low outgassing - Bake off to remove water and hydrocarbons.	Types of pumps including: Rotary, Diffusion, Turbomolecular and Cryogenic
Leak prevention through seals and gaskets	Thermocouples (measuring temperature and pressure).	Leak detection

The need to have an understanding of vacuum systems and complex equipment was validated by the feedback. One of the respondents stated that the essential skills of a technician would be:

> *Vacuum systems, gas handling, chemical handling, ability to handle a complex piece of equipment, and working in a cleanroom environment.*

Interviewees generally agreed that buddy and mentor style training on highly specialised equipment, together with certification / sign off by the mentor and managers was working well in their workplaces. It also gave them a high degree of confidence in ensuring workplace health and safety procedures are followed and the valuable equipment is protected.

Feedback from the Consultation Paper reinforced those findings:

> *Writing and having all members sign off on an agreed pre-task plan (PTP) prior to beginning works is [the] industry standard in the USA semiconductor industry.*

A PTP is a written set of steps that outlines every action involved with the work and needs consensus from stakeholders for any deviation.

Additionally, it was acknowledged by technicians working on the specialised equipment, that it may take many years to become proficient at using some of the equipment and the potential uses of some equipment are only just being realised. One Interviewee from an ANFF node mentioned that it would be great to learn this prior to commencing in the micro and nano industry and went on to state:

> *The area is so small and specialised it is not economical to do so. However, there are some standard equipment that they could familiarise themselves in [the] school environment that is not very expensive. For example, oscilloscopes… cost a couple thousand to few thousand dollars and they could do some analyses of circuitry. That could be useful as they know when they come out what the equipment is doing before they go out into the field, [or] they come to us. That certainly would be very useful.*

Capabilities enabled by specialist equipment requiring one-on-one training and certification included:

Deposition (inc. PVD, CVD, MPCVD, MOCVD, ALD).	Lithography (inc. Photolithography, Direct Write, Embossing).	Dry Etching (inc. Vapour Phase, Plasma, RIE).
Lab Infrastructure for: Wet processing including wet benches for HF, KOH, chromium, and resist coatings. Also: Gloveboxes and Fume hoods.	Manufacturing and Machining (inc. Milling, Injection moulding, 3D printing, Laser engraving and cutting, Optical fibre extrusion, 2D printing).	Packaging (inc. Bonding, Wafer processing and dicing).
3D Modelling and Device Design (X-rays, Advanced Software packages and Laser scanners).	Materials synthesis and modification (inc. Peptide synthesis, Furnaces, Annealing, Ion implantation).	Testing, Validation, Characterisation and Microscopy (inc. SEM, DHM, Surface Profiling, AFM, Electrical Characterisation, LDV, Confocal, and Spectroscopy).

5.7 Attitudes

The data indicated that desirable attitudes for technicians include:

Respect equipment user etiquette	Work autonomously	Attention to detail
Disciplined / Follows Rules	Work as part of a team (including using broader knowledge networks)	Time management / planning
Problem solving	Written and Verbal Communication	Work to deadlines to minimise downtime
Creative thinking / innovation		

Feedback on the Consultation Paper reaffirmed this with the following:

> *Some level of critical thinking, rather than just 'following instructions' type of mentality. A non-risk taker and adhere strictly to WHS regulations.*

> *Problem solving or troubleshooting in your workplace is highly desirable – not just in [the] process, but in the tool operation.*

Additionally, while some workplaces encouraged problem solving and innovation in experienced technicians, in other workplaces, particularly industrial and manufacturing environments, independent problem-solving by technicians was discouraged in favour of referral of issues to the process engineer.

Similarly, while troubleshooting was raised as a valuable attitude, it was encouraged more in senior, very experienced technicians, rather than at operator or entry level. These skills included:

- Troubleshoot issues that arise during operations
- Troubleshoot equipment faults when issues arise.

The importance of agility in troubleshooting and repair and the ingenuity of a number of the technicians was evident. As one senior technician indicated:

> *The organisation needed plates which were usually sourced and made in Europe. The plates cost about €8000 each, there would be significant delay in delivery because of COVID which would slow production. I came up with a solution to have them locally machined for about $250 and am finishing machining them in-house... I got a vacuum pump instead of a vacuum chuck, so that I can hold it in a free state so I'm not clamping it and putting any force on it, when I'm machining it, through suction, and then I can take the final .25 of material off - so I have solved that problem!*

Additionally, a comment on the paramount importance of a willingness to learn and good communication skills, that could actually trump a lack of pre-existing skills, is:

> *It depends how keen they are to learn, and you can generally pick that up with people coming for jobs. If someone wants to learn, they ask a lot of questions, they show a distinct interest in the process. It depends on the person themselves, how they work, but if they were really keen and had little to no mechanical knowledge, I'm sure we could probably work around it.*

Technicians are often the ‘universal joint’ in engagement with internal and external customer service. As one indicated, *‘If I’m not here it all stops’*.

Technicians communicate with a broad range of co-workers, users, researchers, and tradespeople.

> *Communication skills are really important. And often you have to communicate up, so you need to communicate technical information to a non-technical audience. That's an important skill.*
>
> *Sometimes, and especially with the project we're working on … trust with a medical professor, … he has medical jargon we don't understand.* [We have*] engineering jargon he doesn't understand. So yeah, it's important to get on to the right communication page with each other.*

One of the Interviewees observed:

> *You get a lot of people that turn up for a job, and they have little to no interest in it. They're just there for the pay packet at the end of the week. You can tell straight away that they have no interest, as they show no interest. [They] don't want to learn and it's quite difficult.*

5.8 Basic Scientific Knowledge and Mathematics

There is a wide range of basic scientific knowledge and mathematics that Interviewees indicated would be desirable for a technician to understand and apply. However, it was acknowledged that the full range of knowledge would be difficult to find in a single individual. Some existing technicians themselves also indicated they would like more knowledge in particular areas. The range of science and mathematics knowledge identified includes:

Applied Mathematics

Fractions and Percentages	Scale (microns and nanometres)	Graphs
Metric system and conversions	Ratios	Flow rates
Area and Volume	Concentration and Dilution	Trigonometry
x, y, z axes	Tolerance	Scientific notation
Averages, Deviation, and basic statistics	Sequences	

Chemistry

Periodic Table basics	Nitrides	Electroplating
Metals (Al, Cr, Ti, Au, Ag)	Common chemicals in nanofabrication	Hazardous Chemicals inc. reading MSDSs
Oxides (SiO_2, TiO_2, $Al2O_3$)	States of Matter including plasmas	Contaminants and incompatible substances
Silicon	Catalysts	Gases: Argon, Nitrogen, Oxygen, Hydrogen
Effects of temperature and vapour	pH	Chromatography

Physics

Light spectrum and wavelengths	Vibration and Frequency	Measurement of pressure and different units of pressure
Spectroscopy	Electron beams	Surface Roughness

Electronics and Electrical Systems

Basic Circuits	Conductivity and non-conductivity	Voltage: Low and High
Components: Transistors, Resistors, Capacitors, Diodes	Fault-finding and basic diagnosis	Electrical Schematics
Semiconductors (Si, Ge)	ESD Protection	Multi-meters
PCB Design, Build and Test inc. Pick and Place Technology	Oscilloscope use	Soldering

Mechatronics

PID, PLC and VME Controllers	Logic systems (e.g. what is an interlock?)	Electro-pneumatic systems (e.g. solenoid valves)

Mechanical systems and tools

Basic hand tools and workshop equipment	Hydraulics and pneumatics	Alignment procedures
Corrosion	Oil changes	Part replacement
Chuck and slide maintenance	Laser cutting	CNC machining

Most stakeholders indicated that although it would be highly desirable for entry level technicians to have knowledge of nanofabrication, it was currently not realistic. Suggested knowledge / course content that would be ideal included:

Nanofabrication and Semiconductors

General Introduction to Micro and Nanofabrication	MEMS Fabrication	Introduction to semiconductors

Specific nanofabrication processes were generally considered likely to be taught 'in-house'. These included: lithography, photolithography, thin film deposition, patterning, and etching.

Biology

Interviewees in biomedical settings indicated that for their technicians, an understanding of aseptic manufacturing processes was likely to be trained in their own workplaces. Skills which were indicated as being valuable in technicians were the ability to:

- Research anatomical information or biological processes relevant to the manufactured product
- Seek information from own network, university, and industry medical experts to inform an understanding of biomechanics and biocompatible materials.

TAFE SA sought feedback in the Consultation Paper on priority knowledge required in technicians. The question posed was:

If you had to choose between a technician who had knowledge of chemistry and physics; one with an electronics background and qualification; and someone with more mechanical or electrical background what would be your priorities?

The responses to this question included:

> *For a fabrication technician, chemistry and physics are more important. For tool maintenance technician, then mechanical and electronics.*
>
> *Assuming a highly electro-mechanical tool, I would choose the mechanical / electrical background. Assuming a wet etch process, I might choose chemistry. Assuming troubleshooting at or below the component level, electronics. The nature of the specific job matters in this regard.*

As identified across the feedback, the priorities regarding KSAs varied based on the specific job or process that was being undertaken.

5.9 Cleanroom Standards

In relation to cleanrooms, knowledge of the following was important:

- Cleanroom operations
- Cleanroom cleaning procedures
- Equipment clean state.

Additionally, a general knowledge of the existence of the following was also indicated:

- the standards (ISO 14644 or other)
- Specific standards such as ISO 5, ISO 7, and ISO 8
- Class 10,000 and Class 100 as defined by the USA federal standard.

Positive pressure and pressure differentials	Basic cleanroom design	Placement of equipment	PPE Procedures
Sticky mat use	Airflow – unidirectional and non-unidirectional	Zones	Cleaning Practices and Procedures

One of the respondents to the Consultation Paper stated that technician should have knowledge of the cleanroom standards specific to the industry and suggested that perhaps "*PC2 / PC3 environment*" was valuable to know.

Generally, Interviewees indicated that the following was essential:

> *There is an induction procedure and it's basically just showing them the safety hazards. [It] lets them know how to get in and out of the cleanroom, and how to keep it clean. Everything must be cleaned up properly [and] they need to gown up properly. After the induction is done then I get onto a particular tool instrument and that has its own training procedure.*
>
> *Having some knowledge about cleanrooms as well, like positive pressure for example so that dust does not flow in. Knowledge of different levels of classification are useful.*

5.10 Training

The ability to train colleagues and staff due to the unique processes and pieces of equipment was considered essential.

Skills include an ability to:

- Conduct training for users on equipment, machines, and instruments
- Conduct training on safe operating procedures
- Participate in one-on-one learning activities (e.g. mentor, buddy, work shadowing).

With these nuances and varying pieces of equipment, it is vital that individuals participate in one-on-one learning activities, as it is a valuable way for other individuals to learn these skills. One of the respondents to the Consultation Paper confirmed this stating:

> *it would be useful if the experience gained after some time working can be passed on, i.e. train a more junior colleague.*

Additionally, in some of the general feedback that was received from the Consultation Paper, a respondent mentioned:

> *what I will say is that you can't learn this from a course, it is only learned by hands-on, mentor training.*

Workplace specific training practices included:

- Demonstrations, training, assessment, checklists, and signoffs
- Induction – both site and local area.

Workplace training and courses were being delivered on:

- Dangerous goods waste management training
- Nanofabrication processes
- Individual pieces of equipment.

In an industry interview that was conducted, the Interviewee illustrated that the training activities specific to their company that has seen tremendous growth. The Interviewee said their training in the beginning was a little ad hoc.

> *We were only like 6 people, but now we have grown to 60 people. We now have an onboarding process [and] spend about a week for them to go through all the basic training.*

However, it was also noted in the feedback from the Consultation Paper that the *'importance of this [training others] probably varies enormously'*.

Another respondent said the following:

> *In all honesty, I have no faith that formal education courses will teach these skills in a transportable manner.*

> *Australia is obsessed with everyone having a piece of paper that says they can do something. Someone coming out of school, with no experience, then doing a TAFE course to get a certificate… with no hands-on experience, I wouldn't hire them!*

These comments illustrate the importance of combining formal and on-job training to ensure workers get the right type of skills.

5.11 Reporting and Record Keeping

Common Reporting and Record Keeping skills, using both manual and digital processes, included:

- Keeping workplace records and documentation
- Record / fill out logbook (inc. session details, use of machine / equipment, various measurements, oxygen, and moisture levels)
- Report information for projects and work activities
- Develop and write technical reports.

Common knowledge to perform these tasks included:

How to fill out logbook	Booking of equipment	Logbook procedures
Record keeping procedures	Booking system	Report writing
Data and file transfer procedures	Importance of record keeping in a quality system	

Additionally, multiple respondents to the Consultation Paper outlined Reporting and Record Keeping skills and knowledge as 'extremely important' and in one response stating this KSA Area is a skill that should be respected and is a '*must*'. One of the respondents highlighted the importance of this with specific reference to the industry. They stated:

> *A job is not complete until it is written down. Any change to equipment parameters needs to be logged. The measurements taken need to be written down, as well as the process used to record them. Almost every nanofabrication process problem ultimately leads back to tool configuration or part performance, and if a process engineer is unsure of his tool configuration, they will be unable to solve process problems.*

This KSA Area was particularly important for industry-based technicians. One Interviewee stated that record keeping was vital because:

> *Your boss wants to know how much money per hour you made on the job.*

This was also highlighted where industries follow ISO 9001:2015 – Quality Management Systems, as record keeping is specified through the standard.

5.12 Quality Standards

Common Quality Standards skills and knowledge was identified as follows:

- Read, interpret, and apply ISO standards, IPC standards and other standards to facility and projects
- Read, interpret, and apply quality standards of organisation and other quality standards (ISO 9000, ISO 9001 or other) for facility and projects
- Comply with company quality standards.

General and Specific Standards referenced in the interviews included:

Quality Standards – ISO 9000 or ISO 9001 or other	ISO Cleanroom Standards ISO 5, ISO 7, and ISO 8	Organisation-specific quality standards and processes
FED STD 209E US Cleanroom Standards (superseded but still referred to): Class 10,000 and Class 100	IPC-A-610H Acceptability of Electronic Assemblies	Good Laboratory Practices (GLPs) and Good Manufacturing Practices (GMPs)
ISO 14644 Cleanrooms and associated controlled environments	ISO 14698 Cleanrooms and associated controlled environments — Biocontamination control	ISO 13485:2016 Medical devices — Quality management systems — Requirements for regulatory purposes

Knowledge around continuous improvement methodologies, process improvement knowledge and Lean / Six Sigma rated highly with industry Interviewees, probably due to the focus on production and manufacturing.

Kanban boards, shadow boards and dashboards were tools in use that were noted during industry visits.

An Interviewee from the medical technology industry highlighted the importance of quality standards by articulating the following:

> *One of the skills that would be nice to have again would be some kind of quality skill. Like some basic introduction into quality control… because we are quite highly regulated.*

They went on to say that the *ISO 13485:2016 Medical devices — Quality management systems — Requirements for regulatory purposes* standard was a particular standard that required for their industry and although *'it is a great thing to know'*, people *'don't need to know in great detail'*.

5.13 Engineering Topics

Throughout the interviews, it was identified that many ANFF industry employees had higher education qualifications in engineering. Whilst some of these individuals were process engineers, part of their job role also included tasks a technician could complete. One Interviewee gave an overview of the strength of their team stating:

> *Our team have two chemical engineers and four tool makers, sitting in that office.*

This combination of engineering knowledge and technical expertise across the team and individuals was reflected strongly in feedback:

> *My background itself is from materials engineering. I did my PhD at University. After a couple of years of doing postdoctoral research, I decided I wanted a bit more hands-on experience or more industry related experience.*

As part of the Consultation Paper, one of the questions asked was whether a technician needs to understand the underlying scientific knowledge. A respondent to the Consultation Paper gave their response as the following:

> *it depends on how much they are involved because when you optimise something, you can take the engineering approach where to get what you want. Then there is the more scientific approach where you try and understand what you don't like [and] make this change. That requires understanding underlying processes of chemistry and physics to know what's going on. As for what a Technician will need, to have that engineering mindset but having some understanding of the background, it would be useful to aim for that.*

5.14 Mechanical Trade Skills / Maintenance and Repair

From both ANFF and industry technician interviews it was highly evident that to ‘keep the machines running’ there was strong reliance on experienced technician-level staff with trade backgrounds in Fitting and Turning, Engineering-mechanical Trade and Toolmaking.

These mechanically trained technicians and tradespeople were sometimes known as ‘Mechanical Technicians’ or ‘Machine Setters’ or collectively as ‘Machine Shop’.

Additionally, in international job advertisements the roles were also called ‘Mechanical Production Technician’ and ‘Electro-mechanical Technicians’.

It was identified that technicians skilled in maintenance and repair were highly valued. These technicians often have the Mechanical Trade background. The skills for maintenance and repair were:

- Perform routine and planned maintenance for equipment and machinery
- Rectify and repair equipment and machinery faults within capabilities
- Design components using software or by hand
- Implement maintenance plan for equipment, machines, and instruments
- Implement maintenance requirements for facility
- Identify issues and take corrective actions
- Liaise with Original Equipment Manufacturer (OEM) for equipment maintenance and fault rectification.

Specific Maintenance and Repair tasks also included:

Change oil	Install and fit gas bottles	Clean gas lines
Replace filaments, O-rings, and seals	Detect leaks	Soldering
Source and install parts and equivalent components	Restock consumables	TIG Welding
Update software	Replace valves	Calibrate machinery
Find faults and make basic diagnoses	Dismantle and reassemble equipment	Calibrate mass flow controllers

With the unique equipment that the industry utilises, it is worth highlighting that all repairs aren’t straight forward and liaising with original equipment manufacturer is often required. Feedback from a respondent on the Consultation Paper stated that:

> *This comes down to service contracts. For tools still covered by vendor service contracts, there is often no need and no possibility for local techs to have their hands-on these tools. For older legacy tools, there is often no other way to service them.*

Highly skilled technicians within ANFF also design (using hand-sketching or CAD), and then manufacture parts and tools. Many of these staff have a toolmaking or fitting and turning trade qualifications or the equivalent, plus many years of experience.

As mentioned throughout this report, industry and ANFF have different structures and subsequent duties undertaken by job roles. This is again different based on the size of the industry organisation with a respondent to the Consultation Paper stating:

> *At the university level, engineers will have to step in and perform a lot of technician work simply based on budget and human resources available. At a larger scale, one would expect a separation of responsibilities, as engineers would start to direct technicians engaging in this.*

Another industry example from the interviews related to the varied job roles for maintenance and repair was as follows:

> *The machine stops due to a software bug, and it's really late at night. Typically, the machine setter would get involved, but the operator does not troubleshoot or try to solve the problem. Instead, it’s the machine setter that we focus on. They typically would not call the process engineer at that hour, but they try to attend to the basics of the background, …trying to log the error, trying to get the machine to run. They are limited in terms of knowledge and engineering needs to come in in the morning, but to certain degree they've done a background check, understood why it stopped and able to relate to the engineer in the morning [and] make the problem be much easier to be solved.*

5.15 Process Improvement

Process Improvement was another KSA Area that was identified as important. Process and operational improvement skills that were commonly required included:

- Participate in continuous improvements processes
- Liaise with users to understand project requirements
- Write and update work instructions for operators
- Use monitoring systems and sensor equipment to identify faults
- Refer issues to supervisor when fault rectification is beyond capabilities or OEM support is required.

Overwhelming feedback from the Consultation Paper highlighted that these skills were important but would typically sit at the engineering level or process engineering level. One Interviewee expanded on this and explained how a Technician is involved with this KSA Area:

> *Most of the skills highlighted sit at the engineer level, but technicians should have a respect for these items, especially for continuous improvement. They at least should be aware that these matters are priorities for their engineer and be willing to support those efforts.*

5.16 Software and Computing Skills

Common software skills include:

- Microsoft Office (Word, Excel [pivot tables and macros highly desirable], PowerPoint)
- Equipment specific software and interfaces
- G-code used in CNC for machinists.

Software skills that were described as not essential (but highly desirable if they exist) for technicians and possibly more appropriate for engineer level were:

- Computer Aided Design (CAD) skills (software included Inventor, SolidWorks, AutoCAD by AutoDesk, and CorelDRAW)
- Programming (LabView or MATLAB)
- Altium for PCB design
- Firmware for Electronics
- KLayout for Electronics.

Throughout the interviews and reviewing ANFF SOPs there was a substantial list of different software products that are being used. The software, LabVIEW, Altium AutoCAD and SolidWorks are the software programs that were raised the most, however there was a number of different types of software being used, as well as unique equipment that comes 'with its own in-built software'.

Additionally, one Interviewee raised how individuals typically learn the various software used by saying the following:

> *When you pick, normally a company or Institution will pick their favourite manufacture of microcontrollers and then just stick with [it]. They don't have to learn a bunch of different tools. It's important to have this skill to be able to teach yourself the different tools.*

Also, the programming languages that were identified and seen highly desirable include: C; C+; C++; C#; and Java.

When queried about how software and programming skills needs are currently met, the feedback received highlight that currently individuals would 'tinker' or already have some experience across the areas of CAD and programming, which is sufficient for their current needs.

