Developing a Framework for Post 16 Biology Qualifications

Royal Society of Biology Curriculum Committee
The New Context: Transition from Schools into Higher Education
July 8th 2016

Contents

Figures

Developing a Framework for Post 16 Biology Qualifications

Introduction

Royal Society of Biology

The Royal Society of Biology is a single unified voice for biology: advising Government and influencing policy; advancing education and professional development; supporting our members, and engaging and encouraging public interest in the life sciences. The Society represents a diverse membership of individuals, learned societies and other organisations. Individual members include practising scientists, students at all levels, professionals in academia, industry and education, and non-professionals with an interest in biology.

One of the priorities of the Society is to support Biology education at all levels through the stages of compulsory schooling, into further and higher education and beyond with training and professional development opportunities for the biosciences community. We recognise teachers in schools and universities with teaching awards and the Chartered Science Teacher (CSciTeach) professional register and support teachers membership of this through our professional development programme. We produce and collate resources which help support the teaching of biology and the biosciences in schools, colleges and universities and also develop content for students.

We actively engage with education policy and as part of an aim to be pro-active in our approach we brought together a number of experts to form the RSB Curriculum Committee with the objective of developing a long term view of what the school biology curriculum should look like.

Biology Curriculum Committee

The Biology Curriculum Committee was convened in the summer of 2014. The purpose of the committee is to ensure the biology curriculum at all educational stages and through all qualification routes is as relevant as possible and prepares students for their next steps in life – whether they go on to study biology at university, use biology in a related career or use their biology knowledge as non-scientist citizens of the 21st century.

The Curriculum Committee's terms of reference are to:

- develop the Society's content criteria for biology qualifications
- consider and provide guidance and information on appropriate assessment models for biology qualifications
- advise on the Society's responses to external consultations on curriculum, qualification and assessment matters
- advise on the biology content of related science qualifications

- advise the Society's Education Training and Policy Committee on any matters associated with the biology curriculum

The committee is composed of education experts covering biology at the primary and secondary level, the biosciences in tertiary education, assessment, initial teacher education, education research, industry as well as representatives from physics, chemistry and maths. To support the committee a student group composed of students at school and university has been formed to input student voice, as has a primary working group composed of experts in primary education.

Why make a framework?

Over the last 5 years the UK school education system has undergone a number of changes. The responsibility for compulsory 5-19 education is devolved to each of the home nations own governments; the systems are different between England, Northern Ireland, Scotland and Wales. There have been several rounds of curriculum reform bringing in new content and ways of assessing students understanding of science as well as their development of a range of skills. We cannot yet say what the impact of the most recent set of reforms will be, but a large amount of work went into putting them into place. With this in mind the curriculum committee has drawn on current curriculum documents and current bodies of evidence to enable them to begin to put together some recommendations for what the biology curriculum in schools should look like.

The Royal Society of Biology wants to be in a position that the next time the biology curriculum is reviewed (be that in two, five or ten years time) we will have been able to consult with the bioscience community and drawn on evidence to inform our position. The intension is that the final document will be for policy makers, offering the suggestions of the bioscience community as to what biology content, concepts and skills should be taught for school students aged 5-19.

Document development and consultation process

The draft document that is being developed is the result of input from a variety of sources. It is not final, and it is intended to be flexible and evolve as we gather more evidence and see the impacts that the most recent educational reforms have had.

Wider stakeholder engagement

The committee is informed by the student group and the primary working group as well as receiving input from the Biology Education Research Group (BERG), Heads of University Biosciences (HUBS), Education Training and Policy Committee (ETP) and the Education Policy Advisory Group (EPAG). To enable our membership and beyond to input into our work, we have set up an area on the TalkBiology forum (available for anyone to use) where we have posted questions for feedback. In addition we have also turned the questions into an anonymous survey to encourage responses.

Focus groups

For the development of the first draft document, three smaller focus groups composed of members of the curriculum committee were convened to begin to address the following areas:

- Attitudes and ways of thinking, and transferable skills
- Practical skills and mathematical skills
- Core concepts and content

During each meeting the participants in the focus group completed a variety of activities designed to promote discuss of the above areas and come to a consensus on initial principles that could be brought to our conference on transition from school to university for wider discussion.

