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Investing in a Smart, Sustainable and Inclusive Future

Graduate Apprenticeships

Framework document for

Engineering: Design and Manufacture

Engineering: Chemical and Process

SCQF level 10

March 2019

Document control

Version history

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Terms and abbreviations

Term	Meaning
BEng	Bachelor of Engineering
CAD	Computer Aid Design
CAPEX	Capital Expenditure
CEng	Chartered Engineer
EDM	Engineering: Design and Manufacture
ERP	Enterprise Resource Planning
GA(s)	Graduate Apprenticeship(s) / Apprentice(s)
IEng	Incorporated Engineer
ITT	Invitation to Tender
LOPA	Layer of Protection Analysis
MRP	Material Requirements Planning
OPEX	Operating Expenditure
PESTLE	Political, Economic, Social, Legal, Environmental
PI&D	Piping and Instrumentation Design
QA	Quality Assurance
RFP	Request for Proposal
SCQF	Scottish Credit and Qualifications Framework
SDS	Skills Development Scotland
SWOT	Strengths, Weaknesses, Opportunities, Threats
TEG	Technical Expert Group
WBS	Work Breakdown Structure

Contents

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1. Graduate Apprenticeships in Scotland

1.1 Purpose of the Graduate Apprenticeship framework document

The purpose of this document is to provide employers and learning providers with information required to deliver a Graduate Apprenticeship in either:

- **Engineering: Design and Manufacture (EDM)**
- **Engineering: Chemical and Process (ECP)**

The framework sets out the skills and learning outcomes identified through employer consultation that are required to support the development of this programme.

This framework document should be read in conjunction with the following publications:

1. Work-based Learning Principles
2. Product Specification at **SCQF level 10**
3. Quality Assurance Guidance

This documentation is available on the Skills Development Scotland (SDS) corporate website:

www.skillsdevelopmentscotland.co.uk

1.2 What are Graduate Apprenticeships?

Graduate Apprenticeships (GAs):

- are accredited work-based learning programmes that lead to degrees or degree-level, professionally recognised qualifications
- are part of the apprenticeship family, supporting the transition into employment by providing work-based learning pathways from Foundation and Modern Apprenticeships to Higher Apprenticeships at SCQF level 8 and Graduate Apprenticeships at SCQF Levels 9 –11
- have been developed as part of the Scottish Government's approach to developing Scotland's young workforce and Skills Development Scotland's work-based learning strategy

1.3 Why do we need Graduate Apprenticeships in Scotland?

International experience demonstrates how degree-level apprenticeships can drive economic growth. We believe this approach can benefit the Scottish economy.

The range of approaches taken in countries including Switzerland and Germany to develop employer-led, work-based learning pathways to learning and employment provide the basis for how Scotland can use work-based learning to improve the operation of the labour market and to deliver economic growth[1]. Skills Development Scotland is now leveraging the development of Graduate Apprenticeships to support this change.

1.4 Who develops Graduate Apprenticeships?

Graduate Apprenticeships are developed by Skills Development Scotland through consultation with employers, universities, professional bodies and qualification authorities in the form of Technical Expert Groups (TEGs). The TEGs act as advisory groups on behalf of the sector and are based on the current and future skills needs of industry. They advise on the topics and related outcomes that should be included in a framework.

More information about who was involved in the development of this framework can be found in **Appendix C**.

1.5 Who are Graduate Apprenticeships for?

Graduate Apprenticeships provide a new way into degree-level study for individuals who are either currently in employment or are entering into employment. GAs are available to employees aged 16 or over.

1.6 Who delivers Graduate Apprenticeships?

Graduate Apprenticeships are delivered by universities in partnership with employers and college learning providers. An up-to-date list of learning providers and the frameworks they offer can be found on **www.apprenticeships.scot**.

[1] **PWC (2015) Young Workforce' Index: How well are OECD economies developing the economic potential of their young people?**

2. Delivery

As Graduate Apprentices are work-based degrees, the place of employment is the primary place of learning. The learning and skills development must be fully integrated into both the **delivery and assessment** of the degree when part of a Graduate Apprenticeship. This integration can only be satisfactorily achieved by proper planning and design prior to delivery and not by add-on components or ad-hoc modifications.

The authenticity of the programme is shown in the way employers are involved in the design and delivery of the degrees and the way in which work-based learning is positioned as integral to both the learning and the assessment needed for successful completion of the programme.

GAs are designed as full-time programmes. They are not part-time or sandwich courses. Attendance at the place of learning will be agreed between the provider and the employer sending individuals on the programmes. Examples of how this might work are:

- by day release or
- by block release of three or four-week duration, three times per year
- through distance learning with an initial “boot camp or induction”

Fundamentally, most of an individual’s time should be spent in the workplace on directed study.

In designing the degrees to meet the work-based learning requirements of the GA, learning providers must ensure that they also meet the principles and criteria noted here:

Box 1. Principles and criteria

This GA is an SCQF level 10 work-based degree. All proposed university degree programmes for this GA framework must:

- be 480 credits
- be based on a partnership between employers and the learning provider
- evidence how the programmes exemplify the work-based learning requirements
- have clear goals and aspirations in support of equality and diversity with appropriate monitoring and other processes in place
- demonstrate how they will ensure that apprentices, upon graduation, will consistently achieve the necessary industry skills, knowledge and competence defined in Appendix A
- develop learning through reflection and review of work processes and experience
- meet the requirements to apply for professional body recognition

NB Delivery models based on sandwich years or industrial placement block release are not considered as work-based learning as part of this framework.

The successful delivery of Graduate Apprenticeships depends upon an effective partnership between the apprentice, the employer and the learning provider. This will involve additions to their normal responsibilities for employees, learning providers, and apprentices.

Delivery of the content of the GA will be agreed by the participating learning providers, which may involve delivery of specialist or employer-specific content. Employers should also be closely involved with all aspects of the programme, including the course specification, delivery, and assessment of practical activities.

The learning provider has responsibility for the quality assurance and enhancement of all elements of the programmes but they must adhere to the SDS specified documents referenced in **Section 1** and any additional guidance documentation provided as part of their competitive grant award. Practical activities must make use of the work environment and course content must take account of the technologies used in the apprentice's employment.

Apprentices must have individual learning and training plans. The learning provider and existing employer HR systems should be co-ordinated during the development of the individual learning and training plan to ensure that the required employer contextualisation is effective. Even within a specific employer, there may be apprentices who use differing technologies.