In one of the interviews conducted, the Interviewee said the following:

> *Programming skills it's a nice to have. If they have some interaction to things like LabVIEW or MATLAB, then it kind of tells [me] that they can be trained in other programming languages, and they'll be able to pick up other things that we can use. But, from a technologist level, it's not like a must have.*

Programming wasn't always an essential requirement across both ANFF sites and industry organisation. It depended on what processes and equipment was being used. One respondent who said programming was not essential indicated:

> *At this point, no. I have not seen it, but it's because the way the machines are being built in the current environment. Most of the programming is done with a connection to the parent company or the machine builder's company.*

5.17 Industry 4.0 Skills

Interviewees and other data sources indicated the following skills and knowledge areas may be increasingly in demand for nanofabrication technicians:

3D printing (design and print)	Programming skills including Python and C#	Lean Manufacturing
PLCs and Microcontrollers	Quantum Computing	Hydrogen Fuel Cells
Industry 4.0 sensor and IoT, including automated monitoring of processes and entire production line	APP development for products	Statistical process control
Microfluidics		

Multiple Interviewees mentioned similar viewpoints which can be seen below:

> *Our assembly manufacturing… is how can we manufacture things smarter. Smarter, quicker, more efficient, and generally that means automation.*

> *Switching from the traditional 'hands-on' to more of a digital focus, which is essentially industry 4.0.*

> *As industry 4.0 becomes much more of a focus, what we do with data, and how we manage data, and what we can get out of the data, is going to be a very, very big project.*

Additionally, one of the Interviewees elaborated by saying that their organisation has an industry 4.0 program in Europe that has been tested and been very successful. Once the machines are available here in Australia and they have the capability, they will run this program to relevant internal people to upskill them.

A respondent to the Consultation Paper highlighted a new way of thinking that was not identified in our research. The respondent mentioned the following:

> *At the technician level, having some experience interacting with AI prediction systems is going to be necessary. Increasing industrial uptake of AI-like curve fitting for predictive factory analytics is essentially inevitable. Many of these solutions, especially at the beginning, will be stupid. However, the ability for engineers and technicians to query results and investigate intelligently will be important.*

5.18 Alignment with the new work of the National Skills Commission

The National Skills Commission is currently beta testing a new Australian Skills Classification structure. The Classification includes occupation profiles with core competencies, specialist tasks and technology tools for 600 occupations. Unfortunately, the classification does not currently include nanofabrication job roles. This is in contrast the USA national classification system, O*NET which does include the job roles of Nanotechnology Engineering Technologists and Technicians and Nanosystems Engineers (*O*NET OnLine 2021)*.

One of the reasons why the Australian Skills Classification is more limited than the USA O*NET classification is that it is confined to a mix of ANZCO 4-digit and 6-digit codes. The National Skills Commission has ‘rolled up’ ANZSCO 6-digit job roles to the 4-digit code where they map to the same O*NET occupation; there is no substantial difference between the 6-digit occupations’ tasks or there were very few job listings in Australia over a 5 year period. In Australia, ANZSCO codes have not yet been developed for nanofabrication or laboratory operations jobs (the latter is, however, potentially covered instead by ANZSCO 311411 Chemistry Technician).

The Australian Skills Classification system contains core competencies which are essentially ‘soft skills’ or ‘employability skills’; ‘specialist tasks’ and ‘technology tools’. The extant ANZCO occupations which align most closely with nanofabrication technician skills as defined in this report are:

- ANZSCO 323214 Metal Machinist
- ANZSCO 342314 Electronic Instrument Trades Worker
- ANZSCO 3124 Electronic Engineering Draftspersons and Technicians
- ANZSCO 7123 Engineering Production Worker
- ANZSCO 311411 Chemistry Technician.

While there are a number of ‘Operator’ level job roles classified under ANZSCO the machine operator classification is ANZSCO 7111 Clay, Concrete, Glass and Stone Processing Machine Operators. Clay, Concrete, Glass and Stone Machine Operators operate machines to manufacture and finish a variety of clay, concrete, glassware, and stone products by extruding, shaping, mixing, grinding, cutting and other processes.

This classification reflects a continuing reliance on historic industrial processes.

While the National Skills Commission classification system is evolving rapidly, it is potentially an ideal time for ANFF to provide data (from this report or otherwise) to influence the development of the system and ensure that as far as possible the specialist and technology tools required by nanofabrication technicians are included in the classification system. TAFE SA has extracted a full O*NET data report from the US database at Appendix 10.10 O*NET OnLine Summary Report.

There is a high degree of similarity between the O*NET data and the TAFE SA findings for the Australian context.

Overall, feedback that could be given to the National Skills Commission includes providing essential KSA Area descriptors and skills extracts from this report and asking that nanotechnology job roles be included in the data sets.

6. Course Mapping

6.1 Courses that align with key Knowledge, Skills and Attitudes

TAFE SA has examined 59 overseas and 20 Australian courses that develop skills for technicians that align to micro and nanotechnology industry requirements. The courses have been rated against clusters of key Knowledge, Skills and Attitudes (KSA Areas) and more specific Knowledge, Skills and Attitudes (KSA Topics).

The overseas courses that align most with KSA Areas and KSA Topics are:

- Diploma of Nanosystems Engineering Technology (Northern Alberta Institute of Technology – Canada)
- Diploma Nanotechnology Technician (Athens Technical College – USA).

Overseas qualifications in Canada and the US, specifically delivered near nanotechnology businesses were strong on nanoscience but often lacked the more practical skills of: Health and Safety (WHS) Skills, Process Operations, Equipment Operations and Types of Equipment, Training (workplace training), Quality Standards, Mechanical Trade Skills / Maintenance and Repair, Process Improvement, Software and Computing Skills.

The Canadian qualification, the Diploma of Nanosystems Engineering Technology program, at the Northern Alberta Institute of Technology, had the strongest alignment with KSA Areas and KSA Topics at 80%. The Canadian Institute is situated in an industrial hub, closely affiliated with government, industry, and higher education.

The Australian Training Packages that best align to KSA Areas and KSA Topics are:

- Laboratory Operations qualifications (MSL09 – Laboratory Operations Training Package)
- Process Manufacturing qualifications (MSM – Manufacturing Training Package)
- Engineering Mechanical Trade qualifications (MEM05 – Metal and Engineering Training Package).

The Australian qualifications that align to KSA Areas and KSA Topics are:

- Certificate III in Laboratory Skills (MSL30118) (Australia – VET)
- Certificate IV in Laboratory Techniques (MSL40118) (Australia – VET)
- Diploma of Laboratory Technology (MSL50118) (Australia – VET)
- Advanced Diploma of Laboratory Operations (MSL60118) (Australia – VET)
- Certificate III in Engineering (Mechanical Trade) (MEM30205) (Australia – VET)
- Certificate IV in Process Manufacturing (MSM40116) (Australia – VET)
- Diploma of Manufacturing Technology (MSA50108) (Australia – VET).

These qualifications align well to the transferrable skills required by a technician, but currently lack curriculum (training package content) related to nanotechnology topics such as nanofabrication equipment, nanoscience, and Industry 4.0 skills.

Laboratory Operations qualifications have a number of core units of competency which align closely with ANFF and industry skill requirements. These units include:

- Process and interpret data
- Maintain and calibrate instruments and equipment
- Apply quality systems and continuous improvement processes
- Maintain laboratory or field workplace safety, and
- Receive and prepare samples for testing.

These qualifications do not specifically address knowledge and skills related to Cleanroom Standards, Vacuum systems, or Pumps.

Process Manufacturing qualifications provide the skills and knowledge required by advanced production workers who use a range of equipment and are involved in solving complex problems that require theoretical knowledge, combined with an understanding of operating procedures directly related to producing products. The key KSA Areas which were highly aligned included:

- Workplace Health and Safety Skills
- Process Operations
- Training (workplace training)
- Reporting and Record Keeping
- Mechanical Trade Skills / Maintenance, and
- Repair and Process Improvement.

Engineering Trade qualifications provide the foundation skills and knowledge for the design, development and specification of manufactured and installed components or systems. The qualifications align well with key KSA Areas including:

- Workplace Health and Safety (WHS) Skills
- Training (workplace training)
- Reporting and Record Keeping
- Mechanical Trade Skills / Maintenance, and
- Repair and Process Improvement.

This qualification gives a good foundation across many of the key KSA Areas and KSA Topics. However, there are some concerns around timeframe for completion of this qualification as it is an apprenticeship-only pathway, generally taking around 4 years to complete.

Overall, Workplace Health and Safety (WHS) Skills rated highly in Australian qualifications, and the KSA Topic, Safety Practices was particularly strong in Australian VET qualifications.

TAFE SA has examined overseas and Australian courses that align to the micro and nanotechnology industry with 59 overseas and 20 Australian courses examined. Overseas courses included qualifications from the USA, UK, Canada, France, and Germany. A number of these were offered at a Bachelor or Postgraduate level and were pitched at a higher level of job outcome than technician.

Of the 59 overseas courses, nine aligned well to the KSAs that are essential for nanotechnology and nanofabrication technicians.

Mapping Approach

In order to determine which courses align best to the essential and desirable KSAs, TAFE SA examined all course subjects in the curriculum across the 59 overseas courses and mapped them to the KSA Areas. This gave us a broad overview of high-level alignment of learning outcomes and KSA Areas. Nine courses were then mapped in more detail against key KSA Areas and detailed KSA Topics. This mapping document is attached at Appendix 10.6 International Course Mapping Matrix.

A similar process occurred for the Australian courses with a total of 20 courses investigated across the Higher Education and Vocational Education and Training (VET) sectors, as well as two short courses which included both accredited and non-accredited content. Eighteen of the 20 courses were then mapped to key KSA Areas and KSA Topics to identify which courses most align to ANFF and industry requirements. Three of these courses were from the same institution with a large volume of subject commonality; and so were consolidated as one for the purposes of the course mapping. Analysis of the key mapping results is provided below, and the full mapping document is attached at Appendix 10.7 Australian Course Mapping Matrix and Appendix 10.6 International Course Mapping Matrix.

The courses were mapped using a traffic light system (green, orange, and red), based on the following criteria:

- Key KSA Areas / KSA Topics highly aligned to course content – illustrated in green
    - "highly aligned to KSA Area" means that 80% or more of KSA Topics
- Key KSA Areas and KSA Topics partially align to course content – illustrated in orange
- Not aligned to Key KSA Areas – illustrated in red.

The key KSA Areas and KSA Topics are a summary of the essential and desirable KSAs for nanofabrication and microfabrication technicians which were established and identified. These were based on:

- **Job advertisements for 109 technician job listings** in the nanotechnology and nanofabrication industries in the USA, UK, Canada, France, and Germany.
- **21 face-to-face and online interviews** with ANFF staff and key industry stakeholders in Australia.
- **Standard Operating Procedures** (SOPs) for 73 different pieces of equipment used by ANFF in nanofabrication / laboratories / cleanrooms.
- A variety of **workplace documentation**, **asset and equipment lists**, **Kanban boards** and **processes** kindly shared by ANFF and industry.
- **USA O*NET data reports** for Nanotechnology Technicians and Nanotechnology Engineers.
- **Diploma, Advanced Diploma and Associate Degree qualifications for Laboratory and Mechanical Technicians** from the Australian training system and overseas.
- **Specialised nanofabrication courses** at Diploma, Associate Degree, Bachelor and Post Graduate levels offered in Australia and overseas.

The following table (Table 6) outlines the KSA Areas and KSA Topics used in this section:

Key KSA Areas	KSA Topics	
Workplace Health and Safety (WHS) Skills	Safety Practices	Controls
	Common Hazards and Risks	PPE
Process Operations	Preparation	Assembly and Packaging
	During Operations	Packaging and Testing
	Shut down and clean up	Product Manufacturing
Equipment Operations and Types of Equipment	Lab Equipment	Vacuum Systems
	Microscopy	Pumps
Attitudes		
Basic Scientific Knowledge and Mathematics	Chemistry	Maths
	Chemical Structure	Technical Maths / Applied
	Chemical Reactivity	Algebra
	Physics	Trigonometry
	Electrical	Calculus
	Electronics	Statistics
	Biology	Polymer Science
	Material Science	
Nanotechnology Topics	Characterisation	Properties and applications
	Ethics	Deposition
	Intro	Lithography
	Thin Films	Etching
	Nano Materials	
Cleanroom Standards	Cleanroom	
Training (workplace training)		
Reporting and Record Keeping		
Quality Standards	ISO / IPC / FED STD	Project and Quality Management
	Lean / Six Sigma	
Engineering Topics	Engineering	Electrical Engineering
	Mechanical Engineering	Bio Engineering
	Technical Engineering	Engineering Materials
	Chemical Engineering	
Mechanical Trade Skills / Maintenance and Repair	Specific Maintenance and Repair tasks	
Process Improvement	Fault finding	
Software and Computing Skills	Computer Aided Design (CAD)	Programming
	Microsoft Office	Equipment Application Software
Industry 4.0 Skills	PLCs (programmable logic controller)	3D Printing

Table 6 – Key KSA Areas and KSA Topics used for Course Mapping

The courses that align most with key KSA Areas and KSA Topics are:

- Diploma of Nanosystems Engineering Technology (Northern Alberta Institute of Technology – Canada)
- Diploma Nanotechnology Technician (Athens Technical College – USA)
- Certificate III in Laboratory Skills (MSL30118) (Australia – VET)

- Certificate IV in Laboratory Techniques (MSL40118) (Australia – VET)
- Diploma of Laboratory Technology (MSL50118) (Australia – VET)
- Advanced Diploma of Laboratory Operations (MSL60118) (Australia – VET)
- Certificate III in Engineering (Mechanical Trade) (MEM30205) (Australia – VET)
- Certificate IV in Process Manufacturing (MSM40116) (Australia – VET)
- Diploma of Manufacturing Technology (MSA50108) (Australia – VET).

The overseas courses that aligned with nanotechnology, are most usually at a bachelor or post graduate level, and not as suitable for training a worker at a technician level. These course titles included below in Table 7:

Cleanroom Training (Short Course) (London Centre for Nanotechnology – UK)	Associate Degree Semiconductor Technology (Certificate) (Hudson Valley Community College – USA)	Master of Engineering Electronic Engineering with Nanotechnology (University of Surrey – UK)
Nanomaterials and Advanced Composites (Short Course) (Cranfield University – UK)	Associate in Applied Science (Major Nanotechnology) (Multiple Locations – USA)	Masters Nanotechnology and Microfabrication (Bangor University – UK)
Higher National Certificate (HNC) Applied Science (Biological Science) - Level 5 (Multiple Locations – UK)	Bachelor of Science (B.Sc.) Physics with Nanotechnology Degree Scheme (Swansea University – UK)	Master in Micro- and Nanotechnologies (Technical University Ilmenau – Germany)
Applied Sciences Higher National Certificate (HNC) - Level 6 (Multiple Locations – UK)	Bachelor of Engineering (Honours) Electronic Engineering with Nanotechnology (University of Surrey and University of York – UK)	Masters Nanoscience (University of Strathclyde Glasgow – UK and University of Tübingen – Germany)
Higher National Certificate (HNC) APPLIED SCIENCE Level 7 (Multiple Locations – UK)	Bachelor of Science (B.Sc.) Nanoengineering (University Duisburg Essen – Germany)	Master of Science Nanomaterials (The University of Manchester – UK)
Higher National Diploma (HND) Applied Biological Sciences (Multiple Locations – UK)	Graduate Certificate in Nanotechnology and Nanoscience (George Mason University – USA)	Master of Science (MSc) Nanoscience and Functional Nanomaterials (University of Bristol – UK)
Nano-Systems Engineering (Certificate) (NC State University – USA)	Graduate Certificate in Nanomedicine (Northeastern University – USA)	Master of Science (MSc) Nanoscience to Nanotechnology (Swansea University – UK)
Certified Nanotech and Cleantech Professional (CNCP) (Cleantech Institute – USA)	Graduate Diploma Nanobiotechnology (Certificate) (NC State University – USA)	Master of Science (Nanotechnology) (Leibniz University Hannover – Germany)
Nanotechnology Certificate (Multiple Locations – USA)	Graduate Diploma Microsystem Technology Certificate Program (University of Florida – USA)	Nanotechnology Advanced Technical Certificate (Northwest Vista College – USA)
Post Graduate Certificate in Nanotechnology (The University of Oxford – UK)	Diploma of Nanotechnology (1Training – UK)	

Table 7 – List of Overseas Course titles

From the detailed mapping, it is evident which courses align strongly with KSA Areas. In Figure 14 – Overseas Course Mapping and Figure 15 – Australian Course Mapping, the green line illustrates where the courses are highly aligned to the key KSA Areas. The orange line illustrates where the key headings partially align and the red line highlights where there is no alignment at all.

Across all of the overseas courses, the key KSA Areas that are most strongly developed are:

- Reporting and Record Keeping
- Basic Scientific Knowledge and Mathematics, and
- Cleanroom Standards.

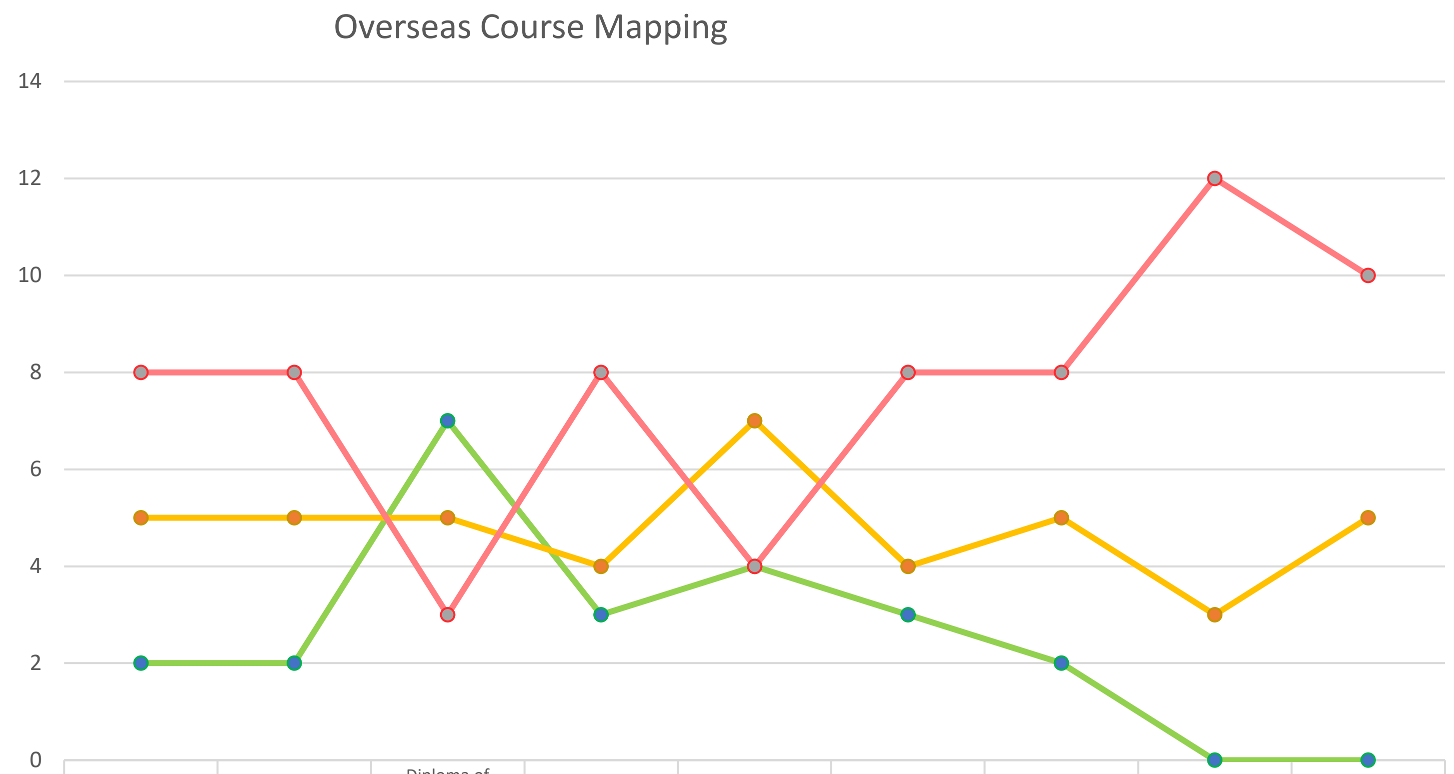
The KSA Topics which overseas courses are particularly strong in, in order of highest to lowest, are:

- Physics
- Material Science
- Characterisation
- Nano Materials
- Maths
- Chemistry
- Thin Films, and
- Safety Practices.

A general observation of overseas courses was that they lacked content on Workplace Health and Safety (WHS) Skills; Process Operations; Equipment Operations and Types of Equipment; Training (workplace training); Quality Standards; Mechanical Trade Skills / Maintenance and Repair; Process Improvement; Software and Computing Skills; and Industry 4.0 Skills.

As the green line indicates in the following graph, the qualifications Diploma of Nanosystems Engineering Technology (Northern Alberta Institute of Technology – Canada) and Diploma Nanotechnology Technician (Athens Technical College – USA) show high alignment as well as good levels of partially alignment to KSA Areas, as shown by the orange line.

The other overseas courses will not be addressed in detail due them not rating highly enough compared with these two courses.



	Diploma of Nanotechnology (Forsyth Tech Community College - USA)	Associate in Applied Science (Major Nanotechnology) (Forsyth Tech Community College - USA)	Diploma of Nanosystems Engineering Technology (Northern Alberta Institute of Technology - Canada)	Bachelor of Science (B.Sc.) NanoEngineering (University Duisburg Essen - Germany)	Diploma Nanotechnology Technician (Athens Technical College - USA)	Nanofabrication Technology A.A.S (Lehigh Carbon Community College - USA)	Postgraduate Certificate in Nanotechnology (University of Oxford - UK)	Diploma in Nanotechnology – Level 3 (1Training - UK)	Nanomaterials and Advanced Composites (Cranfield University - UK)
Key KSA Areas Highly Aligned to course content	2	2	7	3	4	3	2	0	0
Key KSA Areas partially align to course content	5	5	5	4	7	4	5	3	5
Not Aligned to Key KSA Areas	8	8	3	8	4	8	8	12	10

Figure 14 – Overseas Course Mapping

Similar to the approach adopted with overseas courses, the green line on the Australian Course Graph demonstrates the courses that aligned more to KSA Areas and KSA Topics. All laboratory qualifications (Certificate III, through to Advanced Diploma), Certificate III in Engineering (Mechanical Trade), Certificate IV in Process Manufacturing and Diploma of Manufacturing Technology rated highly across the KSA Areas and KSA Topics.