Understanding the Process of Science

Biology is a practical subject, and our understanding of the natural world around us is based upon the evidence derived from testing hypothesises. For students to understand biology they must also understand the processes of science and the importance of practical work.

We have put together some suggested overarching principles which apply across all practical work and allow students the opportunity to experience and develop skills and understanding in the following areas:

- Be able to generate their own questions and consider how they could be answered
- Be able to plan and conduct practical work in an ethical manner
- Be able to manage risks, have an awareness of health and safety issues to conduct practical work safely
- Use ICT to support investigative work
- Be able to evaluate sources of information

Alongside having the opportunity to develop a number of practical skills and techniques, we believe it is important that students are able to complete an **extended independent investigatory project** as part of their post-16 study of biology. The project enables students to focus on an area of personal interest, research around the subject, plan and conduct practical work and interpret their results. Extended practical work also provides students with time to make mistakes, learn from them and practice their practical techniques.

Practical apparatus and techniques

In Appendix 5c of the Department of Education[1] document outlining the core subject content for biology A level lists the following as practical skills which students should learn that will be assessed through the practical endorsement:

1. use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)
2. use appropriate instrumentation to record quantitative measurements, such as a colorimeter or potometer
3. use laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions
4. use of light microscope at high power and low power, including use of a graticule
5. produce scientific drawing from observation with annotations
6. use qualitative reagents to identify biological molecules
7. separate biological compounds using thin layer/paper chromatography or electrophoresis
8. safely and ethically use organisms to measure:
    a. -plant or animal responses
    b. -physiological functions
9. use microbiological aseptic techniques, including the use of agar plates and broth
10. safely use instruments for dissection of an animal organ, or plant organ
11. use sampling techniques in fieldwork
12. use ICT such as computer modelling, or data logger to collect data, or use software to process data

This list of skills formed the starting point of our focus group discussion around the specific practical techniques that students should be able to demonstrate competency in, once they have completed their post 16 biology qualification. Table 1 lists the outcomes of the discussion, with additions and amendments to the statements from the Department for Education document. The table is divided into the updated or retained statements on skills, with the rationale behind why they have been included, some example activities and then where mathematical skill development will be supported through the activities.

[1] Department for Education (2014) GCE AS and A level subject content for biology, chemistry, physics and psychology Appendix 5c
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/446829/A_level_science_subject_content.pdf

Table 1 Post 16 practical techniques

	Practical Technique	Rationale	Examples of practical activities to demonstrate the technique(s)	Suggested mathematical and statistical skills developed through practical work
1.	*select and use* appropriate apparatus *and instruments, including:* • *online applications and technology* • *colorimeters or potometers* to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH).	Students becoming familiar with a variety of apparatus and learning how to use it (including calibration where relevant), enabling students to make decisions about which which apparatus is appropriate to use to measure different variables. Additions of online applications and technology as more become available and more widely used in science. The statement combines the first two requirements using appropriate apparatus as well as naming two specific pieces of equipment.	Measuring transpiration with a photometer Effect of temperature on plant cell membranes – using a colorimeter	Ratio Standard form Calculating volumes Calculating rate changes Calculating concentrations Logs Interpretation of data & displaying data
2.	use laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions *and use of pipettes*	Students again being familiar with a range of common apparatus. Addition of use of pipettes as a key piece of apparatus that would be used when conducting serial dilutions	Investigating osmosis.	Calculate molar concentrations.