3. Roles and responsibilities

3.1 Role of the employer

Apprentices are employees and subject to the standard terms and conditions applying to all employees.

Employers participating in the Graduate Apprenticeship programme must:

- consider whether a candidate has a reasonable chance of achieving the chosen programme during the selection process – this includes not only the course content but the acquisition of wider graduate attributes
- provide agreed information to support the candidate's application to the degree course
- provide apprentices with suitable opportunities to gain the type of experience in the workplace that will support their learning and skills acquisition
- provide each apprentice with a nominated mentor who must be readily accessible to the apprentice and to the learning provider
- liaise with the learning provider on the content and practical activities in the apprentice's individual learning and training plan
- provide information that will support the individual apprentice and their assessment

3.2 Role of the learning provider

Apprentices are both employed by the employer and enrolled with the learning provider. As such they should have access to the same facilities as any other student.

GA course design and delivery must adhere to the principles detailed in the preceding sections and in addition the learning provider must:

- adopt a flexible approach to considering the suitability of candidates by taking account of the portfolio of previous learning and experience an individual brings to the programme – this will include any relevant Foundation or Modern Apprenticeship undertaken – and support best practice in assessing individuals and in gathering evidence from employers where this is required
- liaise with the employer on the content and practical activities in the apprentice's individual learning plan

In addition, the learning provider should liaise with existing employer Training and Development and Quality Assurance (QA) systems to minimise repetition of learning or assessment. Development and meaningful implementation of individual learning plans is an essential component of the GA and assessments should take account of existing evidence wherever possible.

New evidence that directly relates to the workplace may be authenticated by employers or the individual's mentor.

There are a range of potential delivery mechanisms, but the integration of knowledge within contextualised learning opportunities must be a key feature.

3.3 Content delivery and assessment

Content delivery and assessment responsibilities:

	Employer	***Learning Provider***	***Other***
Delivery of knowledge and understanding content	✓ Employer specific topics	✓ Generic and non-employer specific	✓ Private providers
Assessment of practical application	✓	✓	✓ Apprentice
Development of personal and business skills	✓ Specification, delivery, progress monitoring, assessment and mentoring	✓ Specification, delivery, progress monitoring and assessment	✓ May be a third party used for delivery, monitoring and assessment

4. Entry

4.1 Eligibility

- Graduate Apprenticeships are available to new and existing employees of participating employers.
- Candidates must be at least 16 years of age. However, the suitability of an individual for entry onto a GA will be decided by the employer and their learning provider partner.
- Candidates must be resident in Scotland throughout the Graduate Apprenticeship. In addition to this, their employer's working premises must also be located in Scotland. When applying to become a Graduate Apprentice the individual will be required to satisfy the employer that they have the right to live and work in the UK.
- Entry requirements are likely to vary across learning providers. For courses where there is a mandatory requirement for a specific subject, learning providers should consider ways they can provide support to individuals who don't hold a traditional qualification but have nevertheless shown aptitude and competence at the necessary level.

4.2 Recognition of prior learning

Candidates will undergo a selection process for a Graduate Apprenticeship, based on employer HR processes. The admissions departments need to take account of this and liaise with employers to provide advice and guidance on the prior learning and experience that will be accepted for entry onto the course.

A more flexible approach to entry requirements should be adopted by learning providers and be done in consultation with employers. This should involve consideration of candidates on a case by case basis, who have completed relevant Foundation, Modern or Technical Apprenticeships as well as industry / vendor certifications.

Universities and other providers are asked to consider ways they can best recognise the apprentice's prior learning in order to minimise repetition of content.

5. Demand

Manufacturing

Activity within the Engineering sector includes the manufacture of machinery, vehicles, transport equipment and electrical equipment. In addition, related research and development work, technical testing and analysis are included in this sector.

Employment[2]

In 2017, employment in the sector was 168,600 accounting for six per cent of all employment in Scotland. Since the recession in 2008 employment in the sector has grown by less than one per cent, compared to a decline of one per cent growth all sectors. More recently (since 2015) employment has grown by two per cent compared to static employment nationally. This suggests a large sector that is growing slightly faster than the average for all industries.

Employment was highest in Aberdeen City and Shire (47,000). Glasgow (20,000) and Edinburgh, East and Midlothian (19,000) were the next largest regions, where employment in each was approximately two fifths of the employment in Aberdeen City and Shire. There were also concentrations of employment in Fife and West Lothian, where the absolute level of employment was lower but the sector accounts for an above average proportion of regional employment. In the regions mentioned the sector is an important source of jobs.

Looking forward, employment growth in the sector is forecast to slow and decline in the medium term. By 2020, employment in the sector will have declined by 800, a decrease of one per cent compared to no change across all industries. Over the longer term up to 2027, employment in the sector will be maintained at 2017 levels whilst nationally employment will grow by three per cent. Although there will be little expansion demand in the sector, the need to replace workers will generate demand. Based on employment in 2017, 12 per cent of the workforce will need to be replaced by 2027. The sector's net requirement for workers up to 2027 will be 21,100. This is compared to two per cent of the net requirement for workers across all industries.

The greatest proportion of the total net requirement for workers in the Engineering sector will be in Aberdeen City and Shire (29 per cent). Edinburgh, East and Midlothian will account for the next greatest proportion, 18 per cent.

[2] Oxford Economics Regional and Sectoral Forecast (2000-27)

Occupations[3]

In 2017, the majority (56 per cent) of the Engineering workforce were in higher level occupations. The proportion of the workforce in mid and low-level occupations was lower, 25 per cent and 19 per cent respectively. By 2027 there will be a small change in the occupational structure of the workforce with two per cent more of the workforce being in higher level occupations and two per cent fewer in lower level occupations.

Engineering and Advance Manufacturing Sector Skills Investment Plan
The Engineering and Advance Manufacturing Sector Skills Investment Plan (developed in 2014) acknowledges apprenticeships as a principal pathway into the sector.

New Developments Influencing Demand for GAs in Engineering

In February 2016, the Scottish Government launched the Manufacturing Action Plan – a future manufacturing strategy for Scotland. An important pillar of this strategy is skills, including talent attraction and retention. As the strategy has been developed the delivery group has proposed the creation of a National Manufacturing Institute for Scotland (NMIS). Support for this was announced in the September 2017 Programme for Government, with a funding package expected in the autumn statement.