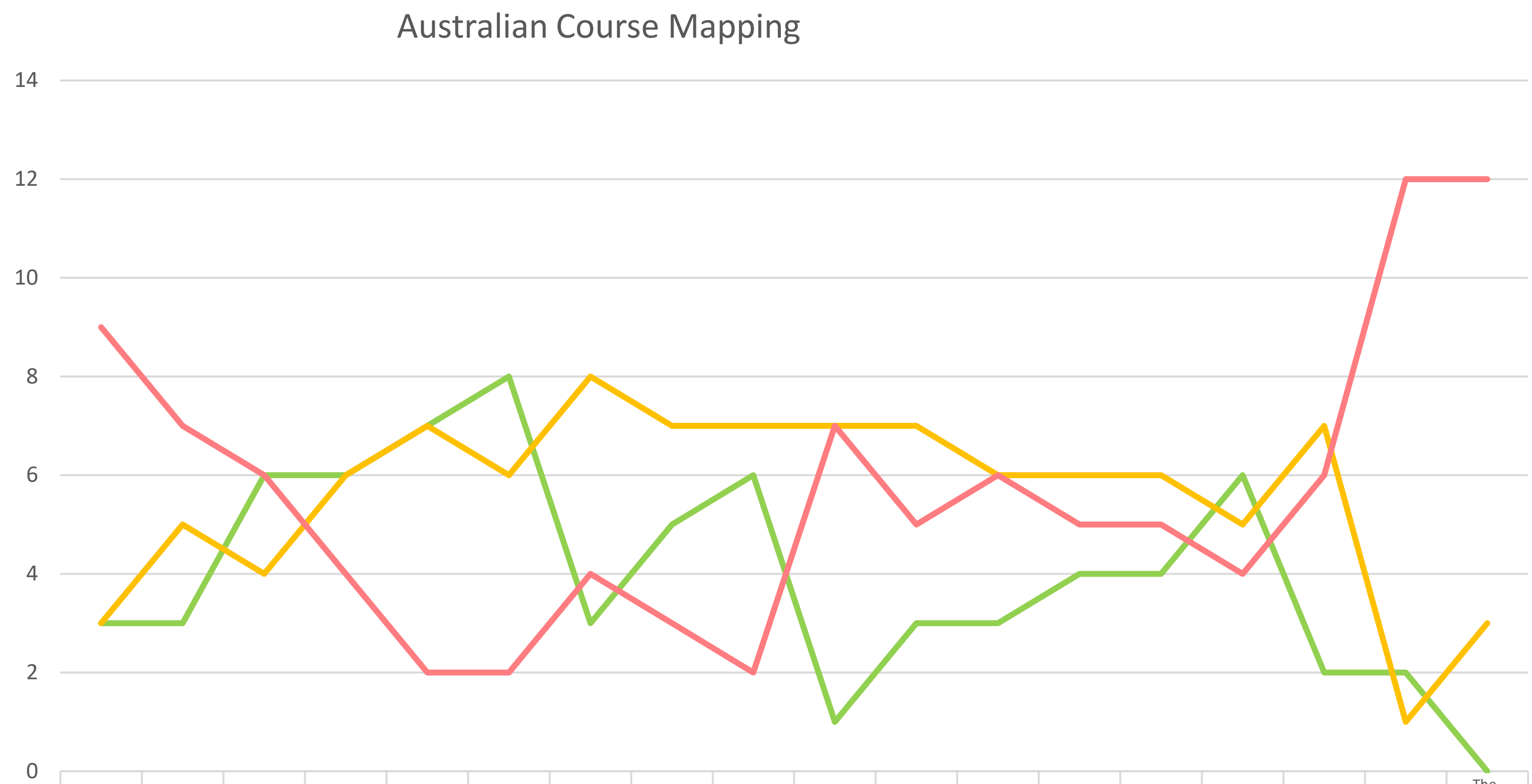
The key KSA Areas that are strong in these Australian courses include:

- Workplace Health and Safety (WHS) Skills
- Basis Scientific Knowledge and Mathematics
- Training (workplace training)
- Reporting and Recording Keeping
- Mechanical Trade Skills / Maintenance and Repair, and
- Process Improvements.

Additionally, the KSA Topics that the Australian courses are particularly strong in, in order of highest to lowest, are:

- Specific Maintenance and Repair Tasks
- Maths (in particular Statistics)
- Safety practices, Fault Finding and PPE.

General observations of Australian courses are that nanotechnology topics were lacking across Australian courses, particularly the VET courses. The nanotechnology courses delivered by Flinders University was an exception and generally had good coverage of the nanotechnology topics.



	Bachelor of Science (Nanotechnology) (Flinders University - Australia)	Graduate Diploma in Nanotechnology (Flinders University - Australia)	Certificate III in Laboratory Skills (MSL30118)	Certificate IV in Laboratory Techniques (MSL40118)	Diploma of Laboratory Technology (MSL50118)	Advanced Diploma of Laboratory Operations (MSL60118)	Certificate III in Manufacturing Technology (MSA30208)	Diploma of Manufacturing Technology (MSA50108)	Certificate III in Engineering (Mechanical Trade) (MEM30205)	Certificate III in Engineering (Fabrication) (MEM30319)	Diploma of Engineering – Advanced Trade (MEM50119)	Certificate III in Engineering – Technical (MEM30505)	Diploma of Engineering – Technical (MEM50212)	Certificate III in Process Manufacturing (MSM30116)	Certificate IV in Process Manufacturing (MSM40116)	Certificate III in Electronics and Communications (UEE30920)	Enterprise Trainer and Assessor Skill Set (TAESS00015)	The Vacuum Lectures (Short Course) (Vacuum Society of Australia - Australia)
Key KSA Areas Highly Aligned to course content	3	3	6	6	7	8	3	5	6	1	3	3	4	4	6	2	2	0
Key KSA Areas partially align to course content	3	5	4	6	7	6	8	7	7	7	7	6	6	6	5	7	1	3
Not Aligned to Key KSA Areas	9	7	6	4	2	2	4	3	2	7	5	6	5	5	4	6	12	12

Figure 15 – Australian Course Mapping

Diploma of Nanosystems Engineering Technology (Northern Alberta Institute of Technology – Canada)

Nature of Course and Local Industry

The Canadian qualification, Diploma of Nanosystems Engineering Technology program, at the Northern Alberta Institute of Technology best aligns with key KSA Areas.

The Diploma covers fabrication and evaluation of micro and nanomaterials and devices commonly used in a wide range of industries, such as health care, smart devices, energy production and storage. The courses provide students with hands-on opportunities to operate systems and equipment such as the scanning electron microscope and nano techniques such as thin film, nano characterisation, lithography, and etching.

The Institute is situated in The Edmonton Research Hub which houses The National Institute for Nanotechnology. The Hub gives students the opportunity to collaborate with higher institutions and industries; to gain hands-on, industry-relevant skills; and gain lab experience, including cleanroom protocols in specialised labs and at partner institutions. Students become familiar with nano skills such as: lithography, microelectromechanical devices, the synthesis of nanoparticles, the fabrication of devices such as Organic LEDs and solar cells, and lab-on-a-chip technology (where medical tests may be carried out on a hand-held device the size of a mobile phone).

Nanosystems Engineering Technology is a two-year qualification, delivered face-to-face. The training focusses on advanced research in medicine, biotechnology, software, petroleum research, cold climate engineering, nanotechnology, and clean energy (Northern Alberta Institute of Technology n.d.).

Upon successful completion of the Nanotechnology Systems Program, students will be able to:

- Design and implement Quality Management Systems; apply fundamental scientific understanding from the nano to the macro world; collect and analyse data; operate and maintain advanced process equipment
- Adopt workplace ethical and safety practices
- Demonstrate communication skills in an interdisciplinary environment
- Demonstrate critical thinking and problem-solving skills.

After graduating from the Nanotechnology Systems program, students typically find employment in research; design; health; and manufacturing areas such as: microfabrication sensors and devices, nanomaterial synthesis, clean technology, and consumer products.

The Diploma include overviews of:

- Various micro and nanofabrication technologies, thin film deposition processes, evaporation, sputtering, oxidation, and chemical vapor deposition
- Basic pattern transfer principles using photolithography and wet / dry etching techniques
- Techniques in nanobiology including the biological impact of nanotechnology advances
- The physical and mechanical properties of materials and how these properties depend on microstructure.

The key KSA Areas and KSA Topics

80% of The Nanosystems Engineering Technology Qualification aligns to the key KSA Areas. These areas include: Process Operations; Equipment Operations; Cleanroom Operations; Reporting and Record Keeping; Nanotechnology Topics; and Mechanical Trade Skills / Maintenance and Repair. The Nanosystems Engineering Technology qualification covers nano skills and nano-specific topics to a much higher degree than the Australian VET qualifications (refer to Figure 16 and Figure 17 below).

Process Operations		
	Preparation	
	During Operations	
	Shut down and clean up	
	Assembly and Packaging	
	Packaging & Testing	
	Product Manufacturing	
Equipment Operations and Types of Equipment		
	Lab Equipment	
	Microscopy	
	Vacuum Systems	
	Pumps	

Figure 16 – Process Operations and Equipment Operations and Types of Equipment

Nanotechnology Topics		
	Characterisation	
	Ethics	
	Intro	
	Thin Films	
	Nano Materials	
	Properties and applications	
	Deposition	
	Lithography	
	Etching	
Cleanroom Standards		
	Cleanroom	
Training (workplace training)		
Reporting and Record Keeping		

Figure 17 – Nanotechnology Topics, Cleanroom Standards, Reporting and Record Keeping

More in-depth mapping of this course can be seen in Appendix 10.6 International Course Mapping Matrix.

The strength of the Nanosystems Engineering Technology qualification is its strong alignment with key KSA Areas. The strengths reflect the fact that the delivery of the qualification takes places in an industrial / research park surrounded by industry that is supportive of strong educational collaboration. Industry is also providing a durable job market which contributes to the success and viability of the qualification. While such as model would be beneficial here, similarly strong industry and government support would be required.

Diploma Nanotechnology Technician (Athens Technical College – USA)
Nature of Course and Local Industry

The course Diploma Nanotechnology Technician is delivered at Athens Technical College (ATC) which is based in Athens, Georgia, USA.

The mission of ATC's Nanotechnology Program is to prepare students for careers as nanotechnology technicians in industrial and academic organisations through "classroom instruction, hands-on training, and industry interaction" (Athens Technical College n.d.).

The ATC trains students for the local industry, which is predominately manufacturing and bioscience. Local companies that recruit graduates include Johnson & Johnson and RWDC Industries (sustainable plastics).

The key KSA Areas and KSA Topics

Key KSA Areas which the Diploma Nanotechnology Technician covers include:

- Attitudes
- Basic Scientific Knowledge and Mathematics
- Reporting and recording keeping
- Mechanical Trade Skills / Maintenance and Repair.

The ATC course has a strong focus on Attitudes, with one of the course subjects focusing purely on Attitudes. As part of their learning outcomes for the course, students must demonstrate appropriate communication skills (written and verbal); apply, describe, and create time management strategies; and identify personal learning styles, including personality traits. All of these learning outcomes rated highly against the in-depth Attitudes matrix.

In contrast, Attitudes were not a big focus for most of the other courses examined, especially across the overseas courses.

This course almost made the highly aligned criteria (>80%) with respect to Nanotechnology Topics. The course subjects have strong coverage of Nanotechnology Topics compared to that of other courses investigated.

The following table (Figure 18) depicts the nanotechnology topics that are aligned:

Characterisation	
Ethics	
Intro	
Thin Films	
Nano Materials	
Properties and applications	
Deposition	
Lithography	
Etching	

Figure 18 – Nanotechnology Topics.

This qualification was also partially aligned to KSA Areas:

- Workplace Health and Safety (WHS) Skills
- Process Operations
- Equipment Operations and Types of Equipment
- Quality Standards
- Mechanical Technicians and Tradespeople
- Software and Computing Skills.

However, the course did not specifically address KSA Areas related to Cleanroom Standards, Training (workplace training), Process Improvement, and Industry 4.0 Skills.

More in-depth mapping of this course can be seen in Appendix 10.6 International Course Mapping Matrix.

Certificate IV in Process Manufacturing (MSM40116) and Diploma of Manufacturing Technology (MSA50108) (VET – Australia)

Nature of Course and Local Industry

Certificate IV in Process Manufacturing (MSM40116) and the Diploma of Manufacturing Technology (MSA50108) have a similar level of alignment to KSA Areas and KSA Topics. However, NCVER data shows there were no enrolments in Diploma of Manufacturing Technology in 2019 and 2020 and only five enrolments from 2016 to 2018 (NCVER, 2020). For this reason, deeper analysis has primarily focussed on the Certificate IV in Process Manufacturing.

	2016	2017	2018	2019	2020
MSA50108 - Diploma of Manufacturing Technology	5	5	5	-	-
MSM40116 - Certificate IV in Process Manufacturing	290	925	1225	1660	1705

Table 8 – Total VET students and courses 2016-2020 (NCVER, 2020)

The Manufacturing Training Package (MSM) states that the Certificate IV in Process Manufacturing provides the skills and knowledge required by advanced production workers who use a range of equipment and are involved in solving complex problems that require theoretical knowledge, combined with an understanding of operating procedures directly related to producing products.

The qualification is designed to develop employees who operate across more than one process manufacturing sector. These workers perform a role that may include the ability to work independently and conduct technical problem solving according to the needs of the work required to produce products. This qualification is designed for use across three process manufacturing sectors:

1. Chemical hydrocarbons and oil refining
2. Plastics, rubber, cable making
3. Manufactured mineral products (Training.gov.au n.d. MSM).

The key KSA Areas and KSA Topics

The Certificate IV in Process Manufacturing aligned highly with KSA Areas and KSA Topics.
The key KSA Areas which were highly aligned included:

- Workplace Health and Safety Skills
- Process Operations
- Training (workplace training)
- Reporting and Record Keeping
- Mechanical Trade Skills / Maintenance and Repair, and
- Process Improvement.

Additional KSA Topics covered include:

- Chemistry
- Technical Maths / Applied
- Polymer Science

- Material Science
- Engineering, and
- Equipment Application Software.

Workplace Health and Safety (WHS) Skills		
	Safety Practices	
	Common Hazards and Risks	
	Controls	
	PPE	
Process Operations		
	Preparation	
	During Operations	
	Shut down and clean up	
	Assembly and Packaging	
	Packaging & Testing	
	Product Manufacturing	
Equipment Operations and Types of Equipment		
	Lab Equipment	
	Microscopy	
	Vacuum Systems	
	Pumps	
Attitudes		

Figure 19 – Workplace Health and Safety Skills, Process Operations and Equipment Operations and Types of Equipment

However, this course lacks content on KSA Areas of Nanotechnology Topics, Cleanrooms, and Industry 4.0 Skills.

Figure 20 – Nanotechnology Topics, Cleanrooms, and Industry 4.0 Skills on the following page depicts more detail for the areas that are not aligned.

Nanotechnology Topics		
	Characterisation	
	Ethics	
	Intro	
	Thin Films	
	Nano Materials	
	Properties and applications	
	Deposition	
	Lithography	
	Etching	
Cleanroom Standards		
	Cleanroom	
Training (workplace training)		
Reporting and Record Keeping		
Quality Standards		
	ISO / IPC / FED STD	
	Lean six sigma	
	Project and Quality Management	
Engineering Topics		
	Engineering	
	Mechanical Engineering	
	Technical Engineering	
	Chemical Engineering	
	Electrical Engineering	
	Bio Engineering	
	Engineering Materials	
Mechanical Trade Skills / Maintenance and Repair		
	Specific Maintenance and Repair tasks	
Process Improvement		
	Fault finding	
Software and Computing Skills		
	Computer Aided Design (CAD)	
	Microsoft Office	
	Programming	
	Equipment Application Software	
Industry 4.0 Skills		
	PLCs (programmable logic controller)	
	3D Printing	

Figure 20 – Nanotechnology Topics, Cleanrooms, and Industry 4.0 Skills

More in-depth mapping of this course can be seen in Appendix 10.7 Australian Course Mapping Matrix.

It is important to note that Certificate IV in Process Manufacturing courses are conducted by a limited number of Registered Training Organisations in Australia. The process manufacturing qualifications were last updated in 2020, which does demonstrate that industry practices and skill needs are constantly changing in response to increased levels of automation and advanced manufacturing processes and that the qualification curriculum includes these recent changes.

Data on student cohorts in Australia

NCVER data illustrates (Table 9) that Certificate IV in Process Manufacturing has had an increase of student enrolments in the last 5 years with the majority of students based in Victoria.

	2016	2017	2018	2019	2020
NSW	-	-	15	-	-
Victoria	290	925	1210	1660	1705
Queensland	-	-	-	-	-
South Australia	-	-	-	-	-
Western Australia	-	-	-	-	-
Tasmania	-	-	-	-	-
Northern Territory	-	-	-	-	-
ACT	-	-	-	-	-

Table 9 – Total VET students and courses 2016-2020, Certificate IV in Process Manufacturing (NCVER, 2020)

The data (Table 10) also indicates that there are greater number of students across Australia in the Certificate III level qualification. However, the Certificate IV in Process Manufacturing is the preferred qualification due to stronger alignment to KSA Areas and KSA Topics in comparison with Certificate III in Process Manufacturing.

NCVER enrolment data

	2016	2017	2018	2019	2020
MSM30116 - Certificate III in Process Manufacturing	115	3055	3375	3950	4435
MSM40116 - Certificate IV in Process Manufacturing	290	925	1225	1660	1705

Table 10 – Total VET students and courses 2016-2020, Certificate III and IV in Process Manufacturing (NCVER, 2020)

Since 2016, there have been no student enrolments in Certificate IV in Process Manufacturing in Queensland, South Australia, Western Australia, Tasmania, Northern Territory, nor the ACT. This is explained by the availability of government subsidised funding for Certificate IV in Process Manufacturing, currently only available in Victoria. Whilst government subsidised funding for Certificate III in Process Manufacturing is currently available in the other states.

Laboratory Skills and Operations Qualifications (VET – Australia)

Nature of Course and Local Industry

Laboratory Skills and Operations courses are run by TAFEs and Registered Training Organisations (RTOs) in all Australian states.

Since 2016 there has been a steady stream of graduates in all states from these courses. The relevant qualifications delivered by TAFEs and RTOs across Australia during that time are:

MSL30109 – Certificate III in Laboratory Skills
MSL30116 – Certificate III in Laboratory Skills
MSL30118 – Certificate III in Laboratory Skills
MSL40109 – Certificate IV in Laboratory Techniques
MSL40116 – Certificate IV in Laboratory Techniques
MSL40118 – Certificate IV in Laboratory Techniques
MSL50109 – Diploma of Laboratory Technology
MSL50116 – Diploma of Laboratory Technology
MSL50118 – Diploma of Laboratory Technology
MSL60109 – Advanced Diploma of Laboratory Operations
MSL60116 – Advanced Diploma of Laboratory Operations
MSL60118 – Advanced Diploma of Laboratory Operations

Table 11 – List of relevant Laboratory qualifications

The numbers of student enrolments in each state across all of the above qualifications in the last 5 years are:

	2016	2017	2018	2019	2020
NSW	1,185	1,160	1,105	1,075	1,055
Victoria	1,190	1,140	1,180	1,240	1,320
Queensland	1,040	935	740	1,185	1,655
South Australia	355	235	110	235	190
Western Australia	980	880	770	920	925
Tasmania	145	95	75	50	45
Northern Territory	15	30	30	55	45
ACT	65	50	60	75	40

Table 12 – Total VET students 2016-2020, Laboratory qualifications (NCVER, 2020)

States with the largest numbers of laboratory students in 2020 were, in order of highest to lowest, Queensland, Victoria, New South Wales and Western Australia.

The greatest number of students are concentrated in qualifications at the Certificate III, IV and Diploma Level.

The National Careers Institute indicates that graduates from these courses are most often employed to perform a range of laboratory techniques, including manual, semi-automated and automated collecting and preparing of samples in a laboratory for the Health Care; Professional, Scientific and Technical Services; and Food industries. A number of TAFE institutes indicate that students will be likely to gain employment in laboratory assistant jobs in environmental, construction materials, water quality, and polymer testing organisations, or as School Laboratory Technicians.

The key KSA Areas and KSA Topics

These qualifications align to a large extent to key KSA Areas and KSA Topics, including:

- Workplace Health and Safety (WHS) Skills
- Basic Scientific Knowledge and Mathematics (KSA Topics include Basic Chemistry, Physics and Mathematics)
- Reporting and Record Keeping
- Quality Standards
- Training (workplace training) (due to the high-level coverage of Workplace training and mentoring skills)
- Specific Maintenance and Repair tasks.

The qualifications do not specifically address KSA Areas related to Cleanroom Standards, Vacuum systems, and pumps nor Nanofabrication and Nanotechnology Topics.