	Practical Technique	Rationale	Examples of practical activities to demonstrate the technique(s)	Suggested mathematical and statistical skills developed through practical work
3.	use of light microscope at high power and low power, including use of a graticule *and camera*	Agreed with this technique – suggesting the addition of using a camera with the microscope to capture images.	Root tip squashes, anther squashes to observe mitosis and meiosis.	Scale Magnification
4.	produce scientific drawing from **observation** with **annotations** **there are opportunities to use this whilst developing microscopy skills, dissection skills and conducting fieldwork.*	Important to retain this skill as it supports students to engage with making observations. The process of observation and recording what can be observed is the key skill rather than the drawing itself.	Recording observations when using the light microscope, completing dissections and conducting fieldwork.	Scale Magnification
5.	use reagents to identify biological molecules	Agreed that this should be retained	Food tests – quantity of protein in powdered milk	Measuring rates of change Understanding binomial data
6.	separate biological compounds using thin layer/paper chromatography or electrophoresis	Agreed that this was important to retain as a means of exemplifying the principles behind PCR and DNA fingerprinting	Identification of pigments contained in leaves	Measurement of RF values
7.	safely and ethically use organisms to measure: -plant and animal responses -physiological functions	Whilst all practical work should be conducted safely and ethically, using living organisms provides students with opportunities to more fully consider the implications and promote discussion of ethical issues.	Possibility of using free apps to measure oxygen saturation of the blood, heart rate etc	Normal distributions Mathematical contexts may vary depending on the nature of the practical activities.

	Practical Technique	Rationale	Examples of practical activities to demonstrate the technique(s)	Suggested mathematical and statistical skills developed through practical work
8.	use microbiological aseptic techniques, including the use of agar plates and broth	Important to retain, can be used to support understanding of antibiotic resistance / effectiveness of antiseptics etc. Techniques may also support practical work that links to genetics addressing gene modification and gene expression.	LAC operon genes, GM kit – glow in the dark genes Identification with gram positive and gram negative bacteria	Logs (growth curves) Area
9.	safely use instruments for dissection of an animal organ ***and*** plant organ	Students should have the opportunity to dissect both animal and plant organs to aid their understanding of structure and function. It will also demonstrate when using real cells, tissues and organs that they do not always match perfectly with their diagrammatic representation. This skill further promotes students understanding of health and safety and managing risk, gives opportunities to use microscopes, develop observation skills and complete scientific drawings. Exceptions made for students on a case by case basis for any ethical concerns.	Dissection of heart, lungs, kidney Leaves, phloem, xylem etc	Scale

	Practical Technique	Rationale	Examples of practical activities to demonstrate the technique(s)	Suggested mathematical and statistical skills developed through practical work
10.	*use appropriate techniques to **measure distribution and abundance of organisms in the field** to include sampling*	This amends the statement "use sampling techniques in fieldwork", the emphasis on enabling students to measure distributions and abundance of organisms, this will involve developing sampling techniques. We want to ensure that to do this, students must go outside of the classroom, ideally beyond the playground and the school fields.	Using quadrats and completing transects. Another opportunity to improve observation skills and scientific drawing. Using online applications to aid identification processes and identification keys.	
11.	*Use keys and appropriate applications to identify organisms **in the field***	Identification skills have been identified as a major skills gap in the biosciences by the Chartered Institute of Ecology and Environmental Management in their report "*Ecological skills shaping the profession for the 21st century*"[2] and the "*UK Plant Science Current status and future challenges*"[3] report.	Using identification keys to identify organisms in the field. Use online applications to aid in the identification of organisms.	

[2] Chartered Institute of Ecology and Environmental Management (2011) Ecological skills shaping the profession for the 21st century http://www.cieem.net/ecological-skills
[3] UK Plant Sciences Federation, (2014) UK Plant Science: Current status and future challenges. http://www.rsb.org.uk/images/pdf/UK_Plant_Science-Current_status_and_future_challenges.pdf

	Practical Technique	Rationale	Examples of practical activities to demonstrate the technique(s)	Suggested mathematical and statistical skills developed through practical work
12.	*Make* ***observations*** *of organisms behaviour* ***in situ***	Opportunity for students to observe animal and plant behaviour within the natural environment	Observing the behaviour of different populations of birds, caterpillars on leaves, leaf orientation over time.	
13.	*use ICT including:* • *build a spreadsheet* • *create a graph* • *use a data logger* • *use excel to interpret data* • *computer modelling* *computer simulations*	Almost all practical activities should offer opportunities for students to develop ICT skills. Students should be able to use online packages such as excel to build a spreadsheet for data generated during practical work and interpret it (could be through modelling, using statistical tests, generating graphs).	Many practical activities will offer opportunities for students to develop ICT skills.	Range of possible statistical tests Displaying data

Transferable skills

We believe that the study of biology at post 16 should support students in understanding biology content and developing a range of skills during the process. Some of these skills will be specific to the study of biology while others will be transferable skills applicable in a variety of contexts. The skills developed should support students to continue with the study of biology or other subjects as well as support them within society and the world of work.

