Unit 11: Using Mathematical Tools in Science

Unit code: M/502/5009

QCF Level 2: BTEC First

Credit value: 5

Guided learning hours: 30

Aim and purpose

This unit enables learners to use mathematical tools which are essential for working in a science environment. Starting with basic numbers and simple algebraic manipulation, learners then move onto collecting and interpreting data on graphs and charts.

Unit introduction

Anyone who works in a science-related area needs to be confident in handling numbers in their day-to-day work. Their calculations may be used to design equipment or to predict how a new chemical is going to work. During experiments, data needs to be accurately collected and results displayed. Valid interpretation of the data is vital in order to make sense of what is going on in science experiments. Without the use of maths, science work would be paralysed.

This unit addresses the need for science workers to learn basic mathematical tools that are essential in all branches of science, including environmental science. The intention is not maths *for* maths but maths *for* science and so there is an emphasis on integrating the maths in to practical scientific work. By studying this unit learners will have the opportunity to consider a number of important concepts, including:

- how to use the International System of Units (SI) correctly
- how to leave an answer to the correct decimal place or significant figure
- how to manipulate and use simple algebra correctly
- how to measure and calculate experimental errors in experiments
- how to display and interpret experimental data.

In the first learning outcome, the learner is introduced to the basics of maths; leaving answers to the correct decimal or significant figure is emphasised, including correct handling of scientific calculators. This outcome also focuses on how simple algebra helps solve scientific problems. Learning outcome 2 looks at the types of scientific data (primary and secondary) and how scientific data is collected and the errors that may occur during the collection process. The unit concludes by investigating how data can be displayed and how to correctly interpret graphs and charts. Throughout this unit learners will have plenty of opportunities to use graphical scientific calculators and ICT in the various activities available. This unit is vital for anyone intending to follow a scientific pathway.

Learning outcomes

On completion of this unit a learner should:

1 Be able to use mathematical tools in science

2 Be able to collect and record scientific data

3 Be able to display and interpret scientific data.

Unit content

1 Be able to use mathematical tools in science

Mathematical tools: SI units (length, mass, time, area, volume, density, force); conversions, eg imperial to metric and vice versa; prefixes, eg giga, mega, kilo, deci, centi, milli, micro, nano, pico; accuracy of data (decimal places and significant figures); fractions; percentages; ratios; standard form; use of scientific calculators

Scientific problems involving algebra: transposition of formulae; substitution of equations; simple linear equations, eg involving force and mass $(F = ma)$, speed and distance $(v = s/t)$, mole calculations $(n = m/M_r)$, voltage and current $(V = IR)$, density and volume $(\rho = m/V)$

Mensuration: standard formulae to solve surface areas, eg total surface area of a cylinder $= 2\pi rh + 2\pi r^2$, surface area of a sphere $= 4\pi r^2$; volume of regular solids, eg volume of a cylinder $= \pi r^2 h$, volume of a sphere $= 4/3\pi r^3$, volume of a cone $= 1/3\pi r^2 h$

2 Be able to collect and record scientific data

Data collection: methods, eg computer automation, manual collection (eg handling of instruments); primary data, eg data obtained from own experiment; secondary data, eg data taken from research papers, data taken from website

Errors and accuracy: precision of instrument, eg rule, measuring cylinder, micrometer, balance; systematic and random errors; maximum error of instrument, eg half the precision value; absolute error of measurement; maximum percentage error of measurement, eg maximum error of instrument divided by measurement

Recording data: data tables in a lab book, eg collecting data manually (borders and correct labelling and units of physical quantities); by data loggers, eg when taking data from an experiment over days

3 Be able to display and interpret scientific data

Charts: data represented by statistical diagrams (bar charts, pie charts); histograms (continuous and discrete variants)

Type of graphs: linear graphs, eg distance time graphs, graphs obeying Ohm's law (voltage against current); non-linear graphs, eg rate of reaction against temperature, hydrogen gas given off against time, radioactive decay, bacterial growth

Interpretation of data: random data, patterns in data; calculation of the arithmetic mean, mode and median; continuous data, eg rate of production over time, population count of invertebrates or plants; discrete data, eg fingerprint type, shoe size; raw and derived data, eg measure time and distance travelled by a vehicle and calculate (derive) the speed

Interpretation of graphs: calculating the gradient of a straight line graph; calculating the area under a straight line graph; taking tangents of non-linear graphs in order to determine the gradient at a point; explaining trends in both linear and non-linear graphs