The qualifications have a number of core units which align closely with ANFF and industry skill requirements. These units include:

- Process and interpret data (MSL924003)
- Maintain and Calibrate instruments and equipment (MSL934004)
- Apply Quality Systems and Continuous Improvement processes (MSL934006)
- Maintain laboratory or field workplace safety (MSL944002)
- Receive and prepare samples for testing (MSL953003)

Each TAFE and RTO offers a range of different combinations of electives, depending upon the nature of nearby industries, however there are some commonalities:

- Aseptic Techniques (RMIT, TAFE NSW, Swinburne, CQU, NM TAFE, TAFE QLD, TAFE SA)
- Microscopy (RMIT, TAFE NSW, Swinburne, CQU, NM TAFE, TAFE QLD, TAFE SA)
- Using laboratory application software (RMIT, TAFE NSW, Swinburne, CQU, NM TAFE, TAFE SA)
- Chemical tests and procedures (TAFE NSW, CQU, NM TAFE, TAFE QLD
- Prepare, Standardise, and use Solutions (TAFE NSW, Swinburne, TAFE QLD, TAFE SA)
- Performing biological procedures (TAFE NSW, Swinburne, TAFE QLD, TAFE SA)
- Perform histological procedures (TAFE NSW, Swinburne, TAFE QLD, TAFE SA)
- Anatomy and physiology (RMIT, TAFE SA)
- Maintain and control stock (CQU, NM TAFE)
- Perform standard calibrations (CQU, NM TAFE)
- Obtain representative samples (CQU, NM TAFE)
- Data analysis and reporting (RMIT, TAFE SA).

More in-depth mapping of this course can be seen in Appendix 10.7 Australian Course Mapping Matrix.

Overall, the Laboratory Skills and Operations qualifications provide a good grounding in many of the essential knowledge and skill elements that nanotechnology technicians require and could form a potential pool from which ANFF, and the nanofabrication industry could recruit each year for further nano-specific upskilling.

In order for these qualifications to be even more suitable for developing the skills ANFF and industry need, ANFF could encourage the development of elective units in Cleanroom Operations, Vacuum Science and Nano science.

MSL Training Package

IBSA Manufacturing is the Skills Service Organisation (SSO) for the Manufacturing Industry. Their role is to identify and document emerging trends as well as future workforce needs through consultation and research (IBSA Group, 2020). IBSA do this by working with industry partners, networks, bodies, and influencers. Their research, analysis and recommendations provide the background for Industry Reference Committees (IRCs) to develop training packages and qualifications for the manufacturing sector.

IBSA IRCs include:

- Aerospace IRC
- Furnishing IRC
- Manufacturing and Engineering IRC
- Process Manufacturing, Recreational Vehicle and Laboratory IRC
- Sustainability IRC
- Textiles, Clothing and Footwear IRC.

IBSA oversees the development of industry competency skills standards and qualifications for the IRCs. The Laboratory Skills and Operations qualifications are aligned to the Process Manufacturing, Recreational Vehicle and Laboratory IRC.

IBSA have indicated that the Process Manufacturing, Recreational Vehicle and Laboratory IRC have a submission for suggested changes to the Laboratory Skills and Operations qualifications which is awaiting approval. Upon approval of this submission, expected later in 2021, IBSA will then commence engaging with industry partners, networks, bodies, and influencers to make the changes. This is then expected to be completed over a further 12-month period.

There is a potential opportunity to request that IBSA include elective units relevant to Nanotechnology and Nanofabrication within these qualifications for the industry.

Certificate III in Engineering (Mechanical Trade) (MEM30205) (VET – Australia)

Nature of Course and Local Industry

The Certificate III in Engineering (Mechanical Trade) covers the skills and knowledge required to work as an Engineering Tradesperson – Mechanical within metal, engineering, manufacturing industries, as well as other associated industries. This trade pathway was historically known as a "Fitter and Turner" and also includes the "Tool Makers" trade.

The qualification has been specifically developed for apprentices and is delivered by TAFEs and RTOs with a combination of on and off job delivery.

The Certificate III in Engineering – Mechanical Trade specifies the skills and knowledge required for mechanical engineering tradesperson job role including the design, assembly, manufacture, installation, modification, testing, fault finding, commissioning, maintenance and service of all mechanical equipment, machinery, fluid power systems, stationary and mobile equipment, instruments, refrigeration, and the use of computer-controlled machine tools. (Training.gov.au n.d. MEM)

The key KSA Areas and KSA Topics

This qualification aligns well with key KSA Areas, including:

- Workplace Health and Safety (WHS) Skills
- Training (workplace training)
- Reporting and Record Keeping
- Mechanical Trade Skills / Maintenance and Repair
- Process Improvement.

There are also quite a few KSA Areas that are partially aligned including:

- Process Operations
- Equipment Operations and Types of Equipment
- Attitudes
- Basic Scientific Knowledge and Mathematics
- Quality Standards
- Software and Computing Skills
- Industry 4.0 Skills.

The qualification does not specifically address KSA Areas related to Nanotechnology Topics and Cleanroom Standards.

Data on student cohorts in Australia

The numbers of student enrolments in each state across all Certificate III in Engineering (Mechanical Trade) in the last 5 years are:

	2016	2017	2018	2019	2020
NSW	1,435	1,240	1,425	1,695	1,645
Victoria	1,735	1,585	1,710	1,825	1,405
Queensland	3,330	3,755	3,320	3,640	3,535
South Australia	420	335	340	410	465

Western Australia	1,730	1,700	1,790	1,865	1,945
Tasmania	240	145	140	175	180
Northern Territory	65	70	65	75	60
ACT	20	15	5	-	-

Table 13 – Total VET students and courses 2016-2020, Certificate III in Engineering (Mechanical Trade) (NCVER, 2020)

Queensland is the state with the highest number of student enrolments for this qualification, with Western Australia, NSW and Victoria following.

The core units from this qualification which align closely to ANFF and the micro / nano industry, requirements include:

- MEM12023A Perform engineering measurements
- MEM12024A Perform computations
- MEM13014A Apply principles of occupational health and safety in the work environment
- MEM14004A Plan to undertake a routine task
- MEM14005A Plan a complete activity
- MEM15002A Apply quality systems
- MEM15024A Apply quality procedures
- MEM16006A Organise and communicate information
- MEM16007A Work with others in a manufacturing, engineering, or related environment
- MEM16008A Interact with computing technology
- MEM17003A Assist in the provision of on the job training
- MSAENV272B Participate in environmentally sustainable work practices.

Each TAFE and RTO selects an array of elective units that meet the needs of their nearby industry. The electives that align to key KSAs Areas of Process Operations; Mechanical Trade Skills / Maintenance and Repair; Reporting and Record Keeping; Software and Computing Skills are:

- MEM07001B Perform operational maintenance of machines / equipment
- MEM07003B Perform machine setting (routine)
- MEM07024B Operate and monitor machine / process
- MEM07032B Use workshop machines for basic operations
- MEM18011C Shut down and isolate machines / equipment
- MEM07018C Write basic NC / CNC programs
- MEM18010C Perform equipment condition monitoring and recording
- MEM18005B Perform fault diagnosis, installation and removal of bearings
- MEM18048B Fault find and repair / rectify basic electrical circuits
- MEM18051B Fault find and repair / rectify complex electrical circuits
- MEM18054B Fault find, test and calibrate instrumentation systems and equipment.

As this qualification has been specifically developed for apprentices, it is delivered across a timeframe of 3 – 4 years based on the contract of training in each state. TAFE NSW delivers the qualification over 3 years, TAFEs across Victoria vary from 3 – 4 years, TAFE WA between 3 – 4 years, TAFE SA over 4 years and TAFE QLD over 4 years.

It is also worth noting that within the MEM training package, there are quite a few of the Units of Competency that have pre-requisites. This means that prior to commencing a specific unit, all units that have been outlined as pre-requisites need to be completed. For example, there are four prerequisite units to be completed prior to commencing the unit MEM07003B - Perform machine setting (routine) which only a trade qualified person is likely to have completed.

Overall, this qualification gives a good foundation across many of the key KSA Areas that nanofabrication and microfabrication technicians require. However, completion timeframes should be taken into account. This qualification is an apprenticeship-only pathway, if ANFF and industry are able to invest in the time required for apprentices. Recruiting experienced tradespeople and training them in the areas of cleanroom standards and Nanotechnology Topics is another way to fill the required need.

Diploma of Engineering – Advanced Trade (MEM50119)

Apprentices who have completed the Certificate III in Engineering (Mechanical Trade) (MEM30205) may choose to continue their studies with the Diploma of Engineering – Advanced Trade (MEM50119).

This qualification contains units of competency relevant to fluid power system, fluid power controls system and pneumatics which is relevant for vacuum systems. The pneumatic units of competencies apply to both positive pressure pneumatics and negative (vacuum) systems. These units include:

- MEM18018 Maintain pneumatic system components
- MEM18019 Maintain pneumatic systems
- MEM18022 Maintain fluid power controls
- MEM18023 Modify fluid power controls.

Entry into this course is only from an engineering trade qualification, so this limits the use for other technicians trained under a different qualification.

MEM Training Package

The MEM Training package makes a sharp delineation between trades people (trained in the trade qualification) and technician (trained in the technical qualifications in the training package). Whereas TAFE SA’s discussion with industry indicated more of a blurred approach to job roles and titles and the terms are often used interchangeably.

Again, IBSA oversees the development of industry competency skills standards and qualifications for the MEM Training Package working with the Manufacturing and Engineering IRC.

IBSA have advised there is a range of new technical qualifications that are currently being developed at Diploma level. These are for Prototyping, Planning, Applied Technologies (Industry 4.0), and Engineering Materials.

There is a potential opportunity to request that IBSA include elective units relevant to Nanotechnology and Nanofabrication within these new qualifications for the industry.

More in-depth mapping of the MEM courses can be seen in Appendix 10.7 Australian Course Mapping Matrix.

Nanotechnology Units of Competency never incorporated into the Australian Training System

IBSA consultant Richard Jenkins has kindly provided TAFE SA with details of twelve draft units of competency that were prepared around nanofabrication skills in 2005. These units were prepared for incorporation into the MSA training package at Certificate II (3 units), Certificate IV (5 units), Diploma (3 units) and Advanced Diploma level (1 unit).

He indicated that he is unsure who holds the copyright to this material but that the units were never adopted as part of the training package for a number of reasons, including that it was thought there would be insufficient utilisation at the time.

Full copies of these documents will be shared with ANFF in this final report. TAFE SA assumes that the copyright is likely to be held by the Commonwealth of Australia, as the Commonwealth holds all copyright in all proclaimed training package content.

The following observations were made:

- The units of competency cover some of the key KSA Areas that TAFE SA has identified as essential skills and knowledge for nanofabrication technicians. These include: Workplace Health and Safety (called Occupational Health and Safety in the documents); Process and Equipment Operations; Identifying fundamental principles of nanotechnology; Preparing SOPs; Applications of Nanotechnology.
- Some of the draft units are particularly strong on:
    - Workplace Health and Safety, including PPE.
    - Microscopy skills, which are covered in a number of units.
    - Many of the essential attitudes documented by TAFE SA are reflected in the units including, attention to detail and respect for cleanliness, precision, and safety.
    - The units reflect the underpinning knowledge and skills required to perform the tasks, however, this does result in repetition across all the units (see further discussion below).
- Where some of the draft units would not meet the needs include:
    - Lists of nanotechnology equipment (in the equipment and process-focussed units) are fairly limited and very focussed on microscopy when compared with current ANFF lists, although this may be expected given the units were written over 15 years ago and the technology is likely to have changed significantly.
    - Operation of the software (which is an integral part of equipment operations) is often not included. Again, this may be due to more manual processes in 2005.
    - There is quite a lot of repetition of required skills and knowledge across the units. If such units were delivered by RTOs, they need to be aware of the duplication and manage the repetition in assessments for the students.
    - Although cleanrooms are mentioned in some units, there is no specific unit with cleanrooms as a central focus.
    - Vacuum technology and systems are not mentioned in any units of competency.

6.2 ANFF Course

See Appendix 10.9 ANFF LMS Course Listing for the full list of course names.

ANFF provided the names of the short courses facilitated by them as part of the information made available for this training needs analysis. A limitation of this information is that the learning objectives were not provided and as such mapping of the course content to KSA Areas and KSA Topics has been limited to the course titles and fabrication areas.

From the information provided, no specific safety short course was listed. Whether there are safety components within some of short courses where a high degree of safety is required on a process, is unknown based on the titles.

An opportunity exists to create a micro and nano industry safety short course that could be provided to all ANFF employees as part of their induction process together with making it available to the ANFF industry network.

7. Recommendations

7.1 Recommendations on Next Steps and Increased Skilled Engagement

TAFE SA recommends that ANFF evaluate whether to increase engagement with what could broadly be termed the 'Key Skills Stakeholders'. These Key Skills Stakeholders include:

- The National Skills Commission.
- Skills Service Organisation IBSA (in respect their MSL, MSM, MSA MEM and MSL training packages.
- TAFE institutes in the states with high numbers of laboratory operations students and where there might be delivery in a location near ANFF nodes and micro and nanofabrication industry customers.

To lead this engagement, ANFF could consider engaging a national nanofabrication skills coordinator or an organisation to perform this function, and to advocate for recognition of nanotechnology and nanofabrication job roles and knowledge, skills, and attitudes in the national VET system. Examples of the type of engagement which could occur are presented below.

7.1.1 Engagement with the National Skills Commission

In engaging with the National Skills Commission, ANFF could:

- Submit selected KSA findings from this Report to the National Skills Commission for consideration in development of their national skills data base and their work on transferable skills cluster.
- Request that the National Skills Commission consider utilising USA O*NET job role data for Nanotechnology Technicians and Nanotechnology Engineers in their skills definition program of work.
- Request that ANZCO codes be updated to include relevant laboratory technician and nanofabrication technician job roles.

7.1.2 Nanofabrication Skills Leadership, Certification or Accreditation

As new technologies rapidly advance in the micro and nano industry, the length of traditional education models will not be able to fill the skills shortage gaps. It is recommended that ANFF together with State Training and Skills Departments, education and micro and nano industries collaborate to create micro-credential that are endorsed by industry.

Micro-credentials are an effective way to implement a competency-based learning model that is flexible and can rapidly adjust to change and will benefit industry in creating a job ready workforce. It will allow the employee to stack micro-credentials to gain small qualifications to fill industry skill shortages, but also have the option to build up to a full qualification. This allows for a flexible approach to learning which fits in with Industry, employees, time, and resources and allows the micro and nano industry to be flexible and to rapidly adjust to change.

It is also recommended, as ANFF has strong existing short-course materials, that ANFF engage with State Training and Skills Departments with a view to accrediting some of its own content as micro-credentials. Funding could also be sought from each state to offer these skills to students and graduates.

7.1.3 Engagement with IBSA

In engaging with Skills Service Organisations, such as IBSA, ANFF could:

- Provide feedback on the development of new units of competency and unit rewrites for the Laboratory Operations suite of Qualifications in the MSL Training Package (IBSA is currently waiting for confirmation and approval of a program of work of around 100 units of competency).
- Provide feedback on the development of new qualifications proposed for the MEM Training Package.

In the short to medium term, it is recommended that ANFF work with IBSA to develop specific unit of competency that cover the gaps identified in the report. For the Certificate III, Certificate IV, and Diploma of Laboratory Operations qualifications, it would be suggested that these extra courses being developed to align to the micro and nanotechnology, sit as elective units in the qualifications or as its own elective group (however the qualification is structured in the future). As part of working with IBSA, ANFF will need to highlight the demand for the skills in the industry and the KSA gaps that have been identified for this technician role.

We note that there are different engagement Officers at IBSA responsible for different training packages and the national training system is currently undergoing significant reform at the moment.

7.1.4 Engagement with TAFE Institutions and Universities

ANFF could partner with TAFE Institutes across Australia which deliver the Cert III, Cert IV, and Diploma of Laboratory Operations with an intent to explore:

- Recruitment of graduates for employment into ANFF and industry as nanofabrication technicians.
- Offering summer internships to 'test' the suitability of partially completed students to be employed full time at the completion of their qualifications. A key question is whether they can be rapidly inducted into ANFF policies and processes and SOPs given their underpinning knowledge of good laboratory practice.
- A short-term recommendation is to focus on recruiting experienced tradespeople from the Certificate III in Engineering (Mechanical). Once recruited, training them in the areas of cleanroom standards, nanotechnology topics and scientific knowledge is another way to fill the required need. This is the similar recommendation to the Laboratory qualifications, with the recruited tradespeople to undertake short course around the gaps identified. Recruiting tradespeople from this qualification is suggested alongside other options, as this qualification will assist with filling the recruitments of mechanical technicians in the industry.
- Licensing ANFF courseware into existing Laboratory Operations Courses across Australia (currently very pathology and histology-focussed), Mechanical Trade and Electronics courses in order 'contextualise' or broaden existing offerings to include nanotechnology and nanofabrication topics. ANFF could provide a low / no cost licence to incentivise institutions to do this and/or additional development funding for contextualised training resources to be developed.

- Selected access to ANFF equipment to support current students to study in a unit of competency, or simply as a field trip to expose students to the industry.
- Provide ANFF short courses to the wide public or transition workers to have a 'taste' of the industry and build awareness of the opportunities and underpinning science.
- Seek a university or higher education partner to develop a Higher Education Diploma or Associate Degree in Nanotechnology. This could be modelled on the Alberta, Canada course which is highly aligned to key KSA Areas. A major question here would be whether one state can support sufficient student interest and demand to run the course in a profitable way and the employment opportunities for graduates.
- Establish a traineeship program whereby ANFF nodes and neighbouring industries take on Laboratory Operations trainees as operators, with a view to developing them into Nanotechnology Laboratory Technicians. Trainees would work part time at ANFF and study at the nearby TAFE Institute part time.
- Partner with TAFE Institutes across Australia which deliver the Certificate III, Certificate IV, and Diploma of Laboratory Operations with an intent to explore the recruitment of graduates for employment into ANFF and industry as micro and nanofabrication technicians. In order for these qualifications to be even more suitable to the nano industry, units across these qualifications need to be contextualised to suit the industry.
- It is also recommended that ANFF provides additional short course products or could encourage others to develop educational products to ensure that the graduates are further aligned to the micro and nano industry. These educational products could include:
    - Short Courses that cover the KSA Topics of Nanotechnology:
        - Ethics
        - Intro
        - Thin Films
        - Nano materials
        - Properties and applications including deposition, lithography, and etching
    - Short Course on Cleanroom Standards
    - Short Course on Vacuum Systems.
- Onsite placement for a period of time to get a better understanding of industry, processes and the bespoke equipment that is used.
- Provide Registered Training Organisations, including TAFEs, with micro and nano specific equipment so students have exposure to the unique industry equipment. This will give them much needed hands-on experience prior to them potentially moving into the industry. It will also highlight the industry to students that might not have thought about a micro and nano career.

As a long-term vision, modelled on Northern Alberta Institute of Technology, which is situated in Canada's nanotechnology hub, Australia could build an innovation hub including micro and nano industries. This would bring together the best innovative and educational minds in one space, working collectively to share information and knowledge in a collaborative environment but at this stage is aspirational-only.