NMIS will consist of a ‘Factory of the Future’, a Skills Academy and regional/digital access points. It is expected that NMIS will attract inward investors creating many hundreds of highly skilled jobs in advanced manufacturing. Discussions with the trade body, Scottish Engineering, confirm that Graduate Apprenticeships in Engineering (Design and Manufacture, and Instrumentation, Measurement and Control) would be the ideal vehicle for businesses to gain the appropriate skills base needed to cope with the growth in advanced manufacturing.

[3] Oxford Economics Regional and Sectoral Forecast (2000-27)

Chemical Sciences

The Chemical Sciences sector covers the manufacture of a broad range of products including plastics, fertilisers, pharmaceuticals and paints. The definition used for the sector captures the manufacturing activity; however, the sector is broader than just manufacturing and activity such as chemical engineering is not captured in the sector's forecast. The Chemical and Process Engineering GA is not confined to the Chemical Sciences sector. Any sector with manufacturing activity could have demand, so demand is expected to be greater than the sectoral forecast suggests. We have included some additional analysis to show this.

Employment
In 2019, employment within the Chemical Sciences sector was 9,500, accounting for less than one per cent of Scottish workforce. This made it the smallest key sector in Scotland in terms of workforce size.

Since 2009, employment in the sector remained static, while nationally employment increased by three per cent over the same period. However, more recently, there have been signs of decline within the sector, with employment decreasing by five per cent since 2017 – greater than the one per cent decrease in employment across all sectors up to 2019.

Whilst the sectoral employment has been in decline since 2017, across all sectors some occupations related to the Chemical and Process Engineering GA have grown, but not all:
Production Managers and Directors, increase of 2,800 people;
Engineering Professionals, increase of 4,100 people; and
Science, Engineering and Production Technicians, decrease of -2,800 people.

Regionally, the highest levels of employment in the Chemical Sciences sector were in Ayrshire (1,200), Forth Valley (1,200), Highlands and Islands (1,200). Compared to the national trend, Forth Valley and Ayrshire had the greatest concentrations, where employment in the sector was almost three times and two and a half times the national average respectively. Also, the sector accounted for an above average proportion of employment in West, West Lothian and Tayside. The Chemical Sciences sector whilst small is an important source of jobs in each of these regions.

The recent employment contraction in the sector is anticipated to continue in both the short and medium term. By 2022, sectoral employment is forecast to decrease by 300 people (a decrease of three per cent) and by 2029 the sector is expected to contract by 1,400 people (a decrease of 15 per cent). This contrasts with overall employment forecasts, with growth expected to both 2022 and 2029 (of two per cent and three per cent, respectively).

Although overall employment will decrease, the need to replace workers leaving the sector will create demand. Based on the number of jobs in the sector in 2019, the forecast suggests that 20 per cent of current positions will experience staff turnover by 2029. The sector's net requirement for workers is forecast to be 300 by 2029.

However, this is just demand for roles in the Chemical Sciences sector. Occupational analysis shows that there will be net demand across all sectors for people in the following roles which are related to the Chemical and Process Engineering GA from 2019 to 2029:

- Production Managers and Directors, forecast requirement for 2,800 people;
- Engineering Professionals, forecast requirement for 18,500 people; and
- Science, Engineering and Production Technicians, forecast requirement for 29,900 people.

The greatest percentage of the net requirement for workers in the Chemical Sciences sector will be in Ayrshire (38 per cent of total net requirement for the sector), with Edinburgh, East and Midlothian, and Tayside accounting for a further 17 and 14 per cent, respectively.

Beyond the Chemical Sciences sector, developments such as the National Manufacturing Institute for Scotland and the Medicines Manufacturing Innovation Centre all present opportunities that could lead to greater demand for Chemical and Process Engineering professionals.

Occupations

In 2019, almost two-fifths of the sectoral workforce were in higher level occupations (39 per cent). Those in mid-level and lower level occupations accounted for 28 per cent and 32 per cent, respectively. By 2029, there will be a small change in the occupational structure of the workforce with two percentage points more of the workforce being in higher level occupations, with no change forecast for mid and lower level occupations.

Life and Chemical Sciences Skills Investment Plan

A refreshed Chemical Sciences Skills Investment Plan (SIP) was launched in 2018, combined with the Life Sciences sector. The SIP identified that demand for a Chemical and Process Engineering GA existed, and this has now been developed with industry commitment to it.

6. The framework

6.1 Overview

The Graduate Apprenticeship is based on industry defined needs and has been developed in collaboration with employers and the education sector to allow knowledge, understanding, skills and competence to be developed with the necessary attributes industry expects from its graduates.

Within the **EDM** and **ECP** Graduate Apprenticeship, the degree content must be delivered as per the principles and outcomes detailed in this framework.

The output of this framework will be a Graduate Apprenticeship at **SCQF level 10** entitled:

- **Graduate Apprenticeship in BEng (Honours) Engineering: Design and Manufacture**
- **Graduate Apprenticeship in BEng (Honours) Engineering: Chemical and Process**

6.2 Purpose

The aim of the Graduate Apprenticeship is to produce graduates with:

- The "meta-skills" required to thrive in the future economy – i.e. self-management, social intelligence and innovation.
- Design for Manufacture 'concurrent engineering' capability, integrating engineering principles, materials and technology selection into structured design methodologies based on their application to real world challenges. There is an emphasis on business economics and sustainability issues alongside design engineering and design creativity.
- Sufficient understanding of the engineering business enterprise environment including strategy development, leadership and business operations management knowledge to play a management role in engineering project planning and delivery.
- Project management and creative thinking skills supported by a set of problem-solving and modelling tools appropriate to engineering business operations.

It is a central requirement of the Graduate Apprenticeship that these 4 key content areas are combined to deliver a holistic learning experience that blends workplace experience with off-the-job learning.

