Biology-specific vocabulary: Students' understanding and lecturers' expectations of student understanding

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Abstract

The current A-level biology curriculum includes a broad coverage of all the biosciences which demands knowledge of a wide range of biological vocabulary. Students (n=184) from two UK universities were presented with a list of vocabulary, associated with a 'Revise Biology' text which highlighted key terms that students should know. Lecturers (n=26) were asked which of these terms they expected students to know, or be aware of. Findings revealed that students' claimed knowledge of vocabulary exceeded lecturer expectations. In addition, there were a number of terms which students did not understand and lecturers did not expect them to know, which could be removed from A-level biology courses. This is discussed in relation to whether A-level curricula need to be so content heavy and whether lecturers would benefit from knowing more about their students' knowledge of discipline-specific terms.

Introduction

Within the sciences, learning new vocabulary is a particular challenge. One reason for this is the large volume of science-specific terminology (Song & Carheden 2014). Yager (1983) found that students studying science subjects were expected to learn more vocabulary than students studying a new foreign language and he argues that one of the problems in teaching science is the huge amount of new vocabulary students are expected to master. Students can find the volume of new vocabulary overwhelming (Marintcheva 2012) and the complexity of scientific terminology can be challenging for many (Krajcik 2010).

Many scientific terms represent abstractions and concepts; they provide a means of effectively communicating concepts through a specialised vocabulary that is seldom encountered elsewhere (Brown and Ryoo 2008). If students are presented with new concepts through a body of new vocabulary it seems likely that they will struggle. In contrast to learning a new language, where new vocabulary typically expresses commonplace ideas, in science the new vocabulary can introduce new concepts and ideas. Brown and Ryoo (2008) found that when students were presented with the concept first, followed by the specific vocabulary, they formed a better understanding of the topic. Johnstone (1991) suggests that an unfamiliar term can take up a lot of working memory and if the context itself is complex there is little chance the student will successfully engage with the unfamiliar vocabulary.

Marintcheva (2012) suggests that students with a good subject-specific vocabulary tend to master scientific concepts quicker than those with a limited vocabulary. Students reported much longer reading times for information where they were unfamiliar with the vocabulary. In developing scientific literacy, though, students need to link new knowledge to prior knowledge (Krajcik 2010). Marintcheva (2012) designed a Wikipedia-based exercise for students to encourage the development of their biology vocabulary and found that in being aware of, and understanding, the vocabulary students' learning efficiency increased.

In the classroom, the biology teacher's role is to organize student learning to understand and retain new concepts and to use the knowledge appropriately in a wide range of contexts (Curzon 2004). Science text books are often the key resource for teachers and the terms highlighted in the books are those which teachers expect their pupils to learn (Yager 1983). Barrass (1979) examined vocabulary in texts for biology O-level courses (assessments for 16-years olds before the introduction of GSCEs in 1986) and discusses the role of textbook writers. These writers interpret the core curriculum and Barrass (1979) found that teachers taught from these texts rather than the curriculum itself; students also use these texts for revision. Therefore the vocabulary students engage with may be governed more by the writers of the texts and their interpretation on the curriculum rather than the curriculum itself.

Scientific vocabulary is not straightforward. A common issue is that there are terms which mean one thing in a general context and another to scientists. For example the term 'secrete', whose general usage is in relation to placing something where it can't be found, to biologists it means the production or release of a liquid. Johnstone (1991) highlighted the potential for confusion in students between the common usage and scientific meaning of certain terms. When learning new vocabulary in particular, Song & Carheden (2014) found that students struggled with this issue. Another problem for students is that there are many synonyms used interchangeably in biology text books. Evans (1975, 1976) reviewed the confusing number of synonyms in the O-level syllabus, for example the terms leucocyte, white blood cell and white blood corpuscle were used interchangeably (Evans 1976). Evans (1975) notes that the purpose of scientific language is to prevent ambiguity. There should be no synonyms in scientific teaching, and yet he found scientific text books regularly contained them. In teaching biology terms can be used loosely, for example the term 'cell surface' might be used to describe the plasma membrane of a cell wall. Evans suggests that the role of the teacher is to introduce general ideas and interpret detail, not to impart specific words, so that pupils absorb concepts, rather than simply the technical terms.

