



## Higher National Unit Specification

### General information

**Unit title:** Machine Learning (SCQF level 9)

**Unit code:** J4YD 36

**Superclass:** CA

**Publication date:** September 2020

**Source:** Scottish Qualifications Authority

**Version:** 01

### Unit purpose

This unit is designed for learners who want to understand and apply the concepts, principles and technologies around machine learning. It is a **specialist** unit, suitable for learners with an interest in artificial intelligence (AI), computer science, data science or statistics.

Learners should be familiar with basic concepts in maths, and experience of using a programming language such as Python or R. Previous experience of working with large datasets is assumed. It is recommended that learners have previously undertaken J0J9 34 *Machine Learning* (SCQF level 7) or J1BB 35 *Machine Learning* (SCQF level 8) before attempting this unit.

The unit covers: the basics of machine learning concepts; machine learning models; application of machine learning in various real-life situations and potential scenarios; most effective machine learning techniques and experience in applying them; best practices in machine learning and the innovation process in machine learning and AI; and ethics and regulations around machine learning and AI solutions. They will have the opportunity to explore contemporary developments in machine learning, such as deep learning, and the implications of the technology for business, science and society.

At the completion of this unit, learners will understand the rationale for machine learning as a powerful method for data analysis and appreciate the applications of the technology in a variety of vocational fields.

## Higher National Unit Specification: General information (cont)

**Unit title:** Machine Learning (SCQF level 9)

### Outcomes

On successful completion of the unit the learner will be able to:

- 1 Explain concepts in machine learning.
- 2 Describe machine learning methods and algorithms.
- 3 Explain deep learning concepts and its applications for individuals and society.
- 4 Explain machine learning model best practices, maintenance and governance.

### Credit points and level

2 Higher National Unit credit(s) at Scottish Credit and Qualifications Framework (SCQF) level 9: (16 SCQF credit points at SCQF level 9)

### Recommended entry to the unit

While entry is at the discretion of the centre, it would be beneficial if learners are familiar with basic concepts in maths, and experience of using a programming language such as Python or R, which may be evidenced by completion of J27C 76 *Software Design and Development* or H173 34 *Developing Software: Introduction*. Alternatively, completion of the HN Unit in HT9T 34 *Artificial Intelligence*, J0J9 34 *Machine Learning* and/or J1BB 35 *Machine Learning*, and H8W8 34 *Big Data*, may provide sufficient underpinning knowledge and understanding.

### Core Skills

Opportunities to develop aspects of Core Skills are highlighted in the support notes for this unit specification.

There is no automatic certification of Core Skills or Core Skill components in this unit.

### Context for delivery

If this unit is delivered as part of a group award, it is recommended that it should be taught and assessed within the subject area of the group award to which it contributes.

Learners are presumed to possess previous knowledge and skills in applying statistical concepts to large datasets and be familiar with at least one high-level programming language such as Python or R. Previous knowledge of machine learning is also desirable.

### Equality and inclusion

This unit specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence.

Further advice can be found on our website [www.sqa.org.uk/assessmentarrangements](http://www.sqa.org.uk/assessmentarrangements).

# Higher National Unit Specification: Statement of standards

## Unit title: Machine Learning (SCQF level 9)

Acceptable performance in this unit will be the satisfactory achievement of the standards set out in this part of the unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Where evidence for outcomes is assessed on a sample basis, the whole of the content listed in the knowledge and/or skills section must be taught and available for assessment. Learners should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

### Outcome 1

Explain concepts in machine learning.

#### Knowledge and/or skills

- ◆ Historical development of machine learning, and its relationship to other fields within computer science
- ◆ Difference between traditional programming and machine learning
- ◆ Computational learning theory and statistical learning theory
- ◆ Machine learning process
- ◆ Machine learning models including decision trees, regression analysis and Bayesian networks
- ◆ Data in machine learning models

### Outcome 2

Describe machine learning methods and algorithms.

#### Knowledge and/or skills

- ◆ Machine learning methods (supervised learning, unsupervised learning and reinforcement learning)
- ◆ Machine learning algorithms (classification algorithms, regression algorithms and clustering algorithms)

### Outcome 3

Explain deep learning concepts and its applications for individuals and society.

#### Knowledge and/or skills

- ◆ Historical development of deep learning and reasons for its growth
- ◆ Artificial neural networks
- ◆ Representation learning
- ◆ Universal approximation theorem and probabilistic inference
- ◆ Deep learning models
- ◆ Applications of deep learning for individuals and society

## Higher National Unit Specification: Statement of standards (cont)

**Unit title:** Machine Learning (SCQF level 9)

### Outcome 4

Explain machine learning model best practices, maintenance and governance.