Details of the high-level learning and skills outcomes for these content areas are provided in **Appendix A.** **Appendix B** provides an illustrative example of low level learning and skills outcomes that might be achieved by individuals undertaking the Graduate Apprenticeship

6.3 Occupational outcomes

This GA is aimed at employment in the following areas:

- **Engineering Design**
- **Manufacturing Engineering**
- **Chemical Engineering**
- **Process Engineering**
- **Bio-process Engineering**
- **Research and Development**
- **Engineering Consultancy**
- **Operations Management**
- **Process Operations Management**
- **Engineering Project Management**

6.4 Learning outcomes

Please refer to **Appendices A** and **B** for a full list of learning outcomes for the GA in either

- **Engineering: Design and Manufacture (EDM)**
- **Engineering: Chemical and Process (ECP)**

6.5 Professional recognition

The primary focus of the GA is on developing the knowledge, understanding and skills outcomes sought by employers. This GA framework can also support the achievement of professional recognition, as it includes the range of learning and skills outcomes outlined in UKSPEC to enable application for Incorporated Engineer (IEng) recognition (regardless of whether an individual university's degree has been accredited by a professional engineering body). A candidate on completion of a GA will also be on course to demonstrate the requirements for Chartered Engineer (CEng) in the future should they or their employer seek such recognition.

6.6 Meta Skills

We are moving into a fourth industrial revolution, driven by technological disruptors. At the same time, we face the challenges of globalisation, an ageing population and increasing diversity within the workplace.

Scotland's workforce will need constantly developing skills, knowledge and capabilities to thrive in this complex, ever-changing environment.

When we refer to meta-skills we mean timeless, higher order skills that create adaptive learners and promote success in whatever context the future brings. These aren't new skills or capabilities, but it is now more important that we define them more clearly and support their development more explicitly.

We classify meta-skills under three headings:

- **Self-management** – taking responsibility for your own behaviour and wellbeing;
- **Social intelligence** – awareness of the feelings, needs and concerns of others, and the ability to navigate social relationships and environments; and
- **Innovation** – the ability to define and implement positive change.

These headings are the basis for the mandatory, high level meta-skills outcomes that are included in Appendix A.

Self-management involves:

- being able to focus on a current task or priority while avoiding distraction;
- integrity – acting in an honest and consistent manner based on clear personal values;
- adaptability – the ability and interest to learn new skills and new ways of doing things; and
- a readiness to take initiative, get started and respond to opportunities.

Social intelligence involves:

- communicating – sharing information openly and in a way that creates mutual understanding;
- feeling – taking the thoughts, feelings and perspectives of others into account and considering impact on them;
- the ability to collaborate and work with others to tackle problems; and
- leading by inspiring and motivating others with a clear vision and direction.

Innovation involves:

- the curiosity to want to know or learn in order to inspire new ideas and concepts;
- the creativity to imagine and think in new ways to address problems or express meaning;
- sense making through recognising themes and patterns in information; and

- the critical thinking needed to evaluate and draw conclusions from information and make informed decisions.

These descriptions provide the basis for the indicative, low level meta-skills outcomes that are listed in Appendix B.

Further background on meta-skills can be found at https://www.skillsdevelopmentscotland.co.uk/what-we-do/skills-planning/skills4-0/

6.7 Related Scottish apprenticeship frameworks

The following Scottish Apprenticeship frameworks and qualifications are relevant pathways that may contribute toward progression into the **EDM or CPE** GA. The apprenticeships are eligible for funding contributions from Skills Development Scotland, and provide individuals and employers with a range of alternative pathways at different levels of entry:

In school:

Foundation Apprenticeship in Engineering (SCQF level 6)

FA Engineering SCQF L6

Post-school:

Modern Apprenticeship in Engineering (SCQF level 6)

MA in Engineering SCQF L6

Modern Apprenticeship in Life Sciences and Related Science Industries (SCQF Level 7)
MA in Life Science and Related Science Industries SCQF 7

Technical Apprenticeship in Life Sciences and Related Science Industries (SCQF Level 8)

Technical Apprenticeship in Life Sciences and Related Science Industries SCQF 8

Modern Apprenticeship in Process Manufacturing (SCQF Level 6)

MA in Process Manufacturing SCQF 6

Appendix A: Learning and Skills Outcomes

This section details the high-level learning and skills outcomes for the GA that must be covered within the degree dependent on the pathway chosen. **Appendix B** provides suggested low-level outcomes that may be covered within each section.

This presents a broad set of outcomes against which universities can position their intended provision to meet the high-level learning outcomes and flavour the programme for their intended employer audience.

Please note: all students will be expected to undertake a significant project at the end their course. This project should draw together all main skills of the course and include a real world applied engineering project.

Topics and high-level learning and skills outcomes:

Learning and skills outcomes
1. Core & meta-skills
1.1. Self-management
1.2. Social intelligence
1.3. Innovation
2. Engineering design and manufacturing principles[1]
2.1. Manufacturing with materials
2.2. Engineering product design
2.3. Computer aided design and analysis
2.4. Electrical and electronic design principles
2.5. Planning and design of manufacturing systems
2.6. Sustainable manufacturing
2.7. Design and manufacture applications
2.8. Engineering IT
3. Chemical and process engineering principles[2]
3.1. Applying scientific and mathematical knowledge
3.2. Core chemical engineering
3.3. Process design and development
3.4. Process operations/process engineering support
3.5. Computer applications and IT

3.6.	Health, occupational and process safety
3.7.	Environment and sustainability
4.	**Engineering business and management**
4.1.	Business functions, behaviours, ethics and courtesies
4.2.	Engineering design and manufacturing operations management
4.3.	Supply chain management
4.4.	Organisational behaviour
4.5.	Business strategy and management
4.6.	Business finance and accounting
4.7.	Industrial engineering
4.8.	Global manufacturing strategy
5.	**Project and delivery management**
5.1	Project management approaches and methodologies
5.2	Project planning
5.3	Project execution
5.4	Project risk assessment and management

1**:** Outcomes applicable to those pursuing a design and manufacturing pathway

2: Outcomes applicable to those pursuing a chemical and process engineering pathway.

Appendix B: Low-level outcomes

The next section provides indicative examples of more detailed learning and skills outcomes which employers may expect individuals to cover in a Graduate Apprenticeship in **Engineering: Design and Manufacture** or **Chemical and Processing**

The detailed learning and skills outcomes are indicative and are not intended to be used as a pro-forma curriculum.

Each learning provider will have their own approach to delivering the degree and progression between stages. The low-level skills and derived learning outcomes that are detailed in the following sections will provide guidance to ensure that each degree covers the desired learning outcomes appropriately.