In a study of first year bioscience students at a Scottish University a mismatch was found between subjects the students perceived as difficult and those that the lecturers perceived as difficult (Bahar et al 1999); in particular, students found genetics difficult. Jones et al (2014) also found genetics to be a particularly challenging subject for students to remember information. Bahar et al (1999) suggested this was because of the large and unfamiliar vocabulary associated with it. Students were uncertain about the precise meaning of many of the terms and were quoted as saying they had to memorize a lot of new terms. They reported understanding at the time but subsequently being confused by topics such as meiosis and mitosis, especially when taught together. At school students can hide ignorance of a subject simply by memorizing the key terms (Johnstone 1991).

Jones et al (2014) studied bioscience students' retention of information between their final school exams and arriving at university. Even students receiving the highest grades had forgotten more than half of the material learnt for their end of school exams. As an extension of this research, the present study explores students' perceptions of their knowledge of vocabulary as they entered university and relates this to the expectations of bioscience lecturers. Findings are discussed in terms of the amount of biological vocabulary students should be expected to know in end-of-school assessments and how higher education should respond to information about students' knowledge of vocabulary. In this paper the term 'student' refers to learners both before and at university. The term 'school' refers to education up to 18 years old, prior to university.

Materials and Methods

A list of biology vocabulary was compiled using the widely available text Letts Revise Biology (2008). The text detailed which exam boards examined each subject and all words in bold typeface in the text were included with the exception of those not taught by all the Boards. The terms selected included single words and multi-word terms up to three words long.

The final-list of 476 terms was presented to bioscience students from two UK universities (For the full list of terms see Appendix Table 1 (available online only)). These universities asked for AAB/ABB grades (320-340 UCAS tariff points) for entry onto their bioscience courses. Students (n=184) completed the task during their first week at university; they were asked to indicate against each word whether they knew, or were aware of, the term, whether they could explain the term or whether they did not recognize it. Students were also asked which exam board had delivered their A-level biology curriculum (A-levels are the standard post-16 assessments in the UK (excluding Scotland) for entry to universities).

The same list of vocabulary was presented to biosciences lecturers at three UK bioscience workshops during 2015. Lecturers (n=30) were therefore from a range of UK universities. They were not asked to state which university they worked at. They were asked to indicate for each term whether they expected new students to know the term, to not know the term, or whether the term was not in their field, meaning they could not make a judgement. Lecturers were advised that the term 'know' should be interpreted as being aware of rather than having full understanding, since full understanding of a term can involve many complex levels.

Terms were each allocated to one of ten sub-disciplines within biology and categorized as to whether they represented a biological concept or a physical object. The results were analysed to compare student knowledge of terms within and between examination boards, to compare examination boards with respect to individual disciplines and of student knowledge against lecturer expectations of that knowledge. The study was passed by the UEA ethics committee in September 2015.

Several comparisons were undertaken. For each term from the list of vocabulary, the percentage of students stating that they knew and understood the term was plotted against the percentage of staff who expected students to know the term. This produced a scatter plot (Figure 1) in which each symbol (data point) represents a term and which relates student knowledge to lecturer expectation. This figure (Figure 1) was then divided into sections at arbitrary key points where fewer than 20% or more than 80% of students understood a term, and fewer than 20% or more than 80% of lecturers expected students to know the term. The resulting grid separated terms into nine sections, labelled A to I. Terms that >80% of staff did not expect incoming students to know were split into those that most students did not understand, terms that between 20 and 80% of students understood, and terms that more than 80 % of students understood.