#### Knowledge and/or skills

- ◆ Technologies used for implementing machine learning models
- ◆ Best practices in machine learning including bias and variance
- ◆ Model maintenance
- ◆ Model governance
- ◆ Ethical implications of machine learning and deep learning

#### Evidence requirements for this unit

Learners will need to provide evidence to demonstrate their knowledge and/or skills across all outcomes. The evidence requirements for this unit will take **one** form.

##### 1 Knowledge evidence

**Knowledge evidence** is required for all outcomes. Evidence is required for all knowledge and/or skills statements within these outcomes. The amount of evidence may be the minimum required to infer competence. The evidence may be produced over an extended period of time in lightly controlled conditions.

Knowledge evidence may be sampled when testing is used. In this case, the evidence must be produced under controlled conditions in terms of location, timing and access to reference materials. The sampling frame must cover all outcomes (1-4) but not all knowledge/skills statements, which may be lightly sampled in some instances. The sampling frame should include the following:

- ◆ machine learning process
- ◆ machine learning methods and algorithms
- ◆ ethical implications of machine learning.

The SCQF level of this unit (level 9) provides additional context on the nature of the required evidence and the associated standards. Appropriate level descriptors should be used when making judgements about the evidence.

When evidence is produced in loosely controlled conditions it must be authenticated. The *Guide to assessment* provides further advice on methods of authentication.

The support notes section of this specification provides specific examples of instruments of assessment that will generate the required evidence, including online/remote assessments.



## Higher National Unit Support Notes

**Unit title:** Machine Learning (SCQF level 9)

Unit support notes are offered as guidance and are not mandatory.

While the exact time allocated to this unit is at the discretion of the centre, the notional design length is 80 hours.

### Guidance on the content and context for this unit

The first part of this guidance relates to all outcomes. Subsequent parts relate to specific outcomes.

This unit is intended to give learners understanding of machine learning core concepts. The main algorithms and models (supervised, unsupervised and reinforcement learning). Algorithms such as classification, regression and clustering. Learners will gain knowledge on how to apply these concepts for the design and development of machine learning models. Learners will also be able to increase their knowledge in developing models and algorithms in their chosen technology (programming environment and various machine learning programming packages).

Learners will have the opportunity to understand concepts around deep learning, such as Computer Vision, Natural Language Processing (NLP) and others. They will explore the various applications of deep learning for individuals and society.

Additionally, learners will be given guidance on best practices in machine learning, model maintenance and its types, and model governance and its features required for an optimum machine learning model, this includes understanding of current regulations and policies, legal and ethical implications of machine learning and deep learning.

Please note that the following guidance, relating to specific outcomes, does not seek to explain each knowledge/skills statement, which is left to the professionalism of the teacher. It seeks to clarify the statement of standards where it is potentially ambiguous. It also focuses on non-apparent teaching and learning issues that may be over-looked, or not emphasised, during unit delivery. As such, it is not representative of the relative importance of each knowledge/skill.

At the time of writing, this unit does not lead to recognition by a professional body. It provides some underpinning knowledge for H8W9 35 *Data Science*.

It is to be noted that these outcomes are not intended to be delivered as separate elements of the unit (see *Guidance on approaches to delivery*).

## Higher National Unit Support Notes (cont)

**Unit title:** Machine Learning (SCQF level 9)

**Outcome 1:** This outcome intends to provide learners with core concepts of machine learning (ML). Learners should explore the historical development of machine learning and its relationship to other fields within computer science. In this outcome, learners will gain an understanding on differences between traditional programming techniques (eg Python, R, MATLAB, ML libraries) and machine learning. It covers an understanding of data in machine learning modelling (including identification of variables, feature selection, and labelling, data cleaning and transformation). Common technologies used in implementing ML models, and key elements to consider in modelling:

- ◆ Knowledge representation and formats (eg decision trees, graphical models, support vector machines, neural networks)
- ◆ Model evaluation techniques (eg squared error, accuracy rate, cost, margin)
- ◆ Model optimisation techniques (eg mini-batch gradient, stochastic gradient descent)

**Outcome 2:** The focus of this outcome is to provide a broad overview of the main methods and algorithms that will be used in developing a machine learning solution for a dataset, including:

- ◆ Machine learning methods:
  - supervised learning
  - unsupervised learning
  - reinforcement learning
- ◆ Machine learning algorithms:
  - classification algorithms
  - regression algorithms
  - clustering algorithms

Practical activities should be organised as part of this outcome, using technologies such as, Python, MATLAB, R and others.