Table 1: Core and meta skills for engineering (replaces personal attributes)

1.	Core & meta-skills
1.1	Self-management
1.2	Social intelligence
1.3	Innovation

1.1 Self-management

1.1.1 Sort and filter complex information and focus attention on current priorities.

1.1.2 Demonstrate openness, resilience and critical self-reflection to support effective change.

1.1.3 Plan and critically evaluate own learning and skills development to support adapting to change.

1.1.4 Take the initiative to resolve complex problems or issues by thinking independently, assessing risk and making considered decisions, and act without relying on influence or encouragement from others.

1.1.5 Demonstrate both personal and professional integrity, acknowledging the importance and value of such disciplined behaviour and exercising responsibilities in an ethical manner.

1.2 Social Intelligence

1.2.1 Communicate effectively in a full range of employment settings (including for example chairing meetings, dealing with confrontation or negotiating) by:

- listening actively and questioning effectively
- interpreting complex verbal and written communications
- providing complex written and verbal communications that are appropriate to and understandable by the intended audience
- motivating/persuading others to make or support progress.

1.2.2 Take account of the feelings and motivations of others and critically evaluate own impact on other people.

1.2.3 Collaborate professionally across a range of cultural settings, developing and maintaining networks to achieve shared goals.

1.2.4 Apply knowledge of high performing teams.

1.2.5 Work with others to produce engineering solutions by planning, implementing and critically reviewing own work goals, priorities and responsibilities.

1.2.6 Promote change effectively by inspiring, influencing, motivating and developing others.

1.3 Innovation

1.3.1 Demonstrate a desire to learn in order to develop new ideas or to improve processes by:

- recognising and defining problems
- observing and questioning
- researching or sourcing information to generate new ideas or approaches.

1.3.2 Demonstrate creativity in addressing problems or technological challenges by:

- generating ideas
- imagining
- visualising
- providing new solutions.

1.3.3 Make sense of complex situations by:

- analysing and synthesising information
- recognising patterns
- thinking holistically
- recognising potential opportunities.

1.3.4 Solve complex problems through critical thinking by:

- deconstructing problems into smaller, more manageable parts
- using logical or computational thinking
- forming judgements after careful thought.

Table 2: Skills and knowledge coverage in engineering design and manufacturing principles

2. Engineering design and manufacturing principles
2.1. Manufacturing with materials
2.2. Engineering product design
2.3. Computer aided design and analysis
2.4. Electrical and electronic design principles
2.5. Planning and design of manufacturing systems
2.6. Sustainable manufacturing
2.7. Design and manufacture applications
2.8. Engineering IT

2.1 Manufacturing with materials

2.1.1 Make appropriate choices of materials and manufacturing processes in a business context and relate these choices to product and process design

2.1.2 Select and optimise methods and manufacturing processes, including how to form or join materials and how those materials might fail or degrade in use

2.1.3 Understand the range of different materials processing methods used for metals, ceramics, carbon fibre composites and polymers and how to apply them

2.1.4 Understand the influence of microstructure on materials performance and the ways in which microstructure is influenced by processing

2.1.5 Understand plastic deformation processes

2.1.6 Understand the fundamentals of heat treatment of metals and can select appropriate treatment methods

2.1.7 Apply knowledge of materials processing methods and of the mechanisms of materials degradation and failure to inform and improve product design

2.1.8 Understand the range of materials, technologies and processes involved in current best practice manufacturing

2.1.9 Be aware of future trends in manufacturing materials

2.1.10 Be aware of common techniques for destructive and non-destructive testing and how to apply these

2.2 Engineering product design

2.2.1 Integrate industrial design issues such as aesthetics and ergonomics with core engineering design concerns including functionality, design for manufacture, product architecture and detailed engineering to design products to customer specifications

2.2.2 Apply engineering principles, science and mathematics to the design and manufacture of products

2.2.3 Determine a product's architecture, understanding the importance of geometries, dimensions and tolerances

2.2.4 Communicate designs, including drafting, solid and assembly modelling, producing product reports and making presentations, including standardisation of detail

2.2.5 Estimate unit cost analysis of a design

2.2.6 Understand and can apply basic ergonomic principles to product design

2.2.7 Understand why products are designed as they are and can explore a product's form, including design for manufacture and part count reduction considerations

2.2.8 Understand and apply dimensional tolerances to producing engineering drawings

2.2.9 Understand and apply design consideration to common components and assemblies (dimensions, tolerances, surface finish, limits and fits)

2.2.10 Can estimate manufacturing parameter specifications (including costs, weights, processes and their selection, and materials selection)

2.2.11 Understand how to select and apply a design methodology

2.3 Computer aided design and analysis

2.3.1 Create solid geometrical parts using a variety of fundamental construction techniques using industry standard solid modelling systems

2.3.2 Apply the principles of B-spline curve and surface creation and CAD modelling techniques to the generation of surface/solid geometry starting from a point data set and/or suitable mathematical formulae

2.3.3 Use drafting tools to generate 2D drawings from 3D geometrical parts

2.3.4 Evaluate a CAE solid modelling tool in terms of the range of solid construction techniques offered

2.3.5 Identify analysis problems which are suitable for finite element or finite difference solution

2.3.6 Demonstrate a working knowledge of numerical solution methods

2.3.7 Generate finite element analysis models by using geometry from a solid modeller

2.3.8 Demonstrate an understanding of how modern CAE Analysis tools are used

2.3.9 Use free mesh and mapped mesh generation techniques

2.3.10 Apply design for manufacture/construction/maintenance principles to the development of computer aided engineering models

2.3.11 Understand the role of simulation and analysis for static and dynamic contexts and how these are used for product operation and manufacturing process simulation

2.3.12 Create an optimisation model to solve a specified engineering design problem, including the use of FMEA (failure mode effect analysis)

2.3.13 Evaluate the features of a design optimisation and maturity model and how this aids design capability improvement

2.3.14 Understand the need for and standards associated with data exchange between systems, to assist the design optimisation process

2.3.15 Can generate solid model outputs suitable for different applications such as rapid prototyping, CNC machining, pattern and tooling manufacture

2.3.16 Communicate clearly in terms of written reports, project meetings and presentations to specialist and non-specialist audiences

2.3.17 Understand how organisations manage complex 3D visualisation and mock up and the application of configuration management and control to represent different product configurations

2.3.18 Understand the importance of verification and validation for modelling and simulation of products and processes

2.4 Planning and design of manufacturing systems

2.4.1 Understand the principles and application of robotics; sensors in automation, fixtures and end-effectors, programmable logic controllers, CNC machine control, pneumatics and mechatronics