Communication

High levels of literacy and the ability to communicate well are essential for succeeding in the study of any subject. To be successful within the scientific field scientists must be able to clearly communicate their findings.

Students should be given opportunities to develop their **verbal** and **written** communication skills through:

- Participating in debates and discussions
- Presenting information to an audience (using power points, posters, etc)
- Writing scientific reports, essays, articles, posters, blogs

Numeracy

Ensuring that students are numerate and are able to analyse and interpret data to understand it's meaning, and determine its validity is important for the study of biology and more widely useful within society.

Students should be given opportunities to develop their numerical skills through:

- Collecting empirical data
- Manipulating primary and secondary data
- Selecting and using statistical tests
- Presentation of data in graphs and tables
- Interpretation of data from graphs and tables and texts

Using digital technology

Students are growing up in a digital age and it puts them at a disadvantage if they are not able to competently use technology. Students should be given opportunities to develop their digital literacy, becoming confident in utilising common software packages for searching for information, presenting and analysing data. There should also be opportunities for students to use more specialist programmes to collect data and generate computer models. Where new technologies have been developed which schools are unable to access, virtual simulations of techniques could support the student understanding of scientific process and give them a greater awareness of the current technology used in research.

Independence

Students should be supported to become independent learners, taking responsibility for their own learning. Independent research projects can give students the opportunity to make their own decisions, plan a course of action and reflect upon their results, taking charge of the endeavour from start to finish.

Team working

It is equally important that students have the opportunity to work collaboratively, some will be able to take on leadership roles within teams, they will be able to identify their strengths and weaknesses helping their development.

Logical reasoning and problem solving

Whether answering their own questions or questions that others have posed students should reason through evidence and arguments to find the logically consistent answer.

Creativity

The study of biology offers students opportunities to be inventive and to think “outside the box”. Investigative work can provide a situation for students to be creative in their search for a solution to a problem.

Resilience

Students in a supportive environment can be confident that making mistakes is not a problem, it is something that can be reflected upon and learned from, and that in many cases can be fixed.

Confidence

Supporting students to develop the above skills will hopefully increase their confidence as biologists.

Table 2: Post 16 transferable skills and attributes

X indicates the activity supports development of the transferable skill / attribute, the dot indicates that in certain circumstances the activity may support the development of the transferable skills.

Transferable skills and Attributes	Skills and Attributes Breakdown	Activities to support development of transferable skills / attributes				
		Writing a scientific report	Oral presentation	Problem solving (using questions / tasks)	Practical work / investigation	Experimental design
Communication	Write scientifically	x				x
	communicate about it to non- specialist audiences (lay audience)		x			
	communicate with appropriate target audience	x	x			
	Summarisation skills	x	x	x		
	Presenting data in an efficient clear way (maths)	x	x	x		x
	Oral presentations		x			
	Debating		x			
	Analyse data	x		x		
	Evaluate data	x		x		
	Use of appropriate key terminology	x	x	x	x	x
	Podcasts		x			
	Recording data				x	
	Writing notes – taking notes				x	x
	Listening		x		x	
	Key messages – appropriate to the audience	x	x			
	confidence		x		x	x

Transferable skills and Attributes	Skills and Attributes Breakdown	Activities to support development of transferable skills / attributes				
		Writing a scientific report	Oral presentation	Problem solving (using questions / tasks)	Practical work / investigation	Experimental design
Numeracy	Presenting data	x	x			
	Analyse data	x	*	x		
	Evaluate data	x	*	x		
	Probability	x		*		x
	Statistics	x		*		x
	Scale				x	x
	Measurement				x	x
	Sampling				x	x
	Understanding variation	x				x
	Confidence in data	x		*	x	
	Correlation	x		*		
	Causation	x		*		
	Graphing skills	x		*		
	Interpretation of data	x		x		
	Describing comparative data	x				
	Calculating rates	*				
	Recording data				x	
	Approximation			x		
	Estimating			x		
	(Guestimate)			x		
	Anomalies / outliers	x		x		