**Outcome 3:** The focus in this outcome is to provide an understanding of deep learning concepts and its models, including:

- ◆ Artificial neural networks
- ◆ Representation learning
- ◆ Universal approximation theorem and probabilistic inference

Learners should explore the historical development of deep learning and the different reasons for its growth. They will learn about how to use deep learning in various machine learning solutions, such as:

- ◆ Computer vision
- ◆ Speech and audio recognition
- ◆ Natural language processing (NLP)
- ◆ Medical computing (bioinformatics, drug design, and medical image analysis)
- ◆ and others (eg finance systems, services recommendations, social network filtering, machine translation, material inspection and board game programs)

and their relationship to the methods and algorithms covered in outcome 2.

## Higher National Unit Support Notes (cont)

### Unit title: Machine Learning (SCQF level 9)

This outcome will include a number of practical activities, using technologies such as Python (with Scikit-learn, OpenCV, Octave), MATLAB (with ML Toolbox) and R (with caret, tree, e1071), and an understanding of popular ML cloud-workbenches, such as Google Machine Learning workbench (TensorFlow), Microsoft Azure ML Studio, Amazon ML SageMaker, IBM Watson Studio, or others.

**Outcome 4:** This outcome builds on the knowledge of machine learning model best practices (bias/variance) around the design and implementation of machine learning models and model maintenance, which includes:

- ◆ Corrective maintenance (fixing detected data and/or algorithm issues)
- ◆ Adaptive maintenance (enabling model to run in various environments)
- ◆ Perfective maintenance (updating model and adding new features/concepts)
- ◆ Preventive maintenance (implementing changes to prevent model errors)

and model governance practices, such as:

- ◆ Data usage and governance
- ◆ Model validation and verification
- ◆ Model risks and security
- ◆ Model testing (operational and performance)
- ◆ Preventive controls (including human intervention)
- ◆ Rules, ethics and regulations compliance
- ◆ Model deployment
- ◆ Model performance monitoring
- ◆ Model calibration and adjustment

When learning about the ethical implications of machine learning and deep learning, learners should explore various initiatives, such as AI for Good (A Move Towards Ethical AI); Google and Microsoft AI principles campaigns; UK and European Governments' initiatives towards a Safe and regulated AI industry, privacy and use of data (eg General Data Protection Regulation (GDPR)); and the importance of using the right motivations and design principles in AI/ML solutions.

### Guidance on approaches to delivery of this unit

A suggested distribution of time, across the outcomes, is:

Outcome 1: 15 hours

Outcome 2: 20 hours

Outcome 3: 20 hours

Outcome 4: 25 hours

Summative assessment may be carried out at any time. However, when testing is used (see evidence requirements) it is recommended that this is carried out towards the end of the unit (but with sufficient time for remediation and re-assessment). When continuous assessment is used (such as the use of a web log), this could commence early in the life of the unit and be carried out throughout the duration of the unit.

## Higher National Unit Support Notes (cont)

### Unit title: Machine Learning (SCQF level 9)

There are opportunities to carry out formative assessment at various stages in the unit. For example, formative assessment could be carried out on the completion of each outcome to ensure that learners have grasped the knowledge contained within it. This would provide assessors with an opportunity to diagnose misconceptions and intervene to remedy them before progressing to the next outcome.

There is a growing trend of online resources around advanced machine learning topics, these include complete online courses from providers, such as Coursera, Udemy, Udacity, edX and FutureLearn; and extensive learning materials from Machine Learning workbench providers, such as Microsoft, AWS, Google and Apple.

Useful online resources can be found at:

<https://www.datascience.com>

<https://elitedatascience.com>

<https://towardsdatascience.com>

<https://machinelearningmastery.com>

Approaches to consider for delivering this unit should include, for example, team working, pair programming, presentations, research findings.

Online resources around governance, maintenance and ethics and legal aspects of AI solutions could be found in website such as:

<https://www.turing.ac.uk/research/research-areas/machine-learning>

<https://www.aiforgood.co.uk/>

<https://ec.europa.eu/digital-single-market/en/artificial-intelligence>

<https://www.gov.uk/government/publications/guide-to-the-general-data-protection-regulation>

### Guidance on approaches to assessment of this unit

Evidence can be generated using different types of assessment. The following are suggestions only. There may be other methods that would be more suitable to learners.