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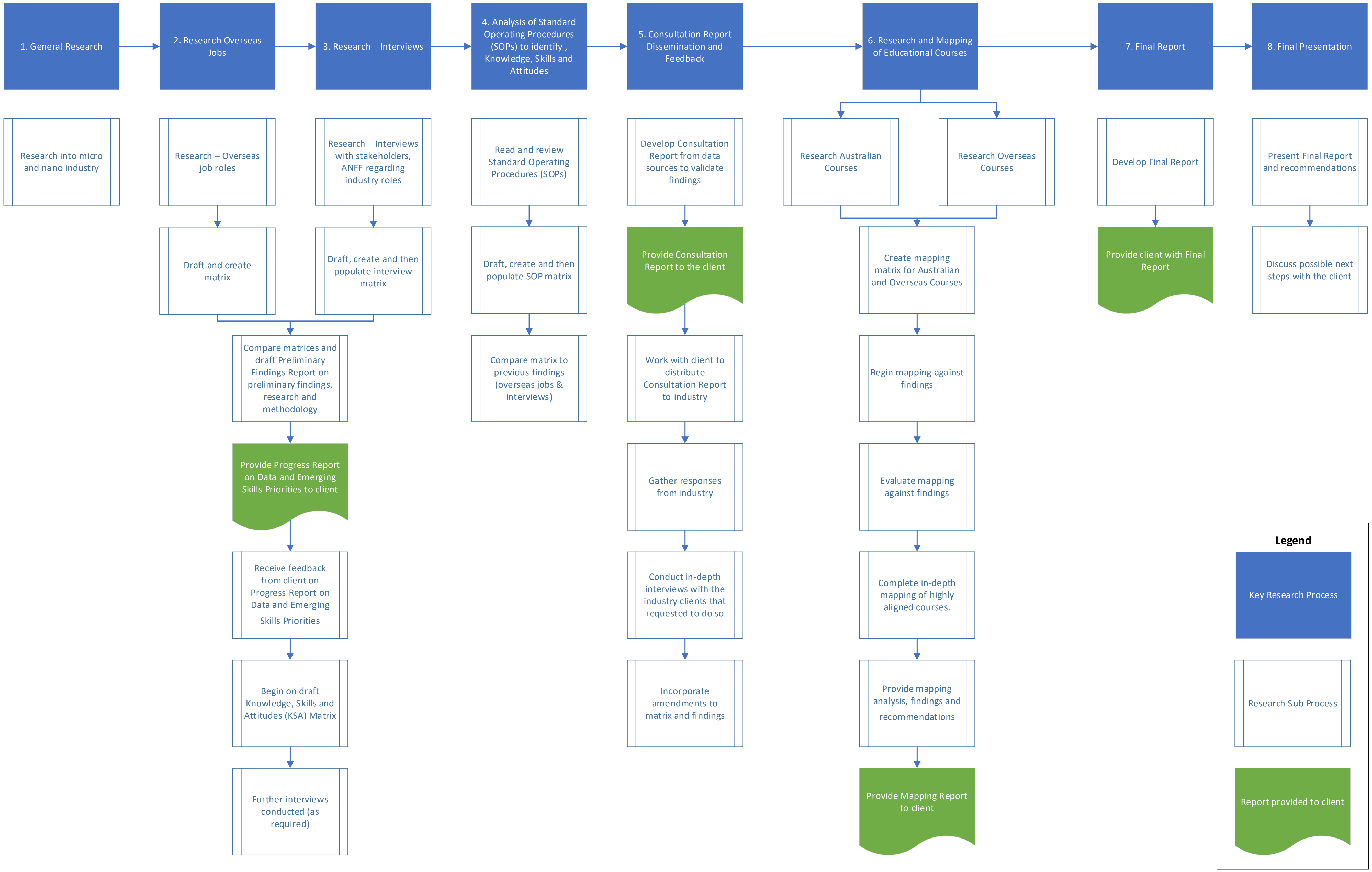
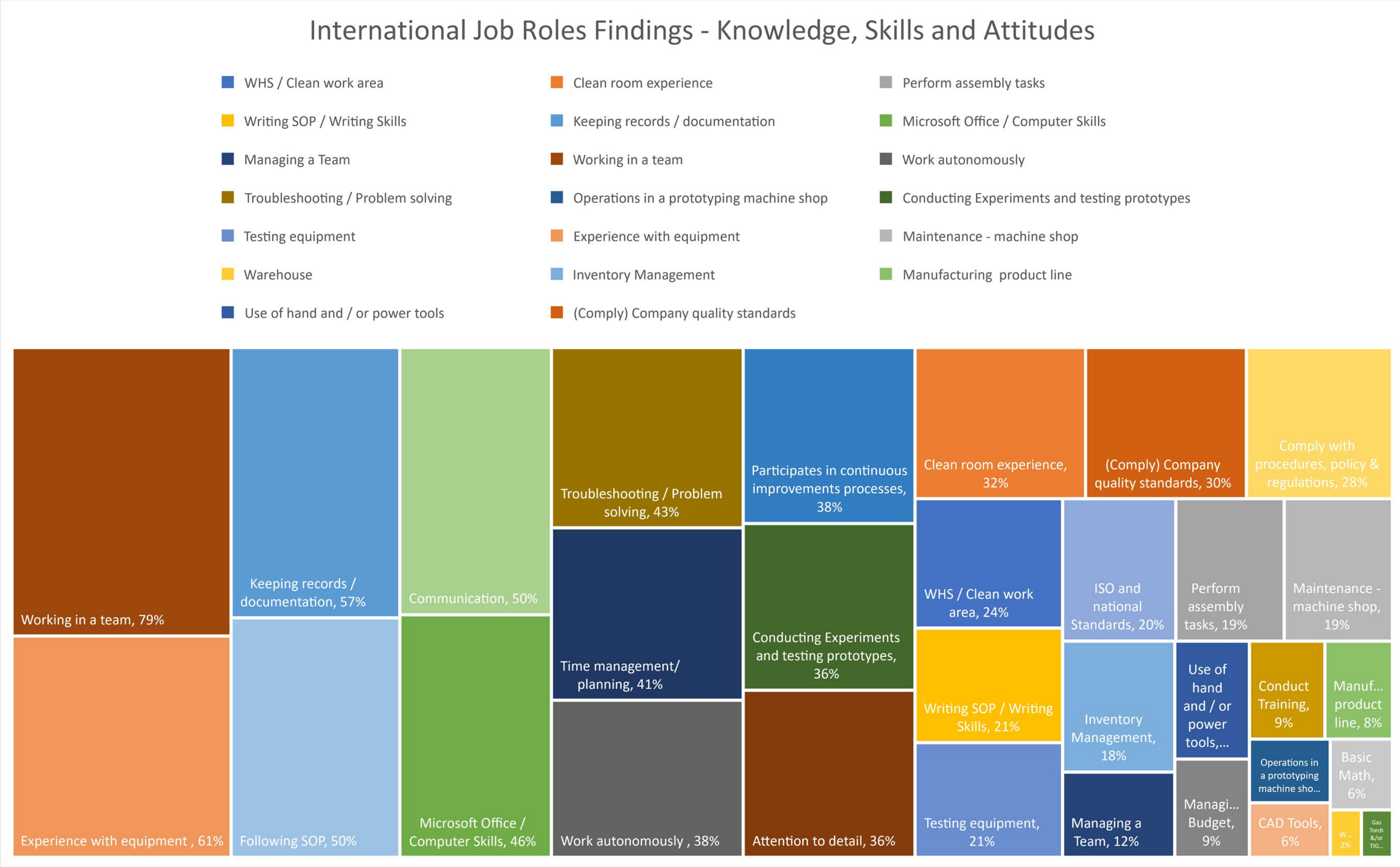
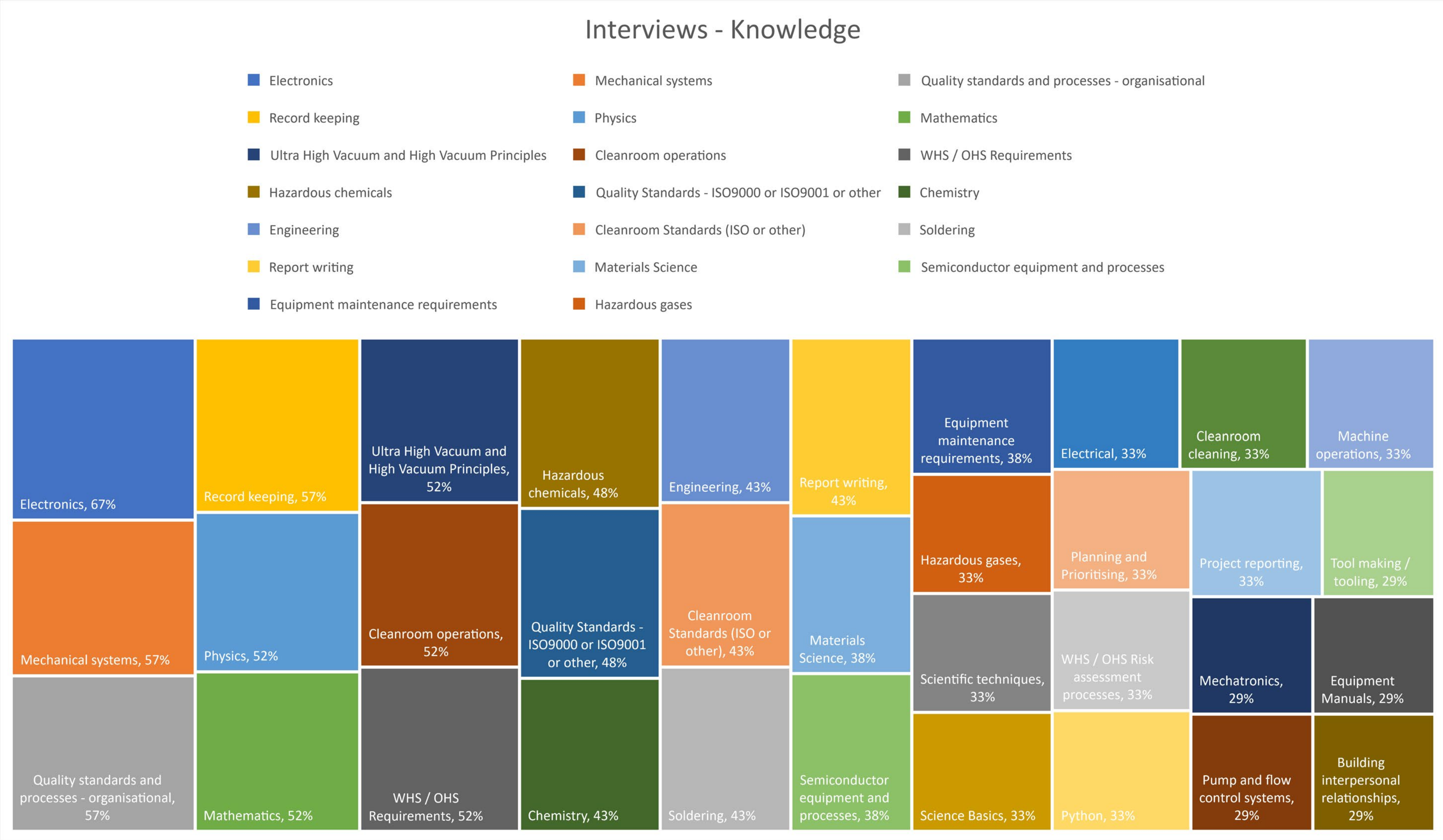
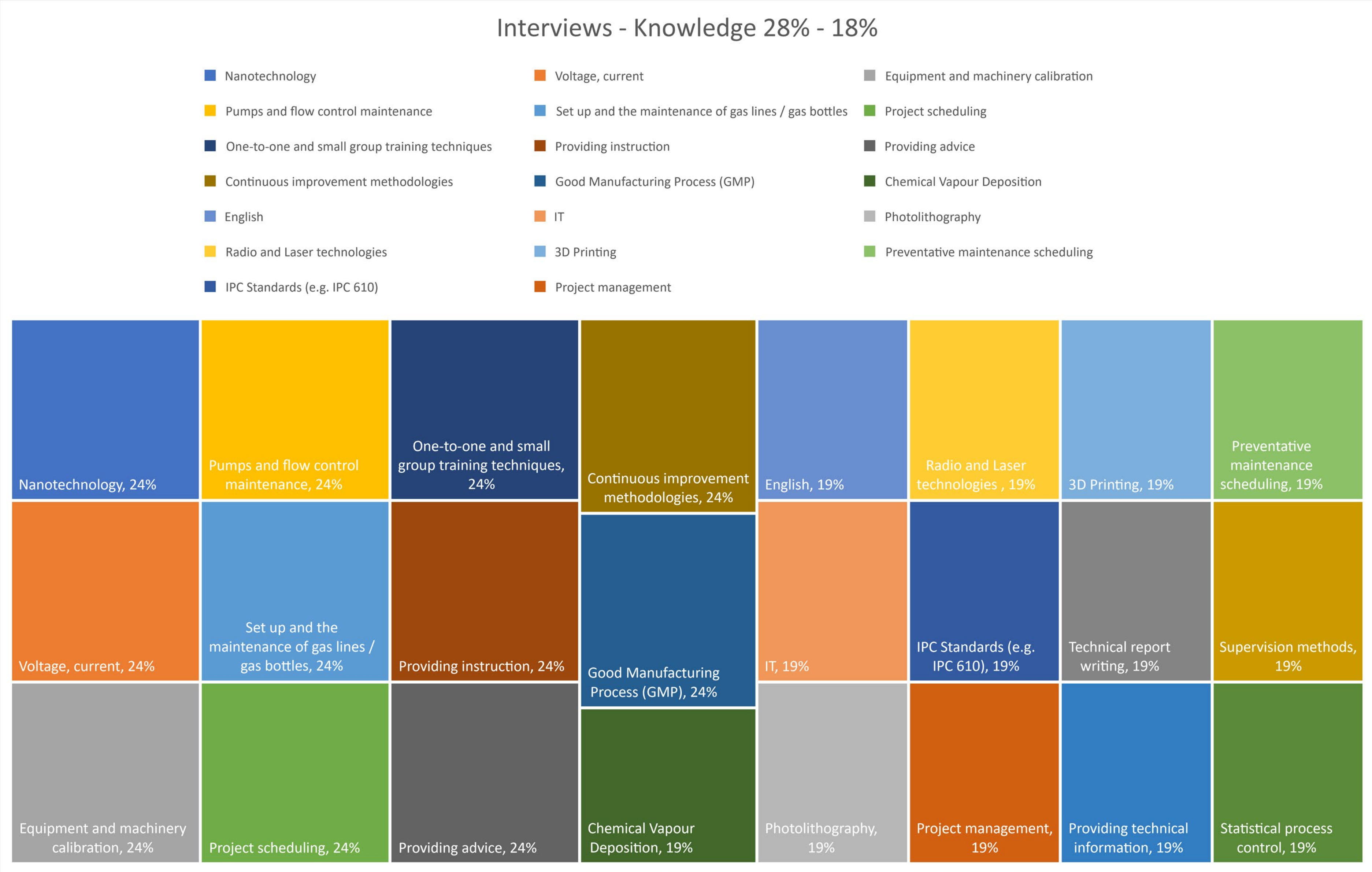