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 carry out mathematical calculations using suitable mathematical tools [IE1, 2; SM3]	**M1** use standard form to solve science problems	**D1** use ratios to solve scientific problems
P2 carry out mathematical calculations using algebra [IE1, 2; CT2; SM3]	**M2** use mensuration to solve scientific problems	**D2** use algebra to solve scientific problems
P3 collect and record scientific data [IE1, 2; SM3]	**M3** describe the process involved in accurately collecting and recording scientific data	**D3** compare methods of data collection
P4 identify errors associated with collecting data in an experiment [IE1; SM3]	**M4** calculate any errors associated with scientific data collected in an experiment	**D4** explain how errors can be minimised in data collected in the experiment
P5 select the appropriate formats to display the scientific data that has been collected [IE1; CT5; SM3]	**M5** interpret the trend in the scientific data collected in an experiment.	**D5** calculate scientific quantities from linear and non-linear graphs.
P6 interpret scientific data.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

This maths unit should be delivered in the context of solving science problems and, where possible, problems related to environmental science. It is expected that learners will carry out a number of experiments as part of this unit. The unit can be delivered in conjunction with other units. There are a number of free internet sites that offer maths help to learners at this level, use of these resources is recommended. The examples indicated in the *Unit content* give the tutor ideas of what could be discussed and are not limited to those mentioned. However, it is expected that at least one of the examples will be covered during lessons.

As this is a maths unit it is not appropriate to use the 'triangle' method to solve equations. The 'triangle' method is commonly used to help learners solve science problems (for example Ohm's law) without actually performing the required algebraic manipulation and this unit requires learners to show the relevant competence.

Learning outcome 1 should be taught first and forms the foundation of the whole unit. The first learning outcome requires learners to understand the basics of numbers, including correct conversions between metric and imperial, which are still used in the science workplace. Standard form and correct use of scientific calculators must be covered here. Astronomical distance and microscopic distance provide useful applications of large and small numbers. Fractions and ratio applications could use biological investigations, efficiency calculations in electrical power and determining formulae from percentage composition.

Learning outcome 1 also looks at algebra, which is the basis of all branches of science. Following sound drilling of the rules, learners should be exposed to using algebra in various branches of science. This can be achieved in many ways, for example by using equations of motion, gas laws, molar calculations and their associated laboratory experiment. With the understanding of the basic rules of algebra, mensuration can then be introduced. There are many applications of mensuration in science to bring this section to life. For example, a worm could be modelled as a tube or a water droplet as a sphere.

Learning outcome 2 relates to collecting scientific data. Learners should understand that there are primary and secondary data which are used in different ways and for different reasons. For secondary data, learners could obtain data from the internet for a number of issues such as investigating the effects of pollution, data on global warming or, energy consumption, for example. Scientific primary data could be collected in the maths lessons or through other units. It is important that learners understand what could limit their data collection and the errors that could be associated with the data collection method. Learners need to be convinced of the need for a logbook and a well-defined table, containing correct units and names of the physical quantities being considered.

Learning outcome 3 looks at how data is displayed. All formats should be investigated. Learners could try plotting data on all formats and then comparing their suitability. Learners should be encouraged to plot either the line of best fit or curve of best fit, depending on the data. In addition to plotting by hand, learners should be encouraged to use spreadsheets with plotting functions and various fit capability. There are plenty of opportunities here to integrate experiments, performed in other units, to this section if required.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Introduction and outline scheme of work Formal teaching: Numbers Learning activity: pictures showing metric and imperial units used in the workplace. Learning activity worksheets on conversions and prefixes Formal teaching: Decimal and significant figures Learning activity: worksheet – science use of decimal points and significant figures Formal teaching: Scientific calculators Learning activity: game on use of calculators in science Formal teaching: Algebra – substitution of equations and transposition of formulae Learning activity: card matching exercise (correct use of transposition formulae) Formal teaching: Algebra 2 – problem solving Learning activity: worksheet on science-related problems Formal teaching: Mensuration Learning activity: worksheet on surface areas Learning activity: worksheet on volumes Learning activity: card matching game (matching picture of surfaces with formulae) Learning activity: problem-solving worksheet – shapes used in science **Assignment 1: Numbers for Science (P1, P2, M1, M2, D1, D2)**
Formal teaching: Data collection methods Learning activity: collecting data from a simple experiment (eg motion of a tennis ball, conductivity of water samples to estimate hardness) Learning activity: group discussion on data collection methods and how data was recorded (tables) Learning activity: collecting secondary data (from internet, eg effects of a particular type of pollution, health effects of smoking) Formal teaching: Errors and accuracy Learning activity: measuring circus: shapes/instrument and corresponding measuring instrument Learning activity: simulation on errors (self-directed study on errors) Learning activity: using ICT to collect data (data loggers) **Assignment 2: Data Collection Methods (P3, P4, M3, M4, D3, D4)**
Formal teaching: Charts Learning activity: learners display their data on bar charts, pie charts and histograms Learning activity: group discussion on displaying data (compare each one) Formal teaching: Type of graphs Learning activity: graph matching exercise (learners to match name of graph to data given to them)