Centres are reminded that prior verification of centre-devised assessments would help to ensure that the national standard is being met. Where learners experience a range of assessment methods, this helps them to develop different skills that should be transferable to work or further and higher education.

One approach to assessment would be the use of testing. The instrument of assessment could be an extended response question paper, done in controlled conditions for a defined period of time. For example, the question paper might comprise six questions covering all outcomes, requiring essay-type responses, over a period of two hours. If each question was worth 10 marks, a pass mark of 30 (out of 60) could be set.

## Higher National Unit Support Notes (cont)

**Unit title:** Machine Learning (SCQF level 9)

A more contemporary approach to assessment would involve the use of a web log (blog) to record learning (and the associated activities) throughout the life of the unit. The blog could provide the knowledge evidence (in the descriptions and explanations) of all of the outcomes and knowledge/skills statements. The blog should be assessed using defined criteria to permit a correct judgement about the quality of the digital evidence. In this approach to assessment, every knowledge and skill must be evidenced; sampling would not be appropriate.

Formative assessment could be used to assess learners' knowledge at various stages throughout the life of the unit. An ideal time to gauge their knowledge would be at the end of each outcome. This assessment could be delivered through an item bank of selected response questions, providing diagnostic feedback to learners (when appropriate).

If a blog is used for summative assessment, it would also facilitate formative assessment since learning (including misconceptions) would be apparent from the blog, and intervention could take place to correct misunderstandings on an on-going basis.

### Opportunities for e-assessment

E-assessment may be appropriate for some assessments in this unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or social software. Centres which wish to use e-assessment must ensure that the national standard is applied to all learner evidence and that conditions of assessment as specified in the evidence requirements are met, regardless of the mode of gathering evidence. The most up-to-date guidance on the use of e-assessment to support SQA's qualifications is available at [www.sqa.org.uk/e-assessment](http://www.sqa.org.uk/e-assessment).

### Opportunities for developing Core and other essential skills

The unit provides opportunities to develop some of the following Core Skills:

- ◆ Information and Communication Technology (ICT) at SCQF level 6
- ◆ Problem Solving at SCQF level 6
- ◆ Numeracy at SCQF level 6

Learners will make use of software to carry out activities for different machine learning scenarios. They will address several components of the Core Skill in *Information and Communication Technology (ICT)* in so doing.

Learners will be required to make decisions about which machine learning methods and models are to be applied to given problems, and to implement the appropriate algorithms to produce a solution. They will address several components of the Core Skill in *Problem Solving* in so doing.

Learners will manipulate, transform and perform calculations on data. They will also encounter a range of statistical concepts. This work will address several components of the Core Skill in *Numeracy*.

## History of changes to unit

Version	Description of change	Date

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## General information for learners

### Unit title: Machine Learning (SCQF level 9)

This section will help you decide whether this is the unit for you by explaining what the unit is about, what you should know or be able to do before you start, what you will need to do during the unit and opportunities for further learning and employment.

The purpose of this unit is to provide you with an understanding on the theory and practice of Machine Learning. It is intended for anyone who has an appreciation of the importance of Machine Learning to their personal and professional life and wishes to understand better the fundamental concepts on which its application is based.

Before undertaking this unit, you should possess previous knowledge and skills in applying statistical concepts to large datasets and be familiar with at least one high-level programming language such as Python or R. Previous knowledge of machine learning would be an advantage.

The unit comprises four outcomes and develops your knowledge and understanding of the concepts and technologies around Machine Learning along with some practical competence in using software tools that perform these technologies.

Some of the topics included in this unit are:

- ◆ Historical development of machine learning, and its relationship to other fields within computer science
- ◆ Difference between traditional programming and machine learning
- ◆ Machine learning process
- ◆ Machine learning models including decision trees, regression analysis and Bayesian networks
- ◆ Data in machine learning models
- ◆ Machine learning methods (supervised learning, unsupervised learning and reinforcement learning)
- ◆ Machine learning algorithms (classification algorithms, regression algorithms and clustering algorithms)
- ◆ Deep learning models
- ◆ Best practices in machine learning including bias and variance
- ◆ Ethical implications of machine learning and deep learning

Assessment will likely be through a range of assessment methods, most of which will be theory based, although you will have opportunities throughout the unit to develop practical competencies.

This unit will provide opportunities for you to develop aspects of the Core Skills in *Information and Communication Technology (ICT)*, *Numeracy* and *Problem Solving*.

At the completion of this unit, you will understand the rationale for machine learning as a powerful method for data analysis and appreciate the applications of the technology in a variety of vocational fields.