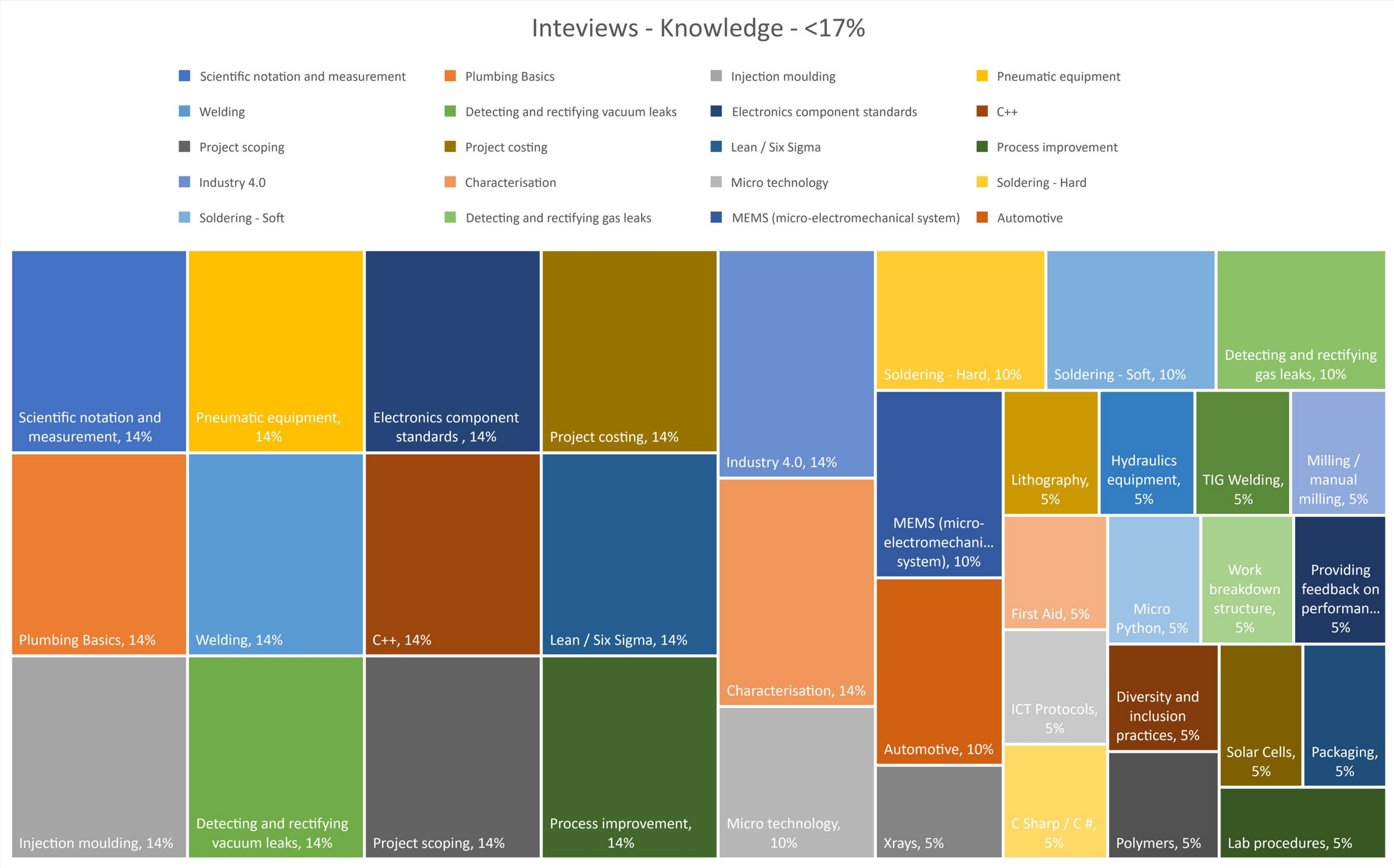
10.2 International Job Roles Figures



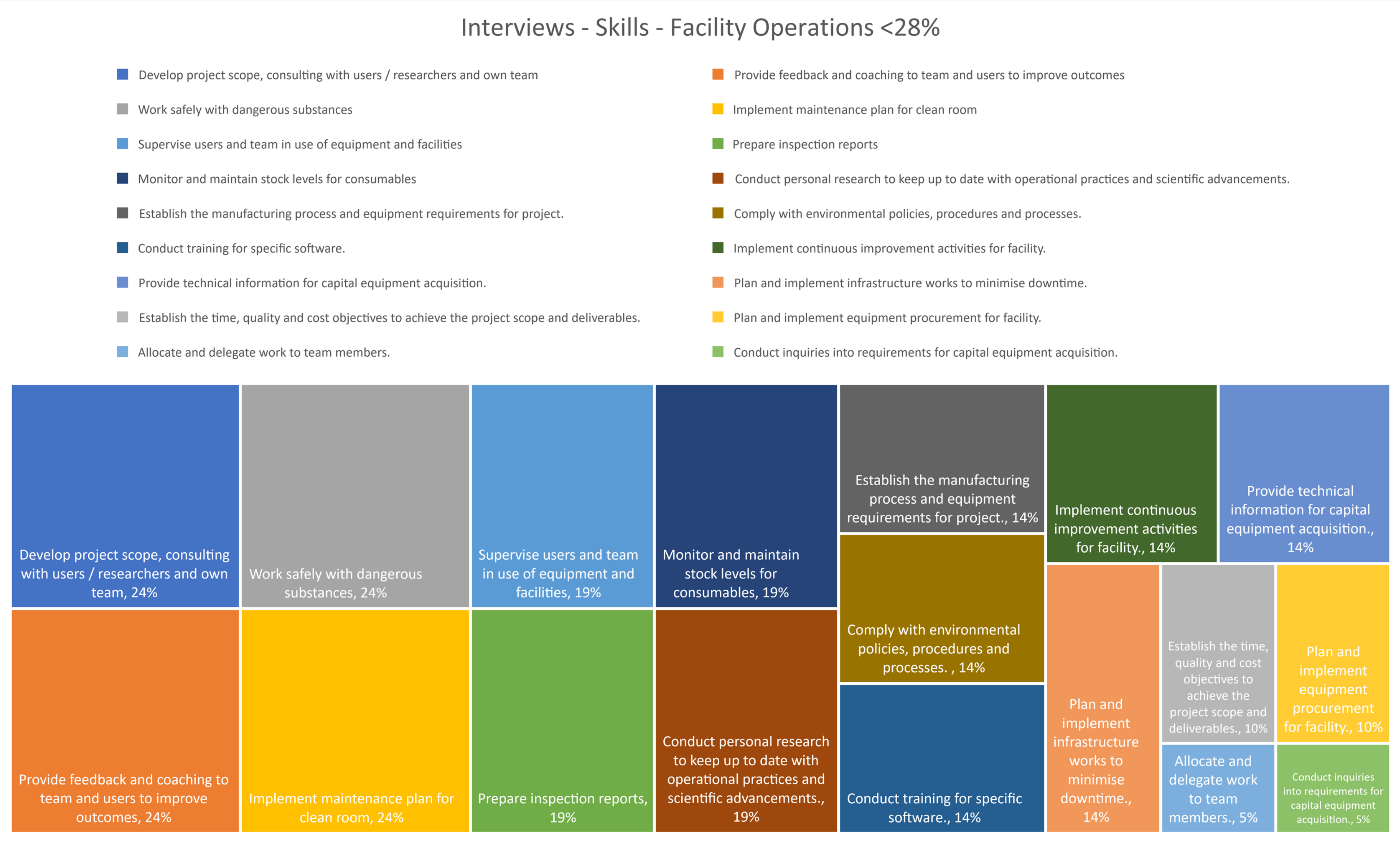
10.3 Interviews Figures



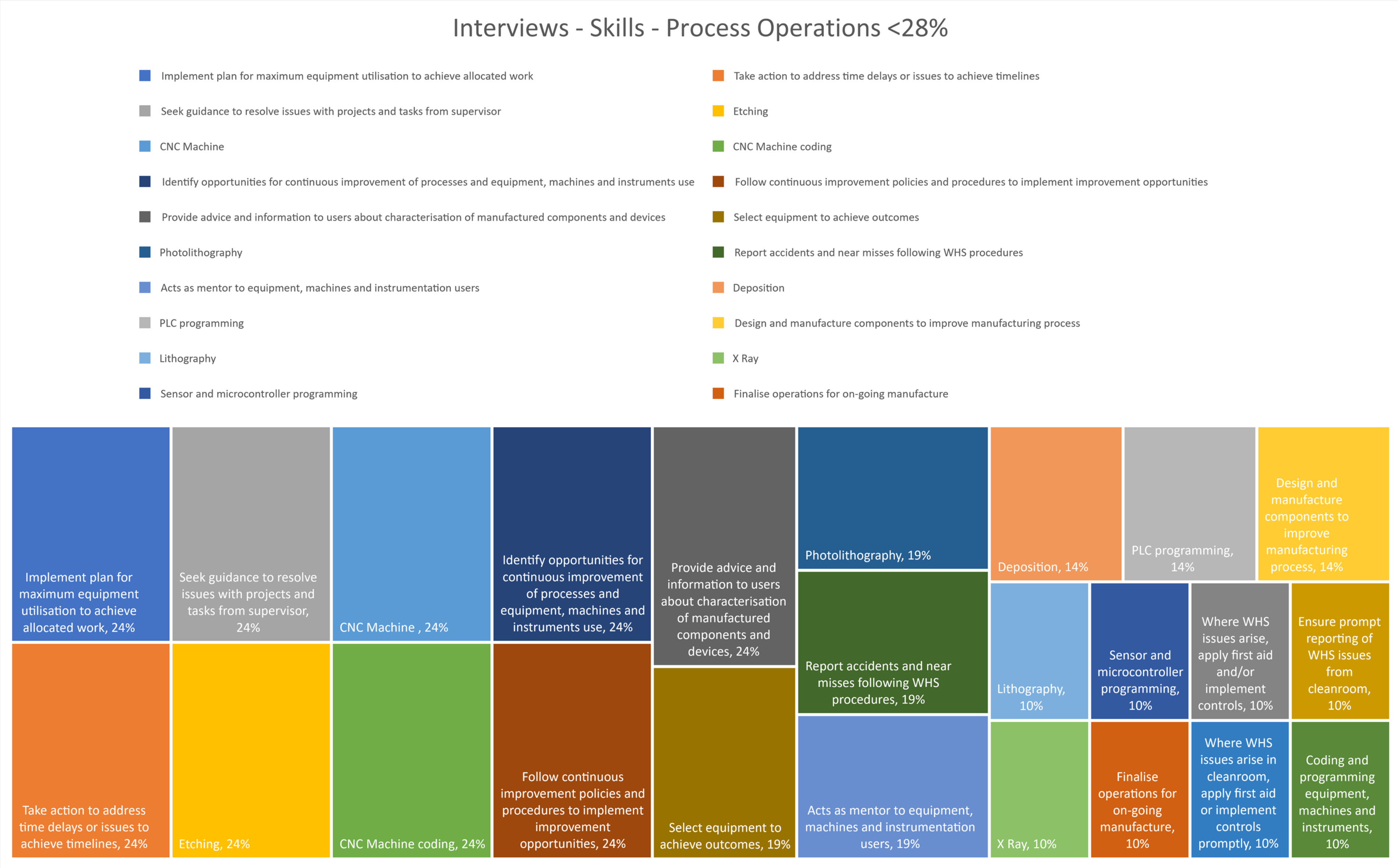

Interviews - Knowledge 28% - 18%
Nanotechnology
Voltage, current
Equipment and machinery calibration
Pumps and flow control maintenance
Set up and the maintenance of gas lines / gas bottles
Project scheduling
One-to-one and small group training techniques
Providing instruction
Providing advice
Continuous improvement methodologies
Good Manufacturing Process (GMP)
Chemical Vapour Deposition
English
IT
Photolithography
Radio and Laser technologies
3D Printing
Preventative maintenance scheduling
IPC Standards (e.g. IPC 610)
Project management
Nanotechnology, 24%
Pumps and flow control maintenance, 24%
One-to-one and small group training techniques, 24%
Continuous improvement methodologies, 24%
English, 19%
Radio and Laser technologies , 19%
3D Printing, 19%
Preventative maintenance scheduling, 19%
Voltage, current, 24%
Set up and the maintenance of gas lines / gas bottles, 24%
Providing instruction, 24%
Good Manufacturing Process (GMP), 24%
IT, 19%
IPC Standards (e.g. IPC 610), 19%
Technical report writing, 19%
Supervision methods, 19%
Equipment and machinery calibration, 24%
Project scheduling, 24%
Providing advice, 24%
Chemical Vapour Deposition, 19%
Photolithography, 19%
Project management, 19%
Providing technical information, 19%
Statistical process control, 19%


Inteviews - Knowledge - <17%
Scientific notation and measurement
Plumbing Basics
Injection moulding
Pneumatic equipment
Welding
Detecting and rectifying vacuum leaks
Electronics component standards
C++
Project scoping
Project costing
Lean / Six Sigma
Process improvement
Industry 4.0
Characterisation
Micro technology
Soldering - Hard
Soldering - Soft
Detecting and rectifying gas leaks
MEMS (micro-electromechanical system)
Automotive
Scientific notation and measurement, 14%
Pneumatic equipment, 14%
Electronics component standards , 14%
Project costing, 14%
Industry 4.0, 14%
Soldering - Hard, 10%
Soldering - Soft, 10%
Detecting and rectifying gas leaks, 10%
Plumbing Basics, 14%
Welding, 14%
C++, 14%
Lean / Six Sigma, 14%
MEMS (micro-electromechani... system), 10%
Lithography, 5%
Hydraulics equipment, 5%
TIG Welding, 5%
Milling / manual milling, 5%
Characterisation, 14%
First Aid, 5%
Micro Python, 5%
Work breakdown structure, 5%
Providing feedback on performan... 5%
Automotive, 10%
ICT Protocols, 5%
Diversity and inclusion practices, 5%
Solar Cells, 5%
Packaging, 5%
Injection moulding, 14%
Detecting and rectifying vacuum leaks, 14%
Project scoping, 14%
Process improvement, 14%
Micro technology, 10%
Xrays, 5%
C Sharp / C #, 5%
Polymers, 5%
Lab procedures, 5%

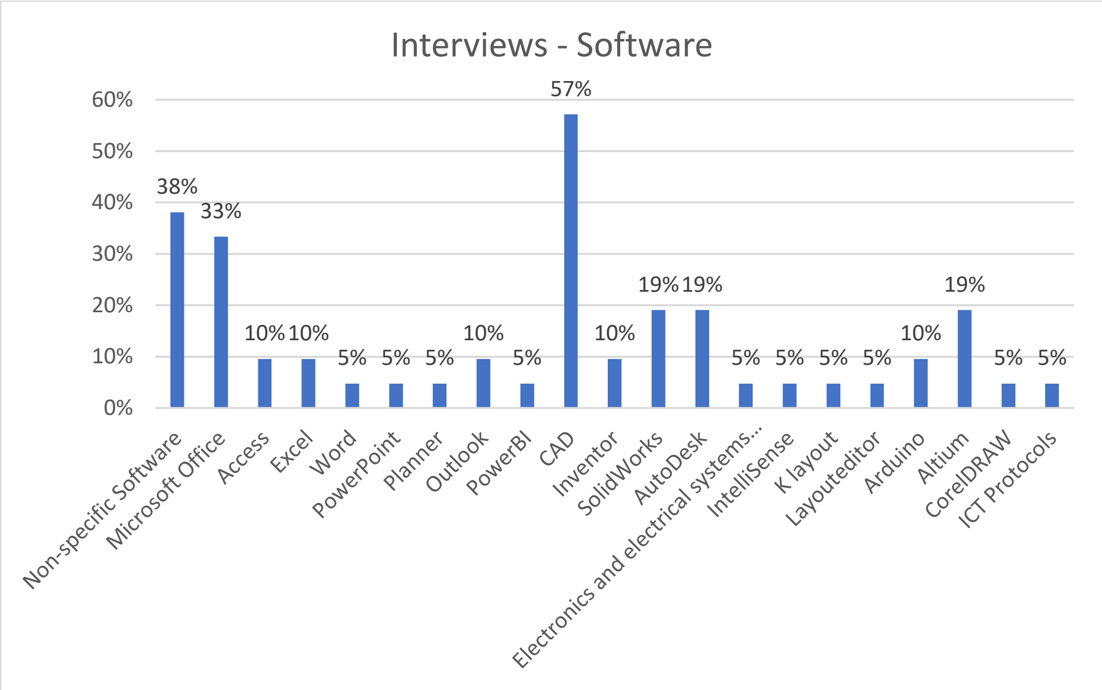

Interviews - Skills - Facility Operations
Implement maintenance plan for equipment, machines and instruments
Develop and maintain standard operating procedures for facility
Read, interpret and apply engineering drawings, schematics and technical documents to plan use of facilities and projects
Implement maintenance requirements for facility
Work safely with equipment, machines and instruments
Read, interpret and apply ISO standards, IPC standards and other standards to facility and projects
Ensure compliance with safe operating procedures
Participate in one-on-one learning activities (mentor, buddy, work shadow etc.)
Read, interpret and apply quality standards of organisation and other quality standards (ISO9000, ISO9001 or other) for facility and projects
Develop preventative maintenance plan
Liaise with Original Equipment Manufacturer (OEM) for equipment maintenance and fault rectification
Liaise with users to understand project requirements
Work effectively in manufacturing environment
Implement WHS requirements for facility from organisational policies and procedures
Apply WHS policies and procedures
Implement policies and procedures from organisation
Conduct training for safe operating procedures of facility
Develop and write technical reports
Plan operational use of equipment and facilities for effective use of resources
Use technical knowledge to perform work activities, provide supervision and advice to others.
Implement maintenance plan for equipment, machines and instruments, 57%
Develop and maintain standard operating procedures for facility, 52%
Read, interpret and apply engineering drawings, schematics and technical documents to plan use of facilities and projects, 52%
Implement maintenance requirements for facility, 52%
Work safely with equipment, machines and instruments, 48%
Read, interpret and apply ISO standards, IPC standards and other standards to facility and projects, 48%
Ensure compliance with safe operating procedures, 43%
Participate in one-on-one learning activities (mentor, buddy, work shadow etc.), 43%
Read, interpret and apply quality standards of organisation and other quality standards (ISO9000, ISO9001 or other) for facility and projects, 43%
Develop preventative maintenance plan, 43%
Liaise with Original Equipment Manufacturer (OEM) for equipment maintenance and fault rectification, 43%
Liaise with users to understand project requirements, 38%
Work effectively in manufacturing environment, 38%
Implement WHS requirements for facility from organisational policies and procedures, 38%
Apply WHS policies and procedures, 38%
Implement policies and procedures from organisation, 38%
Conduct training for safe operating procedures of facility, 38%
Develop and write technical reports, 38%
Plan operational use of equipment and facilities for effective use of resources, 33%
Use technical knowledge to perform work activities, provide supervision and advice to others., 33%
Write and update work instructions for operators, 33%
Liaise with team and users to plan workflows for efficiency, 29%
Use scientific knowledge to perform work activities, provide supervision and advice to others., 29%
Administer and manage access to equipment, 33%
Monitor project to ensure timelines and deliverables are achieved, 29%
Work safely with nano particles, 29%
Participate in professional developm... activities, 29%
Monitor equipment use, 33%
Monitor and ensure compliance of WHS requirements for facility, 29%
Participate in commissio... of new equipment, 29%

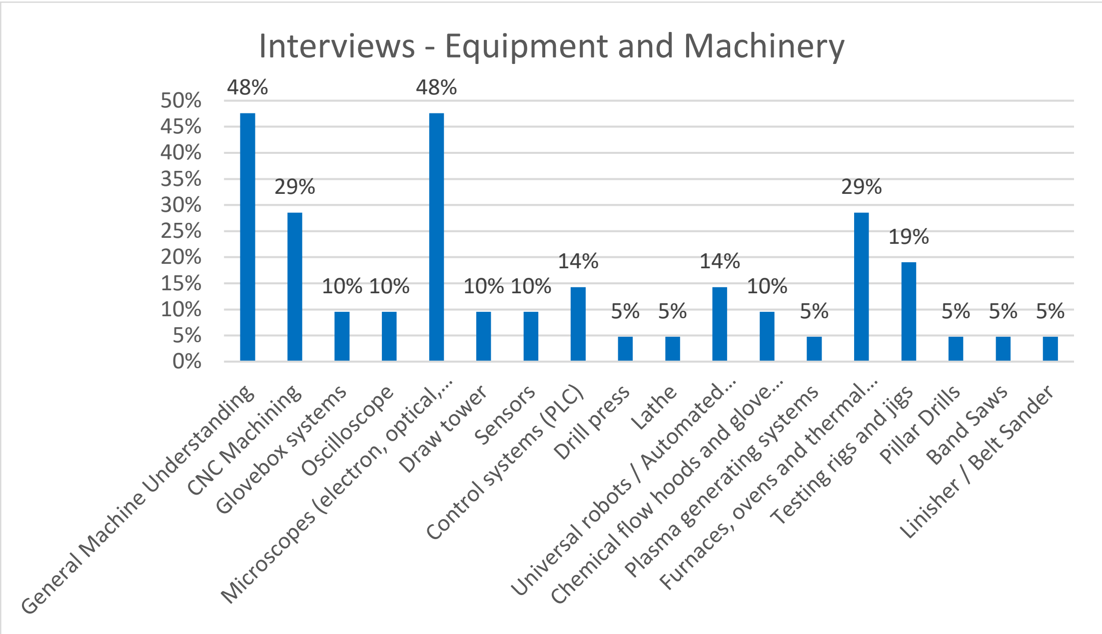

Interviews - Skills - Facility Operations <28%
Develop project scope, consulting with users / researchers and own team
Provide feedback and coaching to team and users to improve outcomes
Work safely with dangerous substances
Implement maintenance plan for clean room
Supervise users and team in use of equipment and facilities
Prepare inspection reports
Monitor and maintain stock levels for consumables
Conduct personal research to keep up to date with operational practices and scientific advancements.
Establish the manufacturing process and equipment requirements for project.
Comply with environmental policies, procedures and processes.
Conduct training for specific software.
Implement continuous improvement activities for facility.
Provide technical information for capital equipment acquisition.
Plan and implement infrastructure works to minimise downtime.
Establish the time, quality and cost objectives to achieve the project scope and deliverables.
Plan and implement equipment procurement for facility.
Allocate and delegate work to team members.
Conduct inquiries into requirements for capital equipment acquisition.
Develop project scope, consulting with users / researchers and own team, 24%
Work safely with dangerous substances, 24%
Supervise users and team in use of equipment and facilities, 19%
Monitor and maintain stock levels for consumables, 19%
Establish the manufacturing process and equipment requirements for project., 14%
Implement continuous improvement activities for facility., 14%
Provide technical information for capital equipment acquisition., 14%
Comply with environmental policies, procedures and processes. , 14%
Provide feedback and coaching to team and users to improve outcomes, 24%
Implement maintenance plan for clean room, 24%
Prepare inspection reports, 19%
Conduct personal research to keep up to date with operational practices and scientific advancements., 19%
Conduct training for specific software., 14%
Plan and implement infrastructure works to minimise downtime., 14%
Establish the time, quality and cost objectives to achieve the project scope and deliverables., 10%
Plan and implement equipment procurement for facility., 10%
Allocate and delegate work to team members., 5%
Conduct inquiries into requirements for capital equipment acquisition., 5%

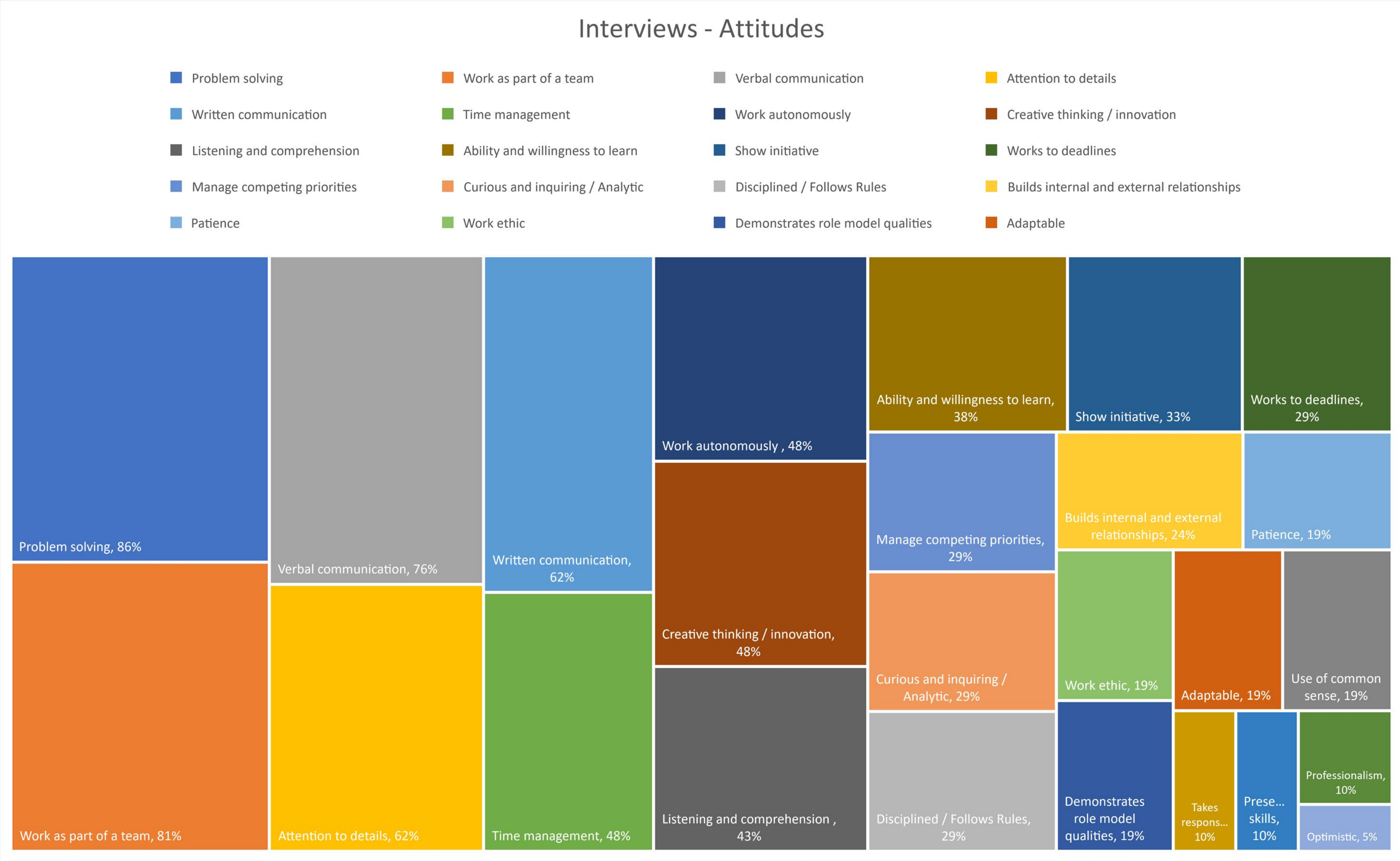

Interviews - Skills - Process Operations
Trouble shoot issues if these arise during operations
Trouble shoot equipment faults when issues arise
Perform routine and planned maintenance for equipment and machinery
Rectify and repair equipment and machinery faults within capabilities
Follow work instructions
Conduct tests to evaluate component, part or product
Assemble components to outcome required
Interpret work / project objectives and requirements to achieve outcomes
Report information for projects and work activities
Follow standard operating procedure to perform task
Perform operations to complete task
Identify issues and take corrective actions
Comply with WHS and standard operating procedures prior to entering cleanroom
Provide technical support and information to facility users
Design component using software or by hand
Microscopes
Cleanroom
Set up equipment and machine to achieve outcome
Follow standard operating procedures when conducting tasks in cleanroom
Use equipment in cleanroom following standard operating procedures
Trouble shoot issues if these arise during operations, 71%
Trouble shoot equipment faults when issues arise, 71%
Perform routine and planned maintenance for equipment and machinery, 67%
Rectify and repair equipment and machinery faults within capabilities, 67%
Follow work instructions, 62%
Conduct tests to evaluate component, part or product, 62%
Assemble components to outcome required, 57%
Interpret work / project objectives and requirements to achieve outcomes, 52%
Report information for projects and work activities, 52%
Follow standard operating procedure to perform task, 52%
Perform operations to complete task, 52%
Identify issues and take corrective actions, 48%
Comply with WHS and standard operating procedures prior to entering cleanroom, 48%
Provide technical support and information to facility users, 48%
Design component using software or by hand, 43%
Microscopes, 43%
Cleanroom, 43%
Set up equipment and machine to achieve outcome, 43%
Follow standard operating procedures when conducting tasks in cleanroom, 43%
Use equipment in cleanroom following standard operating procedures, 43%
Conduct training for equipment, machines, and instrumentation users, 43%
Calibrate equipment and machinery, 38%
Read and interpret technical manuals to perform work, 33%
Check materials, consumables and other resources required to perform task are available, 33%
Read and interpret technical drawings, specifications, standards to perform work,...
Comply with WHS requirements to perform task, 33%
Read and interpret monitoring systems and sensor outputs to ensure conformance to requirements, 33%
Use monitoring systems and sensor equipment to identify faults, 33%
Produce and test a prototype, 38%
Read and interpret monitoring systems and sensor outputs and data to identify faults, 38%
Ensure WHS controls are followed, 33%
Refer issues to supervisor when fault rectification is beyond capabilities or OEM support is required, 33%
Oversee equipment, machines and instrumentation users, 33%
Monitor and manage plan to achieve timelines, 29%
Vacuum systems, 29%
Check for conformance to requirements, 29%
Use hand tools, 29%
Design and manufacture components to rectify or repair faults, 29%