Topic and suggested assignments/activities and/assessment
Formal teaching: Interpretation of data
Learning activity: learners given sets of data (covering random, one with pattern, linear and non-linear). Learners plot appropriate graphs
Learning activity: learners to discuss how appropriate each graph is to the data
Formal teaching: Interpretation of graphs
Learning activity: learners given linear and non-linear graphs and have to calculate slope and area, interpret data
Learning activity: learners to undergo experiments to collect data (eg spring experiment), collect data and plot graph. All learning outcomes discussed
Learning activity: using ICT to plot graphs, compare
Assignment 3: Displaying Data (P5, P6, M5, D5)
Review and evaluation of unit

Assessment

All the pass grade criteria must be met in order for a learner to achieve this unit. To achieve P1, learners need to demonstrate that they can convert imperial to metric units and vice versa. Learners should be able to leave calculations to appropriate significant figures and to use a scientific calculator. In all cases, the calculations should be contextualised, to some extent, to the real world and in particular to science and where possible to environmental science. M1 learners need to solve problems in science using standard form. There should be an example related to biology, chemistry and physics. The D1 criterion can be achieved by learners using ratios in solving science problems; again these problems should include at least one question from biology, physics and chemistry.

For P2, learners are expected to solve simple problems using algebra. Learners should be exposed to a full range of simple equations within lessons. For M2, learners must use mensuration to solve scientific problems. The problems should include both volume and area of shapes and must include at least a chemistry and physics problem. The D2 criterion is obtained by using algebra to solve problems in science. There should be at least one question for biology, chemistry and physics.

The data referred to in P3 and P5 must be both primary and secondary data. For P3, learners need to collect scientific data through an experiment (primary data) and secondary means (secondary data). The data collected could be from any subject in science but it needs to be collected by the learner, although a little assistance can be given for P3 for the experimental collection. There should be a brief statement by the learner stating how the data was collected, as well as a table of results of the data. The table should have borders and contain the quantities with the correct units. For M3, learners needs to describe the process involved in accurately collecting and recording scientific data as carried out in P3. This description should be for both secondary and primary data. To achieve D3, the learner is required to compare different methods of data collection (both primary and secondary); the advantages and disadvantages of the methods should be clearly highlighted. There must be a reference to the collection method used by the learner whilst obtaining P3 and M3.

For P4, learners are required to identify any errors associated with collecting scientific data in an experiment (ideally the experiment used for P3). This could be in the form of a list or a statement. It should include any random and/or systematic errors. The M4 criterion may be obtained by correctly calculating errors, identified in P4. This could be a percentage error of a measurement or absolute errors. D4 can be obtained by describing how the errors identified in P4 can be minimised. It is expected that the errors mentioned in D4 will be linked to errors encountered by the learner during the same experiment mentioned in P4 and M4 and ideally linked to P3. It would be acceptable for a learner to mention how they minimised the errors encountered in P3.

For P5, learners need to select an appropriate format of displaying data. It is expected that learners will be exposed to a full range of formats of displaying data. However, for P3 the learner needs only to select the appropriate formats for a primary and a secondary set of data. For scatter graphs, the plots need to be accurately plotted on graph paper. In all cases, there should be correct labelling of axis and an appropriate title. For M5, learners needs to correctly interpret their data (both primary and secondary). For D5, learners need to calculate a physical quantity and if appropriate with the correct unit. The physical quantity could be, for example, from the slope (number of organisms against time, or acceleration from a velocity time graph) or from the area (the cross-sectional area of a river to calculate water flow or the energy stored in a spring from a force-extension graph).

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, M1, D1 P2, M2, D2	Numbers for Science	You are a trainee environmental scientist using mathematical tools.	Problem solving
P3, M3, D3 P4, M4, D4	Data Collection Methods	You are a trainee analytical chemist collecting data during an experiment.	Problem solving Design problem
P5, P6, M5, D5	Displaying Data	You are a trainee microbiological scientist displaying data from an experiment to grow organisms.	Experiment Description Calculation of errors Comparison

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Applied Science sector suite. This unit has particular links with units in the BTEC Applied Science suite and the BTEC Environmental Sustainability suite:

Level 2	Level 3
Using Mathematical Tools in Science	Mathematical Calculations for Science
	Using Statistics in Science
	Undertake an Investigative Project in the Environmental Sustainability Sector
	Undertake an Extended Investigative Project in the Environmental Sustainability Sector

Essential resources

Using mathematical tools is an essential part of any science technician's work. To deliver this unit the centre will need to provide laboratory space equipped for Level 2 work. Learners will need the facilities to carry out practical work so the technical expertise required at this level can be practised and demonstrated. This will include carrying out practical experiments that allow for the application of the mathematical skills covered in the unit.