2.4.2 Understand the basic principles of machine tool operation, including maintenance, repair and condition monitoring

2.4.3 Understand how control systems can be used to model production cells, mitigate errors in machining and integrate machines into the wider production system

2.4.4 Know the operational aspects of the main categories of machining processes

2.4.5 Understand the types of interaction between components and process tooling

2.4.6 Understand the factors that affect the accuracy and precision of machining and grinding operations

2.4.7 Understand the various control strategies used to mitigate the sources of error in machining processes

2.4.8 Know how machining cells are integrated into factory wide operations

2.4.9 Specify, operate and manage production machines and systems including test planning

2.4.10 Plan and carry out an assigned automation task and to integrate this with other complementary tasks to deliver a fully functioning automated manufacturing system

2.4.11 Understand the importance of surface treatments and coatings for engineering components and the manufacturing systems that provide these

2.4.12 Understand what is meant by SMED (Single-Minute Exchange of Dies) and how this is applied to reduce the time it takes to complete equipment or tool changeovers

2.4.13 Understand that any engineering project that involves equipment being commissioned should have Test and Evaluation incorporated into the system life-cycle

2.4.14 Understand that sales and operations planning (S&OP), is a cross-functional process to align the commercial processes of sales and marketing with the operational processes of supply, and includes the product requirements specified through the master schedule

2.4.15 Understand how the Theory of Constraints, and methods for line balancing can be applied to production and assembly line planning, including for reducing cycle time and moving work elements

2.5 Electrical and electronic design principles

2.5.1 Design, install and commission electrical systems

2.5.2 Understanding basic electrical theory and electronic principles

2.5.3 Understand how to apply basic electrical principles to design electrical circuits, including electrical power systems and analogue and digital electronics

2.5.4 Produce detailed electrical design drawings using industry standard software

2.5.5 Understand the operation of basic semiconductors and passive components including their main areas of application

2.5.6 Design functional electronic systems and circuits from component level, considering heat dissipation, electrical interference and other factors affecting layout

2.5.7 Utilise modelling techniques for circuit design, embedded software development and thermal management

2.5.8 Understand how to assemble and test electronic circuits

2.5.9 Understand how to design both analogue and digital circuits and the basic design rules for mixed analogue and digital circuit boards

2.5.10 Understand how to wire and test electrical equipment, in line with organisational standards

2.5.11 Understand the principles of electro-technology design needed for mechanical engineering systems

2.6 Sustainable manufacturing

2.6.1 Produce a detailed carbon footprint analysis of a product

2.6.2 Understand what is meant by sustainability in an industrial context

2.6.3 Understand the drivers of and barriers to sustainable manufacturing

2.6.4 Understand the practical limits of sustainability in an industrial and global context

2.6.5 Understand the implications of resource scarcity

2.6.6 Understand the growing importance of design for remanufacture and the concept of the circular economy to retain control of products and materials throughout the product life cycle, reducing life cycle costs of products and increasing sustainability

2.6.7 Understand the importance of design for disposal or reuse: The end-of-life of a product is an important consideration, especially where products contain toxic chemicals or other hazardous substances require careful disposal

2.7 Design and manufacture for applications

2.7.1 Understand and analyse Engineering Thermofluid systems, based on mass and energy conservation

2.7.2 Design products for thermodynamics, fluid mechanics and turbomachinery applications

2.7.3 Understand the principles of structural design, including; statics and dynamics, simply supported beam and torsion

2.8 IT for Engineers

2.8.1 Understand and apply IT software which supports engineering applications (such as spreadsheets, MATLAB etc.)

2.8.2 Understand the role of software programming in embedded systems within engineering products and systems

2.8.3 Understand the role and application of ERP, MRP and other enterprise software systems

2.8.4 Can apply industry standard project planning tools e.g. Prima Vera

2.8.5 Understand the range of product processing (e.g. for metal casting, metal forming and plastic injection moulding) and work flow simulation (e.g. Simul8)

Table 3: Skills and knowledge coverage in chemical and process engineering principles

3. Chemical and process engineering principles	
3.1.	Applying scientific and mathematical knowledge
3.2.	Core chemical engineering
3.3.	Process design and development
3.4.	Process operations/process engineering support
3.5.	Computer applications and IT
3.6.	Health, occupational and process safety
3.7.	Environment and sustainability

3.1 Applying scientific and mathematical knowledge

3.1.1 Apply the chemistry of materials (organic; inorganic; physical properties).

3.1.2 Apply mathematics required to support engineering (functions; expressions; data handling/representation; multivariable functions and solutions; 2nd order equations; calculus; vectors; statistics; differentiation; integration; matrices; algebra; geometry).

3.1.3 Carry out hypothesis testing using accepted principles.

3.1.4 Develop and apply mathematical modelling tools (e.g. using spreadsheets to develop conceptual models).

3.1.5 Use scientific principles: applied chemistry (atomic structure, molecular shape and chemical bonding etc.), biology (biochemistry, enzymes, cells, bacteria etc.) and physics (e.g. mechanics, forces, particle dynamics, work, energy, electrical circuits).

3.1.6 Recognise and apply relevant elements from other engineering disciplines (e.g. electrical power, motors, pressure vessels and their design; structural mechanics; micro-electronics).

3.2 Core chemical engineering

3.2.1 Apply principles of unit operations (e.g. separation, crystallisation, evaporation, distillation, filtration etc.) to complex process and chemical engineering tasks.

3.2.2 Apply underpinning engineering principles when carrying out process and operational monitoring (e.g. flow measurement; use of pumps etc.).

3.2.3 Apply fluid mechanics principles to core chemical engineering processes (e.g. determining pipe flow).

3.2.4 Apply the principles of heat transfer (conduction and convection; radiation; boiling and condensation) to heat exchange across a range of different types and design of heat exchanger.

3.2.5 Carry out chemical/bio-chemical reaction calculations (material balance and energy balance; mass transfer; thermodynamics; fermentation) and show their application.

3.3 Process design and development

3.3.1 Investigate, develop and implement solutions to design and operational problems, including those related to waste minimisation and reduction.

3.3.2 Design and conduct detailed practical experiments based on existing and well-defined processes.

3.3.3 Implement pilot plant including scaling-up/scaling down processes (knowledge of reaction kinetics; chemical equilibrium; material properties; thermodynamics).