Interviews - Skills - Process Operations <28%
Implement plan for maximum equipment utilisation to achieve allocated work
Take action to address time delays or issues to achieve timelines
Seek guidance to resolve issues with projects and tasks from supervisor
Etching
CNC Machine
CNC Machine coding
Identify opportunities for continuous improvement of processes and equipment, machines and instruments use
Follow continuous improvement policies and procedures to implement improvement opportunities
Provide advice and information to users about characterisation of manufactured components and devices
Select equipment to achieve outcomes
Photolithography
Report accidents and near misses following WHS procedures
Acts as mentor to equipment, machines and instrumentation users
Deposition
PLC programming
Design and manufacture components to improve manufacturing process
Lithography
X Ray
Sensor and microcontroller programming
Finalise operations for on-going manufacture
Implement plan for maximum equipment utilisation to achieve allocated work, 24%
Seek guidance to resolve issues with projects and tasks from supervisor, 24%
CNC Machine , 24%
Identify opportunities for continuous improvement of processes and equipment, machines and instruments use, 24%
Provide advice and information to users about characterisation of manufactured components and devices, 24%
Photolithography, 19%
Deposition, 14%
PLC programming, 14%
Design and manufacture components to improve manufacturing process, 14%
Report accidents and near misses following WHS procedures, 19%
Lithography, 10%
Sensor and microcontroller programming, 10%
Where WHS issues arise, apply first aid and/or implement controls, 10%
Ensure prompt reporting of WHS issues from cleanroom, 10%
Take action to address time delays or issues to achieve timelines, 24%
Etching, 24%
CNC Machine coding, 24%
Follow continuous improvement policies and procedures to implement improvement opportunities, 24%
Select equipment to achieve outcomes, 19%
Acts as mentor to equipment, machines and instrumentation users, 19%
X Ray, 10%
Finalise operations for on-going manufacture, 10%
Where WHS issues arise in cleanroom, apply first aid or implement controls promptly, 10%
Coding and programming equipment, machines and instruments, 10%

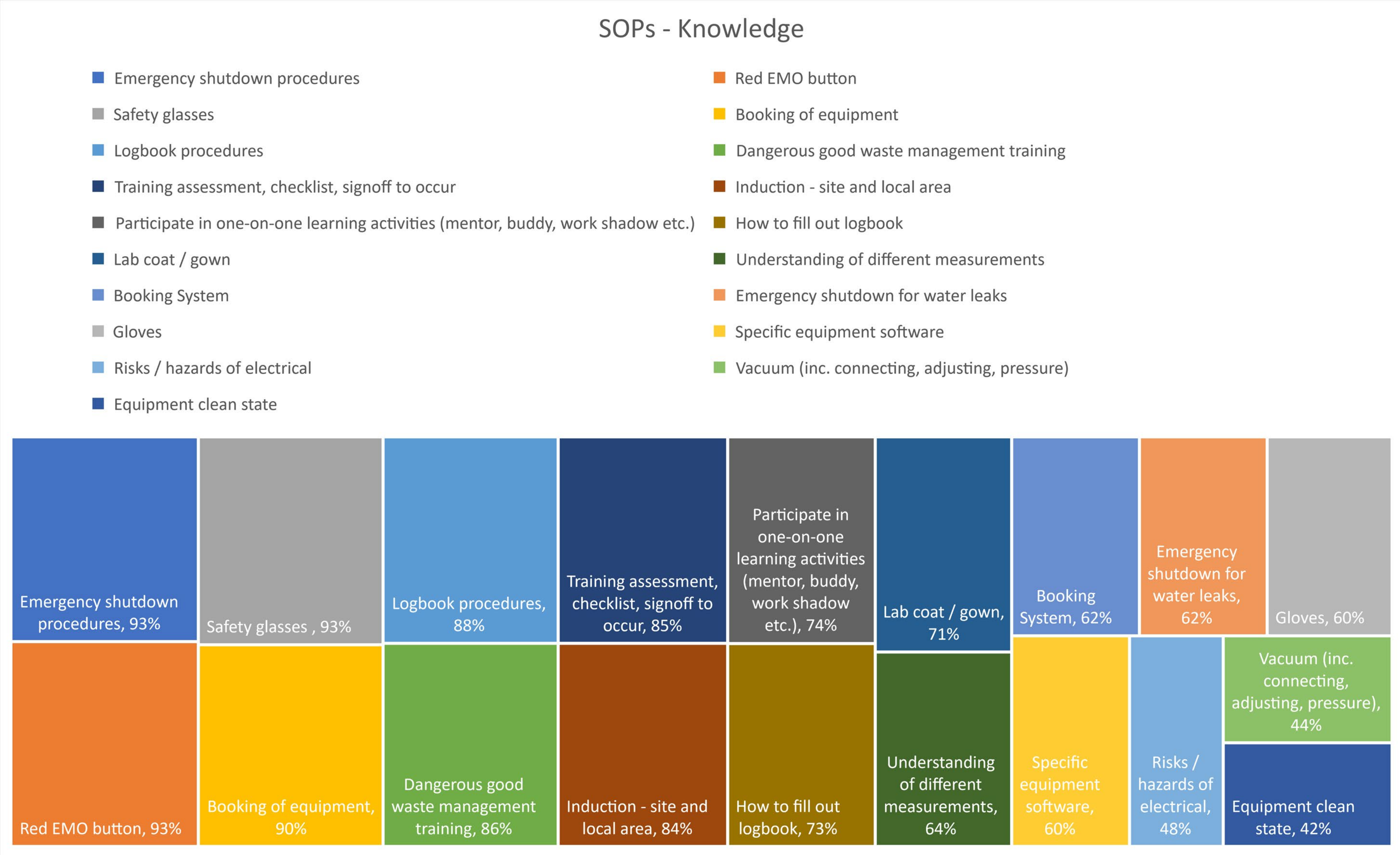

Interviews - Software
60%
50%
40%
30%
20%
10%
0%
38%
33%
10%
10%
5%
5%
5%
10%
5%
57%
10%
19%
19%
5%
5%
5%
5%
10%
19%
5%
5%
Non-specific Software
Microsoft Office
Access
Excel
Word
PowerPoint
Planner
Outlook
PowerBI
CAD
Inventor
SolidWorks
AutoDesk
Electronics and electrical systems...
IntelliSense
K layout
Layouteditor
Arduino
Altium
CorelDRAW
ICT Protocols

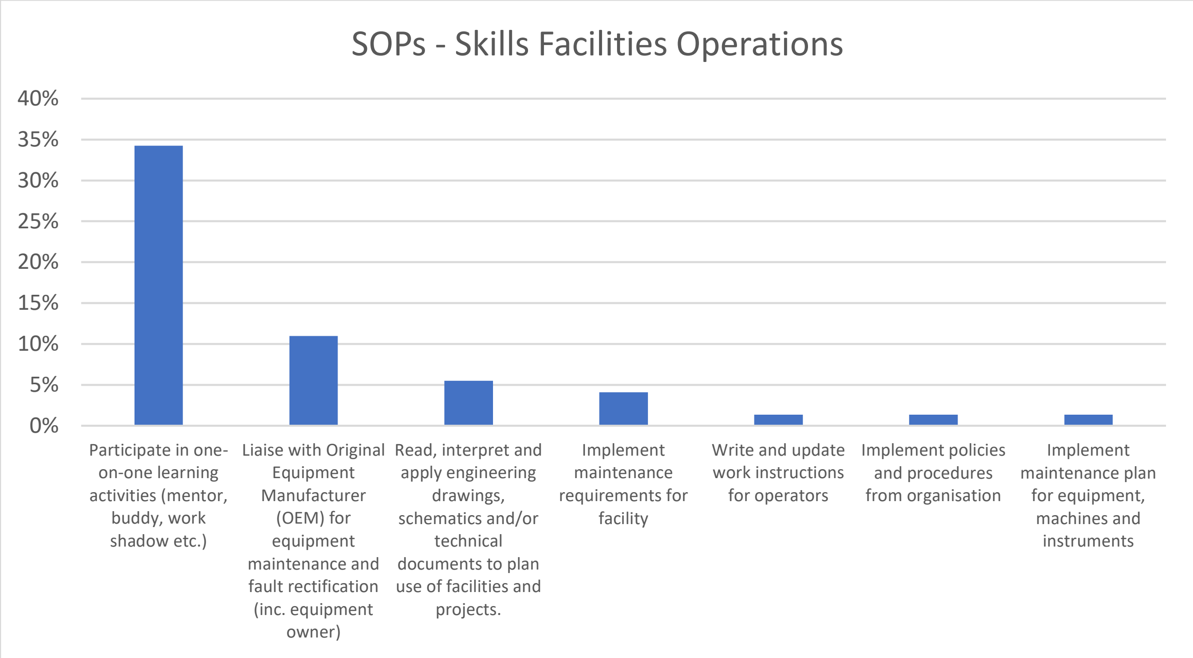

Interviews - Equipment and Machinery
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
48%
29%
10%
10%
48%
10%
10%
14%
5%
5%
14%
10%
5%
29%
19%
5%
5%
5%
General Machine Understanding
CNC Machining
Glovebox systems
Oscilloscope
Microscopes (electron, optical,...
Draw tower
Sensors
Control systems (PLC)
Drill press
Lathe
Universal robots / Automated...
Chemical flow hoods and glove...
Plasma generating systems
Furnaces, ovens and thermal...
Testing rigs and jigs
Pillar Drills
Band Saws
Linisher / Belt Sander

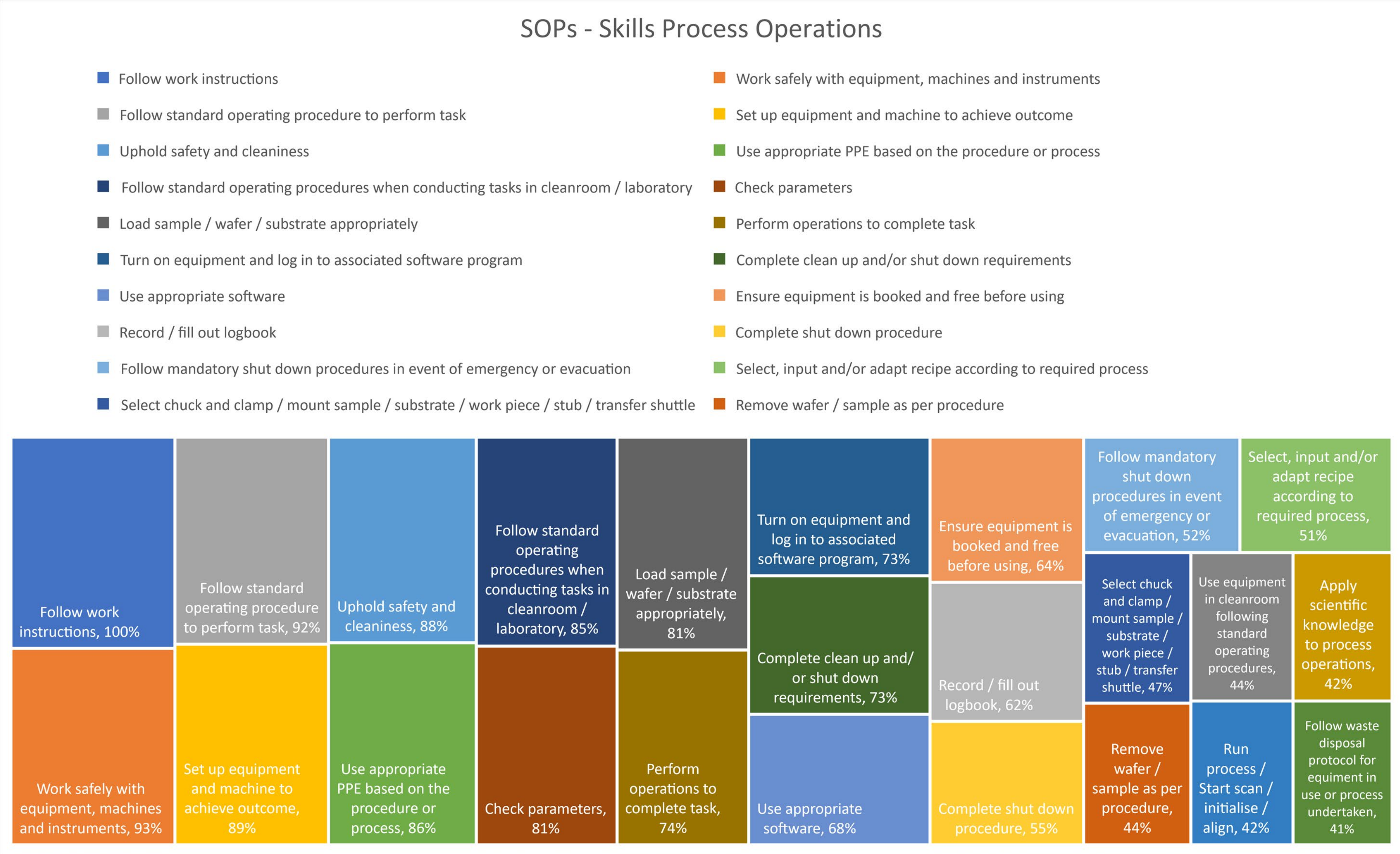


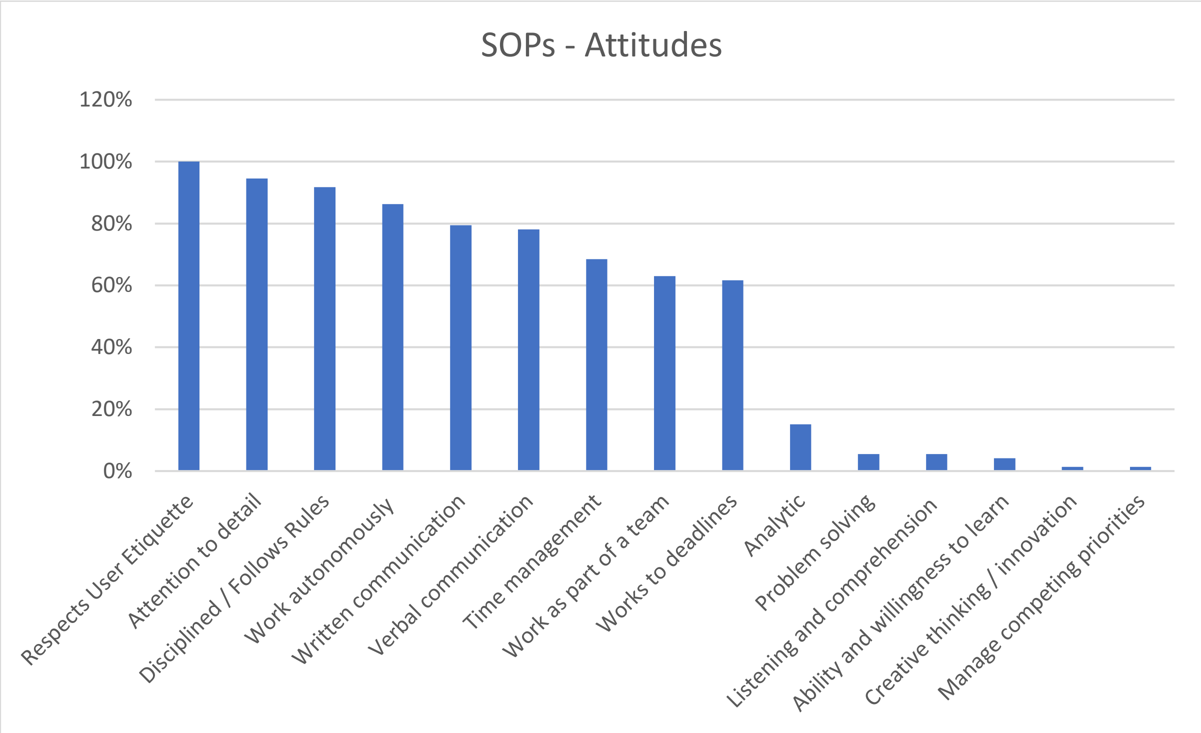
Interviews - Attitudes
Problem solving
Work as part of a team
Verbal communication
Attention to details
Written communication
Time management
Work autonomously
Creative thinking / innovation
Listening and comprehension
Ability and willingness to learn
Show initiative
Works to deadlines
Manage competing priorities
Curious and inquiring / Analytic
Disciplined / Follows Rules
Builds internal and external relationships
Patience
Work ethic
Demonstrates role model qualities
Adaptable
Problem solving, 86%
Work as part of a team, 81%
Verbal communication, 76%
Attention to details, 62%
Written communication, 62%
Time management, 48%
Work autonomously , 48%
Creative thinking / innovation, 48%
Listening and comprehension , 43%
Ability and willingness to learn, 38%
Manage competing priorities, 29%
Curious and inquiring / Analytic, 29%
Disciplined / Follows Rules, 29%
Show initiative, 33%
Works to deadlines, 29%
Builds internal and external relationships, 24%
Patience, 19%
Work ethic, 19%
Adaptable, 19%
Use of common sense, 19%
Demonstrates role model qualities, 19%
Takes respons... 10%
Prese... skills, 10%
Professionalism, 10%
Optimistic, 5%

10.4 Standard Operating Procedures (SOPs) Figures




SOPs - Skills Facilities Operations
40%
35%
30%
25%
20%
15%
10%
5%
0%
Participate in one-on-one learning activities (mentor, buddy, work shadow etc.)
Liaise with Original Equipment Manufacturer (OEM) for equipment maintenance and fault rectification (inc. equipment owner)
Read, interpret and apply engineering drawings, schematics and/or technical documents to plan use of facilities and projects.
Implement maintenance requirements for facility
Write and update work instructions for operators
Implement policies and procedures from organisation
Implement maintenance plan for equipment, machines and instruments


SOPs - Skills Process Operations
Follow work instructions
Work safely with equipment, machines and instruments
Follow standard operating procedure to perform task
Set up equipment and machine to achieve outcome
Uphold safety and cleaniness
Use appropriate PPE based on the procedure or process
Follow standard operating procedures when conducting tasks in cleanroom / laboratory
Check parameters
Load sample / wafer / substrate appropriately
Perform operations to complete task
Turn on equipment and log in to associated software program
Complete clean up and/or shut down requirements
Use appropriate software
Ensure equipment is booked and free before using
Record / fill out logbook
Complete shut down procedure
Follow mandatory shut down procedures in event of emergency or evacuation
Select, input and/or adapt recipe according to required process
Select chuck and clamp / mount sample / substrate / work piece / stub / transfer shuttle
Remove wafer / sample as per procedure
Follow work instructions, 100%
Work safely with equipment, machines and instruments, 93%
Follow standard operating procedure to perform task, 92%
Set up equipment and machine to achieve outcome, 89%
Uphold safety and cleaniness, 88%
Use appropriate PPE based on the procedure or process, 86%
Follow standard operating procedures when conducting tasks in cleanroom / laboratory, 85%
Check parameters, 81%
Load sample / wafer / substrate appropriately, 81%
Perform operations to complete task, 74%
Turn on equipment and log in to associated software program, 73%
Complete clean up and/ or shut down requirements, 73%
Use appropriate software, 68%
Ensure equipment is booked and free before using, 64%
Record / fill out logbook, 62%
Complete shut down procedure, 55%
Follow mandatory shut down procedures in event of emergency or evacuation, 52%
Select, input and/or adapt recipe according to required process, 51%
Select chuck and clamp / mount sample / substrate / work piece / stub / transfer shuttle, 47%
Use equipment in cleanroom following standard operating procedures, 44%
Apply scientific knowledge to process operations, 42%
Remove wafer / sample as per procedure, 44%
Run process / Start scan / initialise / align, 42%
Follow waste disposal protocol for equiment in use or process undertaken, 41%


SOPs - Attitudes
120%
100%
80%
60%
40%
20%
0%
Respects User Etiquette
Attention to detail
Disciplined / Follows Rules
Work autonomously
Written communication
Verbal communication
Time management
Work as part of a team
Works to deadlines
Analytic
Problem solving
Listening and comprehension
Ability and willingness to learn
Creative thinking / innovation
Manage competing priorities

10.5 List of Standard Operating Procedures (SOPs)

Classes	Standard Operating Procedure (SOPs)
Medium normal safety	PQMS3-MCN-SOP-0001-V-ABM UV Flood Light Source.pdf
	PQMS3-MCN-SOP-0005-V-Bruker Contour GT-I Optical Profiler.pdf
	PQMS3-MCN-SOP-0006-V-Cleanroom (Dimension Icon) Atomic Force Microscopy (AFM).pdf
	PQMS3-MCN-SOP-0007-V-CytoViva 3D Imaging.pdf
	PQMS3-MCN-SOP-0008-V-CytoViva Hyper Spectral Imaging (HSI).pdf
	PQMS3-MCN-SOP-0009-V-Digital Matrix SA1000 (Alkaline Electro-cleaning).pdf
	PQMS3-MCN-SOP-0010-V-Digital Matrix SA1000 (Nickel Electroforming).pdf
	PQMS3-MCN-SOP-0013-V-Dynatek Scriber.pdf
	PQMS3-MCN-SOP-0015-V-EVG620 Mask Aligner.pdf
	PQMS3-MCN-SOP-0018-V-FIJI F200 Atomic Layer Deposition (ALD) System.pdf
	PQMS3-MCN-SOP-0019-V-FILMETRICS F20 Thin Film Measurement.pdf
	PQMS3-MCN-SOP-0020-V-FILMETRICS F40 Thin Film Measurement.pdf
	PQMS3-MCN-SOP-0021-V-FILMETRICS F50 Thin Film Mapper.pdf
	PQMS3-MCN-SOP-0022-V-HITACHI TM3030 Table Top SEM.pdf
	PQMS3-MCN-SOP-0023-V-Hitech Furnace (Wet and Dry Oxidation).pdf
	PQMS3-MCN-SOP-0027-V-IoN Wave 10 Plasma Asher.pdf
	PQMS3-MCN-SOP-0028-V-JPK Nanowizard II Bio Atomic Force Microscope (BioAFM).pdf
	PQMS3-MCN-SOP-0029-V-Kulicke & Soffa Model 4524-Ball Bonder.pdf
	PQMS3-MCN-SOP-0030-V-Kulicke & Soffa Model 4526 Wedge Bonder.pdf
	PQMS3-MCN-SOP-0031-V-Light Field Microspectrometer.pdf
	PQMS3-MCN-SOP-0032-V-Malvern Nanosizer ZS.pdf
	PQMS3-MCN-SOP-0035-V-Nikon A1Rsi Laser Scanning Confocal Microscope.pdf
	PQMS3-MCN-SOP-0036-V-Nikon Eclipse TIRF Microscope.pdf
	PQMS3-MCN-SOP-0037-V-Objet 3D Printer.pdf
	PQMS3-MCN-SOP-0041-V-PC2 Laboratory.pdf
	PQMS3-MCN-SOP-0042-V-PDMS Soft Lithography.pdf
	PQMS3-MCN-SOP-0043-V-Savannah S100 ALD.pdf (Atomic Layer Deposition (ALD))
	PQMS3-MCN-SOP-0044-V-Seki 6300 Diamond Deposition System.pdf
	PQMS3-MCN-SOP-0045-V-Seki 6500 Diamond Deposition System.pdf
	PQMS3-MCN-SOP-0046-V-Signatone WL-1160 Series Probe Station.pdf
	PQMS3-MCN-SOP-0047-V-Surpass Electrokinetic Analyser (Solid Surface Analysis).pdf
	PQMS3-MCN-SOP-0052-V-UV Vis Spectrophotometer.pdf