Access to scientific calculators, computers, CD ROMs and the internet is also essential. The computers need to have packages for plotting graphs etc. Access to mathematical tutorial packages would be an advantage.

Employer engagement and vocational contexts

Ideally, input from technicians and scientists working in a range of environmental laboratory situations would help to make the unit vocationally relevant. Work placements may help put mathematical skills into a scientific context. Suitably experienced staff will be needed as this unit is to be delivered with the emphasis on mathematics as a scientific tool. The network for science, technology, engineering and maths (STEM) has developed resources for anyone interested in using maths for science.

The following websites are useful:

www.futuremorph.org

www.stemnet.org.uk

Indicative reading for learners

Textbooks

Johnson T and Clough T – *Aim High 2: Aiming for Grade A/A* in Edexcel GCSE Mathematics* (Edexcel, 2007) ISBN 9781846901881

Metcalf P – *GCSE Edexcel Maths (Revision Guide)* (Collins, 2006) ISBN 9780007213610

Parsons R – *GCSE Maths Edexcel Modular Revision Guide: Higher* (Coordination Group Publications, 2006) ISBN 9781841460932

Pledger K (editor) – *Edexcel GCSE Maths: Higher Student Book* (Heinemann Educational Secondary Division, 2006) ISBN 9781841465463

Journals

Isquared magazine

Mathematical Association

Mathematical Gazette

Mathematics in Schools

Websites

BBC GCSE Bitesize	www.bbc.co.uk/schools/gcsebitesize
BBC Skillswise	www.bbc.co.uk/skillswise
GCSE guide	www.gcseguide.co.uk
Gcsevise	www.gcsevise.com
Mathstutor	www.mathstutor.com
University of Birmingham selection of mathematics education sites	www.education.bham.ac.uk/subjects/maths/links

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	identifying mathematical problems that need solving and identifying appropriate formats for displaying scientific data planning and carrying out calculations, appreciating the consequences of decisions
Creative thinkers	asking questions to extend own thinking related to using algebra to solve scientific problems selecting the appropriate formats for displaying scientific data
Self-managers	organising time and resources in order to submit their assignments within deadlines.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Independent enquirers	comparing methods of data collection, making judgements on their relevance
Reflective learners	calculating errors in own experimental work, evaluating own work to inform future progress
Effective participators	explaining how errors can be minimised in the future when collecting data.

Functional skills – Level 2

Skill	When learners are ...
ICT – Using ICT	
Select, interact with and use ICT systems safely and securely for a complex task in non-routine and unfamiliar contexts	using appropriate software to plot graphs using mathematical tutorial software
ICT – Finding and selecting information	
Select information from a variety of sources to meet requirements of a complex task	collecting secondary data
ICT – Developing, presenting and communicating information	
Enter, develop and refine information using appropriate software to meet requirements of a complex task	presenting data and text using ICT systems
Use appropriate software to meet the requirements of a complex data-handling task	collecting, interpreting and displaying data
Combine and present information in ways that are fit for purpose and audience	presenting data and text to suit purpose
Mathematics – Representing	
Understand routine and non-routine problems in familiar and unfamiliar contexts and situations	carrying out mathematical calculations and using standard form to solve science problems
Identify the situation or problems and identify the mathematical methods needed to solve them	solving science problems using methods such as mensuration, algebra or ratios
Choose from a range of mathematics to find solutions	selecting what mensuration to use when solving a science problem
Mathematics – Analysing	
Use appropriate checking procedures and evaluate their effectiveness at each stage	converting between imperial and metric units comparing methods of data collection
Mathematics – Interpreting	
Interpret and communicate solutions to multistage practical problems in familiar and unfamiliar contexts and situations	selecting appropriate formats for displaying data interpreting data
Draw conclusions and provide mathematical justifications	comparing methods of data collection
English – Reading	
Select, read, understand and compare texts and use them to gather information, ideas, arguments and opinions	investigating secondary data
English – Writing	
Write a range of texts, including extended written documents, communicating information, ideas and opinions, effectively and persuasively	describing and comparing the methods of data collection.