Transferable skills and Attributes	Skills and Attributes Breakdown	Activities to support development of transferable skills / attributes				
		Writing a scientific report	**Oral presentation**	**Problem solving (using questions / tasks)**	**Practical work / investigation**	**Experimental design**
ICT	Spreadsheets (excel)					x
	Statistical testing	x				x
	Blogs / podcasts / social media		x			
	Using apps				x	
	Data logging				x	
	Microsoft Office	x	x			x
	Reliability of sources	x				
	Quotation / referencing software	x				
	How to search for information	x		x		
Critical thinking	Evaluating / comparing / validity / reliability of sources	x		x		
	Synthesis	x	*	x		
	Questioning – being able to question	x		x	x	x
	Balancing opposite views	x	x	x		
	Spotting bias	x		x		
	Understanding limitations of a scientific study / publication (beyond A level?)	x		x		x
	Reverse engineering – working backwards how / why things are the way they are?			x		x
	deductions			x		x
	inferences			x		x
	logical thinking		*	x	x	x

Transferable skills and Attributes	Skills and Attributes Breakdown	Activities to support development of transferable skills / attributes				
		Writing a scientific report	**Oral presentation**	**Problem solving (using questions / tasks)**	**Practical work / investigation**	**Experimental design**
Research	Reliability of sources	x				x
	How to search for information	x		x		x
	Understanding peer review	x				
	Reverse engineering an answer			x		x
	Ethical consideration	x				x
	Peer review process	x				
Team working	Delegation		x		x	x
	Leadership		x		x	x
	Timekeeping / management (deadlines)		x		x	x
	Organisation		x		x	
	Setting objectives	*			x	x
	Planning	*	x		x	x
	Collective responsibility	*	x		x	
	Collaboration		x		x	
	Accountability				x	
	Listening		x		x	
	Cooperation		x		x	
	Empathy		x		x	
	Recognising diversity of skill sets		x	*	x	

Transferable skills and Attributes	Skills and Attributes Breakdown	Activities to support development of transferable skills / attributes				
		Writing a scientific report	**Oral presentation**	**Problem solving (using questions / tasks)**	**Practical work / investigation**	**Experimental design**
Independence	Time keeping	x	x		x	x
	Goal setting	x	x	x		x
	Resilience		x	x	x	x
	Reflective		x	x	x	x
	Taking responsibility		x		x	x
	Confidence		x	x	x	x
	Using criticism constructively		x	x		
	Meeting deadlines	x	x			x
	Prioritising workload		x		x	x
	organisation	x	x		x	x
	Engaging with formative assessment / learning		x	x	x	
Creativity	“Think outside the box”			x		x
	Innovative solutions			x		x
	Problem solving			x		x
	Applying knowledge to unfamiliar contexts			x	x	x
	Communicating science / presenting – key messages	*	x			
	Reverse engineering an answer			x		x
	Interdisciplinarity			*		

Session 3 Workshop

In this session there will be time to discuss in small groups aspects of the above document.

The session will be split into three sections:

	Timing	Content
Part 1	10 minutes	Discussion on post 16 practical skills
Part 2	10 minutes	Discussion on post 16 transferable skills
Part 3	20 minutes	Feedback key points from the groups

Questions for discussion

Please use the following questions to frame your discussions. Please ensure there is a scribe for the group and that there is a person delegated to give the feedback.

Practical skills

1) Have we identified the key practical skills should be developed by the end of a post 16 biology qualification?
   - Is there anything additional to be included?
   - Is there anything that should be removed?
   - How can we support the teaching of practical skills?
   - How can we raise the value of practical skills with students?

Transferable skills

2) Have we identified the main transferable skills that should be developed by the end of a post 16 biology qualification?
   - Is there anything additional to be included?
   - Is there anything that should be removed?
   - How can we support the teaching of transferable skills?
   - How can we raise the value of transferable skills with students?