3.3.4 Specify and select equipment and instrumentation, demonstrating an understanding of the pros and cons of different types of equipment.

3.3.5 Apply process modelling theory/tools including using computer modelling (e.g. representing chemical and physical processes; process control; transmitters and sensors; process instrumentation diagrams).

3.3.6 Apply an understanding of design economics (e.g. capital cost, value added and cashflow and impact on profit and loss).

3.3.7 Prepare basic designs including PI&D to support specification of equipment.

3.3.8 Evaluate process measurement and control systems.

3.4 Process operations/engineering support

3.4.1 Perform start up and shut down operations.

3.4.2 Conduct pre-commissioning, commissioning and operations/process handover.

3.4.3 Apply knowledge for trouble-shooting of process engineering (reactors, heat exchangers).

3.4.4 Identify defects and apply elimination methodologies (e.g. root cause analysis) for trouble-shooting.

3.5 Computer applications and IT

3.5.1 Apply appropriate IT software to support engineering applications (such as process modelling software and spreadsheets etc.).

3.5.2 Outline the role of software programming in embedded systems within engineering products and systems.

3.5.3 Outline the role and application of ERP, MRP and other enterprise software systems.

3.5.4 Apply industry standard project planning tools.

3.5.5 Source and collect data and provide the data for analysis.

3.5.6 Test the validity and robustness of data, using appropriate statistical techniques (such as significance testing, A/B test etc).

3.6 Health, occupational and process safety

3.6.1 Develop knowledge of and comply with current, relevant health and safety legislation.

3.6.2 Identify and take responsibility for health, safety and welfare issues.

3.6.3 Maintain an awareness of hazards and the process of their identification.

3.6.4 Understand and evaluate process safety (e.g. potential impacts of chemical reaction/fire and explosion/flammability for dusts, vapours, gases etc.).

3.6.5 Conduct risk and hazard assessment using recognized principles and indicating potential consequences.

3.6.6 Apply risk management and process safety mitigation strategies (e.g. LOPA).

3.6.7 Analyse how human factors can impact on process safety.

3.6.8 Comply with relevant codes of practice and industry standards.

3.7 Environment and sustainability

3.7.1 Apply an understanding of environmental management systems.

3.7.2 Produce a detailed carbon footprint analysis of an engineering process.

3.7.3 Outline the principles of sustainability in an industrial context.

3.7.4 List the drivers of and barriers to sustainable manufacturing.

3.7.5 Describe and explain practical limits of sustainability in an industrial and global engineering context.

3.7.6 Assess the implications of resource scarcity.

3.7.7 Explain the growing importance of design for remanufacture and the concept of the circular economy to retain control of products and materials throughout the product life cycle.

3.7.8 Relate the importance of design to disposal or reuse.

3.7.9 Observe fully relevant environmental compliance and management regulations.

Table 4: Skills and knowledge coverage in engineering business and management

4.	Engineering business and management
4.1	Business functions, behaviours, ethics and courtesies
4.2	Engineering design and manufacturing operations management
4.3	Supply chain management
4.4	Organisational behaviour
4.5	Business strategy and management
4.6	Business finance and accounting
4.7	Industrial engineering
4.8	Global manufacturing strategy

4.1 Business functions, behaviours, ethics and courtesies

4.1.1 Demonstrate professionalism in basic business behaviour, ethics and courtesies, including timeliness, focus when faced with distractions, and the ability to complete tasks to a deadline and to high quality standards.

4.1.2 Explain how basic business functions, organisational structures and organisational design contribute to creating successful engineering business.

4.1.3 Apply basic management considerations: prioritisation, task versus responsibility management, managing up and across the organisation, people considerations.

4.1.4 Understand the importance of conforming to the organisational values.

4.2 Engineering design and manufacturing operations management

4.2.1 Design, control, and improve processing and manufacturing operations.

4.2.2 Explain how manufacturing processes are managed to achieve the right quality of product, manufactured to meet the customer requirements, delivered on time, and making the most efficient use of resources available.

4.2.3 Evaluate the role of inventory in manufacturing systems, and apply basic ordering, replenishment, and forecasting techniques.

4.2.4 Identify the major influences on the efficient processing through a factory, apply MRP techniques to scheduling, describe the implications of different co-ordination structures on job design, and describe how improvement processes relate to co-ordination strategies.

4.2.5 Show how manufacturing operations are integrated with other aspects of the business; how operations are managed across supply networks; and how the Internet affects manufacturing.

4.2.6 Analyse simple operational systems to enable discrete event models and spreadsheet models to be defined.

4.2.7 Explain how complex processing plants and manufacturing systems are maintained and managed and the challenges associated with this.

4.2.8 Explain the importance of managing process design for manufacture and the application of methods.

4.2.9 Analyse problems rigorously to develop and appraise options, and select an option appropriately taking into consideration relevant factors such as risk, opportunities, resources, cost, environmental issues, and fitness for purpose.

4.3 Supply chain management

4.3.1 Understand that the make-versus-buy decision is based upon three key criteria; business strategy, product supply chain risks, and economic factors.

4.3.2 Understand the organisation’s position in the supply-chain.

4.3.3 Explain the challenges of improving the performance of supply networks, including their re-design.

4.3.4 Explain the commercial aspects of supply chain management (including ITT, RFP, contract negotiation and dispute management).

4.3.5 Explain the roles of supplier selection, procurement and supplier management.

4.4 Organisational behaviour

4.4.1 Understand models of organisational behaviour, processes and change.

4.4.2 Apply organisational models to “real world” examples and situations.

4.4.3 Understand how changing organisational behaviours can deliver improvements in business results.

4.5 Business strategy and management

4.5.1 Apply strategic business practices (including goal and objective setting, risk identification and response strategies).

4.5.2 Understand organisational theory, change management, marketing, human resource management and service management to engineering technology solutions development.

4.5.3 Understand the importance of business processes and demonstrate the ability to document and analyse them.

4.5.4 Understand the principles of business transformation by being able to decompose and abstract a non-obvious business problem, collect relevant information, perform root cause analysis, consider options and make recommendations.

4.5.5 Understand and apply the principles of quality management.

4.5.6 Understand the application of systems thinking, flow charting, type and frequency data analysis, modelling future flows.