	PQMS3-MCN-SOP-0055-V-West Bond Model 7476E-Wedge Bonder.pdf
	PQMS3-MCN-SOP-0056-V-Pico Track PCT-150RRE Develop Station.pdf
	PQMS3-MCN-SOP-0057-V-ICnanoS-2000 Scanning Ion Conductance Microscope.pdf
	PQMS3-MCN-SOP-0058-V-NanoPrint TMLM60 Nanoarray Spotter.pdf
	PQMS3-MCN-SOP-0059-V-PCT-150RRE Pico Track System.pdf
	PQMS3-MCN-SOP-0060-V-Jandel 4-Point Probe Station .pdf
	PQMS3-MCN-SOP-0061-V-Sutter P-2000 Micropipette Puller.pdf
	PQMS3-MCN-SOP-0062-V Magnetron Sputter Coater DSR-1 System.pdf
	PQMS3-MCN-SOP-0065-V Bruker MALDI.pdf
	PQMS3-MCN-SOP-0067-V-EBL Sputter Coater Q300TT.pdf
	PQMS3-MCN-SOP-0068-V-NeaSNOM.pdf
	PQMS3-MCN-SOP-0069-V-NanoFrazor Explore.pdf
	PQMS3-MCN-SOP-0070-V-LS 55.pdf
	PQMS3-MCN-SOP-0071-V Contact Angle Measurement.pdf
	PQMS3-MCN-SOP-0072-V-F&S Bondtec Deep Access Wedge Bonder.pdf
	PQMS3-MCN-SOP-0075-V-Harrick Plasma cleaner.pdf
	PQMS3-MCN-SOP-0085-V EBPG5000+ Overlay Exposure.pdf
Easier v safe difficulty	PQMS3-MCN-SOP-0002-V-Ambios XP200 Stylus Profilometer .pdf
	PQMS3-MCN-SOP-0003-V-ANATECH Hummer RF_DC Sputter System.pdf
	PQMS3-MCN-SOP-0011-V-DISCO DAD321 Dicing Saw.pdf
	PQMS3-MCN-SOP-0012-V-Dymax Light Source.pdf
	PQMS3-MCN-SOP-0025-V-Intlvac Nanochrome I AC_DC Physical Vapour Deposition (PVD) Sputtering System.pdf
	PQMS3-MCN-SOP-0033-V-MBraun Glovebox System.pdf
	PQMS3-MCN-SOP-0048-V-SUSS Delta 80 Spin Coater.pdf
	PQMS3-MCN-SOP-0049-V-SUSS Delta 80 Spinner.pdf
	PQMS3-MCN-SOP-0063-V-SOP IPA Dryer.pdf
	PQMS3-MCN-SOP-0064-V-SOP Standalone Wetbench.pdf
	PQMS3-MCN-SOP-0073-V Vacuum Oven.pdf
	PQMS3-MCN-SOP-0074-V-Laurell Spinner.pdf
	PQMS3-MCN-SOP-0083-V Robotic Wet Bench.pdf
	PQMS3-MCN-SOP-0084-V LC GLOVEBOX (BIOLAB).pdf
Advanced More Dangerous	PQMS3-MCN-SOP-0014-V-EVG 520IS Hot Embosser.pdf
	PQMS3-MCN-SOP-0016-V-FEI Helios Nanolab FIB-SEM.pdf
	PQMS3-MCN-SOP-0017-V-FEI NOVA FEG-SEM.pdf
	PQMS3-MCN-SOP-0026-V-Intlvac Nanochrome II Electron Beam and Thermal Evaporation System.pdf

	PQMS3-MCN-SOP-0034-V-MSA-400 LASER Doppler Vibrometer.pdf
	PQMS3-MCN-SOP-0038-V-Oxford Plasma Lab100 (Deep Reactive Ion Etching for Silicon Only).pdf
	PQMS3-MCN-SOP-0039-V-OXFORD Plasma Lab100 (ICP-RIE)-General Etch.pdf
	PQMS3-MCN-SOP-0040-V-Oxford Plasma Lab100 (Plasma Enhanced Chemical Vapour Deposition).pdf
	PQMS3-MCN-SOP-0051-V-UHF-120 LASER Doppler Vibrometer.pdf
	PQMS3-MCN-SOP-0053-V-VASE Ellipsometer.pdf
	PQMS3-MCN-SOP-0054-V-VISTEC EBPG5000plus Electron Beam Lithography (EBL).pdf

10.6 International Course Mapping Matrix

Provided under separate PDF attachment '*International Course Mapping*'.

10.7 Australian Course Mapping Matrix

Provided under separate PDF attachment ‘*Australian Course Mapping*’.

10.8 Job roles, Interviews and SOPs Consolidated Matrix

Skills	%	Knowledge	%	Attitude	%
Follow work instructions	100%	Emergency shutdown procedures	93%	Respects User Etiquette	100%
Work safely with equipment, machines, and instruments.	93%	Red EMO button	93%	Attention to detail	95%
Follow standard operating procedure to perform task.	92%	Safety glasses (e.g. polycarbonate, googles, laser safety glasses)	93%	Disciplined / Follows Rules	92%
Set up equipment and machine to achieve outcome.	89%	Booking of equipment	90%	Work autonomously	86%
Uphold safety and cleanliness	88%	Logbook procedures	88%	Problem solving	86%
Use appropriate PPE based on the procedure or process	86%	Dangerous goods waste management training	86%	Work as part of a team	81%
Follow standard operating procedures when conducting tasks in cleanroom / laboratory (inc. PC2 lab)	85%	Training assessment, checklist, signoff to occur	85%	Written communication	79%
Check parameters (recipe, scan, deposition time, gas flow rate, target selection, exposure time, pressure, perform leak tests, enter actual coordinates, select beam current pA/nA, room temperature, mTorr, Torr, electrolyte, rinse program, pH Titration, revolutions per minute (RPM), precursor cylinders)	81%	Induction - site and local area	84%	Verbal communication	78%

Load sample / wafer / substrate appropriately (e.g. in draw, receiver cassette, sample holder, molybdenum puck, Potassium hydroxide (KOH), into baths, use x and y controls, with metal tweezers / plastic tweezers))	81%	Participate in one-on-one learning activities (mentor, buddy, work shadow etc.)	74%	Verbal communication	76%
Working in a team	79%	How to fill out logbook	73%	Time management	68%
Perform operations to complete task.	74%	Lab coat / gown	71%	Work as part of a team	63%
Turn on equipment and log in to associated software program	73%	Electronics	67%	Attention to details	62%
Complete clean up and/or shut down requirements	73%	Understanding of different measurements (200ml, 100mm, 5mm, 40-50g, 10%, 4", 6", nm to µm, Zeta potential, electrolyte, pressure program, rinse program, pH Titration)	64%	Written communication	62%
Troubleshoot issues if these arise during operations.	71%	Booking System	62%	Works to deadlines	62%
Troubleshoot equipment faults when issues arise.	71%	Emergency shutdown for water leaks	62%	Following SOPs	50%
Use appropriate software (e.g. delta control software, NIS - Elements, Flexcontrol, FL WinLab Software, PSV 9.1 Acquisition)	68%	Gloves (inc. blue, red)	60%	Communication	50%
Perform routine and planned maintenance for equipment and machinery.	67%	Specific equipment software (e.g. NIS - elements, Flexcontrol, Igor Pro, Control Software, FL WinLab software)	60%	Time management	48%

Rectify and repair equipment and machinery faults within capabilities.	67%	Mechanical systems	57%	Work autonomously	48%
Ensure equipment is booked and free before using	64%	Quality standards and processes - organisational	57%	Creative thinking / innovation	48%
Follow work instructions	62%	CAD	57%	Listening and comprehension	43%
Conduct tests to evaluate component, part, or product	62%	Programming	57%	Time management / planning	41%
Record / fill out logbook (inc. session details, use of machine / equipment, various measurements, oxygen, and moisture levels, including manual record keeping)	62%	Record keeping	57%	Ability and willingness to learn	38%
Experience with equipment	61%	Physics	52%	Attention to detail	36%
Implement maintenance plan for equipment, machines, and instruments.	57%	Mathematics	52%	Show initiative	33%
Assemble components to outcome required.	57%	Ultra-High Vacuum and High Vacuum Principles	52%	Works to deadlines	29%
Keeping records / documentation	57%	Cleanroom operations	52%	Manage competing priorities	29%
Complete shutdown procedure	55%	WHS / OHS Requirements	52%	Curious and inquiring / Analytic	29%
Develop and maintain standard operating procedures for facility.	52%	Communication - written and verbal	52%	Disciplined / Follows Rules	29%
Read, interpret, and apply engineering drawings, schematics, and technical documents to plan use of facilities and projects.	52%	Risks / hazards of electrical	48%	Comply with procedures, policy and regulations	28%
Implement maintenance requirements for facility.	52%	Hazardous chemicals	48%	Builds internal and external relationships	24%

Interpret work / project objectives and requirements to achieve outcomes.	52%	Machines	48%	Patience	19%
Report information for projects and work activities.	52%	Microscopes (electron, optical, etc)	48%	Work ethic	19%
Follow standard operating procedure to perform task.	52%	Quality Standards - ISO9000 or ISO9001 or other	48%	Demonstrates role model qualities	19%
Perform operations to complete task.	52%	Vacuum (inc. connecting, adjusting, pressure (e.g. 200mTorr)	44%	Adaptable	19%
Follow mandatory shut down procedures in event of emergency or evacuation	52%	Chemistry	43%	Use of common sense	19%
Select, input and/or adapt recipe according to required process (e.g. select accelerating voltage kV, cleaning recipe)	51%	Engineering	43%	** matrix includes data that had 19% or higher*	
Work safely with equipment, machines, and instruments.	48%	Cleanroom Standards (ISO or other)	43%		
Read, interpret, and apply ISO standards, IPC standards and other standards to facility and projects.	48%	Soldering	43%		
Identify issues and take corrective actions.	48%	Report writing	43%		
Comply with WHS and standard operating procedures prior to entering cleanroom.	48%	Equipment clean state	42%		
Provide technical support and information to facility users.	48%	Chemical Element library (e.g. Al, Cr, Ti, Cu, W, Mo, Co, Ni, Fe) and oxides (ZnO, TiO2, Al2O3)	38%		

Select chuck and clamp / mount sample / substrate / work piece / stub / transfer shuttle	47%	Class 10,000 / ISO7 (ISO equivalent)	38%
Microsoft Office / Computer Skills	46%	Face masks (including chrome / printed)	38%
Remove wafer / sample as per procedure (e.g. wafer, dummy wafer, coated wafer) inc. using correct tool	44%	Knowledge of temperature recommendations for vacuum ovens, hot plates, deposition processes, likely hot surfaces	38%
Use equipment in cleanroom following standard operating procedures.	44%	Waste disposal rules (e.g. labelling, designated area, appropriate acid / base waste carbides in corrosive cabinet	38%
Troubleshooting / Problem solving	43%	Materials Science	38%
Ensure compliance with safe operating procedures	43%	Semiconductor equipment and processes	38%
Participate in one-on-one learning activities (mentor, buddy, work shadow etc.)	43%	Equipment maintenance requirements	38%
Read, interpret and apply quality standards of organisation and other quality standards (ISO9000, ISO9001 or other) for facility and projects.	43%	Software	38%
Develop preventative maintenance plan.	43%	Techniques and tools	38%
Liaise with Original Equipment Manufacturer (OEM) for equipment maintenance and fault rectification.	43%	Pinching of equipment (e.g. doors, mixer lid, tools)	37%

Design component using software or by hand.	43%	Substrate	36%
Microscopes	43%	UV rays from gas plasma or UV light source	34%
Cleanroom	43%	Hazardous gases	33%
Set up equipment and machine to achieve outcome.	43%	Scientific techniques - hypothesis, experimentation, control, results, analysis, report.	33%
Follow standard operating procedures when conducting tasks in cleanroom.	43%	Science Basics	33%
Use equipment in cleanroom following standard operating procedures.	43%	Electrical	33%
Conduct training for equipment, machines, and instrumentation users.	43%	Cleanroom cleaning	33%
Apply scientific knowledge to process operations	42%	Machine operations	33%
Run process / Start scan / initialise / align	42%	Planning and Prioritising	33%
Follow waste disposal protocol for equipment in use or process undertaken (e.g. labelled correctly, screw top labelled container, sharp disposal container)	41%	WHS / OHS Risk assessment processes	33%
Liaise with users to understand project requirements.	38%	Microsoft Office	33%
Work effectively in manufacturing environment	38%	Python	33%

Implement WHS requirements for facility from organisational policies and procedures.	38%	Project reporting	33%
Apply WHS policies and procedures.	38%	Dangers of UV light	30%
Implement policies and procedures from organisation.	38%	Data transfer	30%
Conduct training for safe operating procedures of facility.	38%	Understanding of contamination when mixing chemicals and/or samples (e.g. photoresist or polymer samples in Potassium hydroxide (KOH) bath to protect against contamination)	29%
Develop and write technical reports.	38%	Tool making / tooling	29%
Read and interpret technical drawings, specifications, standards to perform work.	38%	Mechatronics	29%
Produce and test a prototype.	38%	Pump and flow control systems	29%
Read and interpret monitoring systems and sensor outputs and data to identify faults.	38%	Equipment Manuals	29%
Calibrate equipment and machinery.	38%	CNC Machining	29%
Work autonomously	38%	Furnaces, ovens, and thermal annealing	29%
Participates in continuous improvements processes	38%	Building interpersonal relationships	29%
Conducting Experiments and testing prototypes	36%	** matrix includes data that had 29% or higher*	

Participate in one-on-one learning activities (mentor, buddy, work shadow etc.)	34%
Plan operational use of equipment and facilities for effective use of resources.	33%
Use technical knowledge to perform work activities, provide supervision and advice to others.	33%
Write and update work instructions for operators	33%
Administer and manage access to equipment.	33%
Monitor equipment use.	33%
Read and interpret technical manuals to perform work.	33%
Check materials, consumables and other resources required to perform task are available.	33%
Comply with WHS requirements to perform task.	33%
Read and interpret monitoring systems and sensor outputs to ensure conformance to requirements.	33%
Use monitoring systems and sensor equipment to identify faults.	33%
Ensure WHS controls are followed.	33%
Refer issues to supervisor when fault rectification is beyond capabilities or OEM support is required.	33%

Oversee equipment, machines, and instrumentation users.	33%
Clean room experience	32%
(Comply) Company quality standards	30%
Liaise with team and users to plan workflows for efficiency.	29%
Use scientific knowledge to perform work activities, provide supervision and advice to others.	29%
Monitor project to ensure timelines and deliverables are achieved.	29%
Monitor and ensure compliance of WHS requirements for facility.	29%
Work safely with nano particles.	29%
Participate in professional development activities	29%
Participate in commissioning of new equipment.	29%
Monitor and manage plan to achieve timelines.	29%
Vacuum systems	29%
Use hand tools	29%
Check for conformance to requirements.	29%
Design and manufacture components to rectify or repair faults.	29%

** matrix includes data that had 29% or higher*

Percentage Colour Index
Overseas
Interviews
SOPs
Common across job roles, interviews, and SOPs

10.9 ANFF LMS Course Listing

Title	Fabrication Area	Level	Stage
2D Printing	2D Printing	Fabrication Area	Waiting
3D Modelling	3D Modelling	Fabrication Area	Waiting
3D printing	3D printing	Fabrication Area	Waiting
2D CAD	CAD	Technique	Sourcing Content
3D CAD	CAD	Technique	Sourcing Content
Chromatography	Chromatography	Fabrication Area	Waiting
Cleaning	Cleaning	Fabrication Area	Waiting
Cleanroom Gowning	Cleanroom Gowning	Fabrication Area	Waiting
Deposition	Deposition	Fabrication Area	Sourcing Content
Atomic Layer Deposition (ALD)	Deposition	Technique	Sourcing Content
Evaporation (E-Beam Evaporation & Thermal)	Deposition	Technique	Sourcing Content
Metal-Organic Chemical Vapour Deposition (MOCVD)	Deposition	Technique	Waiting
Microwave Plasma-enhanced Chemical Vapour Deposition (MPCVD)	Deposition	Technique	Content Review
Molecular Beam Epitaxy (MBE)	Deposition	Technique	Waiting
Plasma Enhanced Chemical Vapour Deposition (PECVD)	Deposition	Technique	Sourcing Content
Sputtering	Deposition	Technique	Ready for LMS
Plasma Polymerisation	Deposition	Technique	Storyboard Review
Low pressure chemical vapour deposition (LPCVD)	Deposition	Technique	Sourcing Content
Etching	Etching	Fabrication Area	Rise Review
RIE and DRIE	Etching	Technique	Rise Review
Plasma etching	Etching	Technique	Not required
Lithography	Lithography	Fabrication Area	Content Review
step 1 Cleaning/Surface preparation	Lithography	Technique	Contnet Approval
Step 3- Direct laser lithography	Lithography	Technique	Waiting
Exposure step 3 - Electron Beam Lithography (EBL)	Lithography	Technique	Rise Updates
Embossing	Lithography	Technique	Waiting
Focused Ion Beam (FIB) milling	Lithography	Technique	Storyboard Review
Step 3 -Maskless lithography	Lithography	Technique	Sourcing Content
Step 3 - UV lithography	Lithography	Technique	Sourcing Content
Nano Imprint Lithography	Lithography	Technique	Waiting
Step 2: Resist Application	Lithography	Technique	Storyboarding
Step 3 - Stepper	Lithography	Technique	Sourcing Content
Thermal Scanning Probe Lithography (t-SPL)	Lithography	Technique	Sourcing Content
Soft Lithography(PDMS)	Lithography	Technique	Storyboard Review
Design for fabrication	Lithography	Technique	Waiting
Step 4: Development	Lithography	Technique	Storyboard Review
Laser microprocessing	Manufacturing and machining	Technique	Sourcing Content
Microinjection moulding	Manufacturing and machining	Technique	Waiting
Material modification	Material modification	Fabrication Area	Waiting
Fibre processing	Materials synthesis and modification	Technique	Waiting
Microscopy	Microscopy	Fabrication Area	Sourcing Content
Confocal microscopy	Microscopy	Technique	Waiting
Digital holographic microscopy	Microscopy	Technique	Waiting
Optical microscopy	Microscopy	Technique	Waiting
Scanning Electron Microscopy (SEM)	Microscopy	Technique	Sourcing Content
Scanning Helium Microscopy (SHeM)	Microscopy	Technique	Sourcing Content
Scanning Near-field Optical Microscopy (SNOM)	Microscopy	Technique	Waiting
Milling	Milling	Fabrication Area	Sourcing Content
Optical fibre pulling and processing	Optical fibre pulling and processing	Fabrication Area	Waiting
Packaging	Packaging	Fabrication Area	Waiting
Wafer bonding	Packaging	Technique	Waiting
Wafer Dicing	Packaging	Technique	Storyboard Review
Wire bonding	Packaging	Technique	Waiting
Physical and Electrical Characterisation	Physical and Electrical Characterisation	Fabrication Area	Waiting
Electrical characterisation	Physical and Electrical Characterisation	Technique	Waiting
Physical property analysis	Physical and Electrical Characterisation	Technique	Waiting
Laser Doppler Vibrometry (LDV)	Physical and Electrical Characterisation	Technique	Waiting
Specialised environments	Specialised environments	Fabrication Area	Ready for LMS
Spectroscopy	Spectroscopy	Fabrication Area	Sourcing Content
Spectrophotometry	Spectroscopy	Technique	Waiting
Fourier Transform Infrared (FTIR) Spectroscopy	Spectroscopy	Technique	Waiting
X-ray Photoelectron Spectroscopy (XPS)	Spectroscopy	Technique	Waiting
Thin film characterisation	Thin film characterisation	Fabrication Area	Sourcing Content
Spectroscopic ellipsometry	Thin film characterisation	Technique	Content Review
Reflectometry	Thin film characterisation	Technique	Waiting
Topological analysis and surface profiling	Topological analysis and surface profiling	Fabrication Area	Sourcing Content
Atomic Force Microscopy (AFM)	Topological analysis and surface profiling	Technique	Waiting
Contact angle analysis	Topological analysis and surface profiling	Technique	Waiting

10.10 O*NET OnLine Summary Report

Provided under separate attachment '*Summary Report for Nanotechnology Engineering Technologists and Technicians – USA – ONet OnLine*'

10.11 ANFF Equipment List

Provided under separate PDF attachment '*ANFF Equipment List*'.

10.12 References

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