4.5.7 Demonstrate the importance of integrating management and business practices with the engineering firm's strategic objectives, including vision and strategy formulation.

4.5.8 Understand the nature of governance, and assurance, for organisational effectiveness.

4.5.9 Understand the significance of human factors including leadership in the effective implementation and management of business operating systems and business processes.

4.6 Business finance and accounting

4.6.1 Demonstrate a range of financial techniques and skills including (but not limited to):

- managing a budget
- cash flows
- profit and loss accounts)

4.6.2 Provide an example of the value of technology investments and apply benefits management.

4.6.3 Formulate a well-reasoned investment proposal.

4.6.4 Explain the difference between Capital Expenditures (CAPEX) and Operating Expenses (OPEX) and provide examples of each.

4.7 Industrial Engineering

4.7.1 Understand the roles of time standards in manufacturing.

4.7.2 Appraise the ways in which time standards can be determined, showing the advantages and disadvantages of each method.

4.7.3 Explain the factors that affect the layout of a production facility.

4.7.4 Select the appropriate method of materials for a range of engineering tasks.

4.7.5 Explain the concept of quality and list the different attributes of quality.

4.7.6 Explain the role of inspection; design and apply sampling plans for inspections.

4.7.7 Apply an understanding of process improvement techniques (e.g. Six Sigma, lean).

4.8 Global manufacturing strategy

4.8.1 Explain the principles and practice of industrial economics and the role of manufacturing in the global economy.

4.8.2 Explain the different strategies that firms may adopt for growth, how changing global conditions influence their management and the implications for industrial policy.

4.8.3 Explain the importance of the global economy and the evolving structure of industries and firms.

4.8.4 Evaluate the key aspects of management decision-making that shape the development of global business and the way in which it is governed.

4.8.5 Describe key characteristics of modern manufacturing industries, and what factors are driving changes within them.

4.8.6 Analyse the ways in which companies and governments can respond to industrial transformation.

4.8.7 Explain some of the different ways in which incumbent and new firms can capture value from changes in the industry structures.

4.8.8 Describe the basics of how industrial and innovation policies are developed and implemented.

4.8.9 Recognise the complexity and trade-offs that are a feature of policy implementation.

4.8.10 Explain in what ways analytical tools (including PESTLE and SWOT) can be used for strategic business planning and to aid understanding of external influences on a business.

4.8.11 Explain how macroeconomics, including the effects of currency fluctuations/hedging may impact engineering business.

Table 5: Skills and knowledge coverage in engineering project and delivery management

5. Engineering project and delivery management
5.1 Project management approaches and methodologies
5.2 Project planning
5.3 Project execution
5.4 Project risk assessment and management

5.1 Project management approaches and methodologies

5.1.1 Understand engineering project development lifecycles and processes, including Lifecycle Management, Cradle to Grave analysis and Stage and Gate interval controls.

5.1.2 Specify project scope and identify project objectives and critical success factors.

5.1.3 Follow a systematic methodology for initiating, planning, executing, controlling, and closing process engineering projects by applying quality and industry standard processes, methods, techniques and tools to execute projects.

5.1.4 Be aware of structured programme and project management environments (e.g. including the principles of agile in a project situation (even in a non-agile environment).

5.1.5 Understand and fulfil customer requirements using development and management processes: elicitation, specification, analysis and applying tools for managing requirements.

5.2 Project planning

5.2.1 Identify and agree project scope, timescale and deliverables and construct a project specification.

5.2.2 Construct a project plan, including milestones, for a multi-threaded project applying assumptions, dependencies and constraints, and including resource balancing and scheduling.

5.2.3 Produce a work breakdown structure (WBS), identifying activities and calculating overall estimates of costs/effort incorporating the allocation and management of appropriate phased contingency.

5.2.4 Develop a logic diagram and perform network and critical path analysis.

5.3 Project execution

5.3.1 Manage an engineering project (typically less than six months, no inter-dependency with other projects and no strategic impact) including identifying and resolving deviations and the management of problems and escalation processes.

5.3.2 Apply project controls, including S-curves (to allow the progress of a project to be tracked visually over time), identifying and managing deviations from the planned schedule of a project.

5.3.3 Conduct regular project reviews and effectively manage the project review process (including planning and management).

5.3.4 Resolve any issues of quality, cost and time concerned with project implementation (including contractual obligations and resource constraints).

5.3.5 Set up the project team, including defining the roles and responsibilities of a typical project management team and how they interact.

5.4 Project risk assessment and management

5.4.1 Define, analyse and prioritise project risks and issues, identifying risk severity, ranking risks and dealing with residual risk.

5.4.2 Record and communicate risks through risk reports, registers or logs.

5.4.3 Plan and implement contingency plans and risk responses.

5.4.4 Track risks and associated tasks, linking risks and dependencies to project activities.

5.4.5 Apply issues management techniques.

Appendix C: Framework development summary

A GA framework sets out the required knowledge, skills and learning outcomes identified through employer and key partner consultation to support the delivery of a Graduate Apprenticeship programme. This is achieved through employer and key partner input to Technical Expert Groups (TEGs).

TEGs are short life working groups designed to act as an advisory group on behalf of the sector and contribute to the development and course design of a GA. TEGs are integral to the process of developing GAs that provide quality, consistency and relevance to industry.

Each TEG is made up of employers, professional or industry bodies, learning providers, and subject/technical experts from the related industry.

The following organisations were consulted in the development of this framework:

Engineering: Design and Manufacture (including Chemical & Process pathway) at SCQF level 10.

Employers	Learning Providers	Professional Bodies
Engineering: Chemical & Process TEG		
Petroineos	Heriot-Watt University	IChemE (Heriot-Watt
CalaChem	University of Strathclyde	
Fujifilm		
Booth Welsh		
IBioIC		
Wood Group		
Syngenta		
Scotmas		
Engineering: Design and Manufacture TEG		
Babcock Marine	Glasgow Caledonian	Semta
BAE Systems	University of Strathclyde	
Booth Welsh	Forth Valley College (on	
FMC Technologies	University of Dundee	
GlaxoSmithKline		
Leonardo		
MacTaggart Scott		
Michelin Tyre Plc.		
QinetiQ		
Raytheon UK		
Thales Optronics		
Tokheim Ltd.		

Skills Development Scotland

This framework is also available on the Skills Development Scotland corporate website:
www.skillsdevelopmentscotland.co.uk