Terms were sub divided in a variety of ways. Firstly, to examine variation between exam boards, terms were grouped according to the exam board the students had studied under. Because these are percentage data, for significance testing, an arcsin transformation was applied to normalize the data distribution and a one-way anova test performed. Secondly, terms were placed into ten sub-disciplines of the biological sciences (judgement was made where terms might be in more than one category): Anatomy n=104, Biochemistry n=83, Botany N=41, Cell biology n=78, Ecology n=52, General biology n=25, Genetics n=42, Laboratory work n=22, Reproductive biology n=10 and Zoology n=18. Finally, each of the 476 terms was designated either 'concept' or 'object' and we compared the percentage of students who reported understanding each term.

Results

There was much variation in the percentage of terms students said they understood and in the terms staff expected students to know. An arbitrary split was created at the point where 80% of students did or did not understand a term, and the same with staff. It was decided that this figure represented a point which was considered a majority. So in Figure 1, terms the majority of students did not understand are represented by Sections A, B and C. Of those terms Section A (Appendix Table 1 (available online only)) are those that staff did not expect them to know, Section B only comprised three terms: photoperiodism, sequential effect and tetraploid, and Section C had no terms in it. Terms that 80% of staff expected students to know are represented by Sections D and I (there were no terms in Section C) and these are shown in Appendix Table 2 (available online only). Terms the majority of students did understand are grouped into Sections G, where more than 80% of the staff did not expect them to know the terms (Appendix Table 1) Section H, where between 20 and 80% of staff expected them to know the terms (Appendix Table 3 (available online only)) and Section I where more than 80% of staff expected them to know the terms (Appendix Table 2). Section E represents terms that between 20 and 80% of students understood and between 20 and 80% of staff expected students to understand (Appendix Table 3).

Data were analyzed by exam board. ANOVA indicated a significant difference in the percent understanding between the three major exam boards under which the students studied. $F_{2,169} = 4.04$, $p < 0.05$ (Figure 2). Figure 2 also includes a category for students who had been admitted to their biology degree course without having taken A-level biology. Their understanding of scientific vocabulary was considerably lower than that of those with A-level biology, although the low sample number precludes significance testing.

Each of the 476 terms was allocated to one of ten sub-disciplines which, together, comprise the biology curriculum. Comparisons between mean percent term recognition show that students showed better recognition of terms from some disciplines over others ($F_{9,465} = 4.25$, $p < 0.001$) (Figure 3) The data were further split between exam boards and for each, the variation was similar for all examination boards: for AQA $F_{9,465} = 2.90$, $p < 0.01$; for OCR $F_{9,465} = 3.39$, $p < 0.001$; for Edexel $F_{9,465} = 3.96$, $p < 0.001$. However, there were differences, for example students who studied under AQA had better perceived knowledge of reproductive terms and poorer perceived knowledge of botanical terms than students who studied under the OCR exam board. In general students who studied under Edexcel had poorer perceived recognition of terms than those who studied under OCR and AQA. For all the examination boards, botanical terms were those most poorly remembered by students.

Taking terms from each area of biology and comparing between exam boards, there was no significant difference in terms relating to general biology ($F_{2,72}$=0.736), lab work ($F_{2,63}$=0.886), genetics ($F_{2,123}$=2.033) plant science ($F_{2,120}$=2.382), zoology ($F_{2,51}$=0.654) and reproductive biology ($F_{2,27}$=0.874). However, in other areas differences were significant (Figure 4). In all cases, the 'No biology A-level' group was excluded from the ANOVA calculation because of its very small sample size. Terms were categorized by whether they were conceptual or object-related; there was no evidence that students found conceptual terms more difficult than object-related terms. Using arcsin-transformed data no significant difference was found between the two groups, $t = 0.674$, $df = 238$, NS.

Discussion

The data here illustrate some interesting relationships between students' knowledge, in terms of awareness and understanding, of subject-specific vocabulary and lecturers' expectations. By dividing Figure 1 into sections, groups of terms can be looked at in isolation and provide information for both exam boards and lecturers in higher education. Section A comprises terms that over 80 % of lecturers did not expect students to know and more than 80 % of students said they did not understand (Figure 1, Appendix Table 1). There is a strong case for suggesting these terms are removed from A-level courses, unless somehow they are central to understanding the material. There are not many of these terms, but any reduction in the content of the A-level biology syllabuses would place more focus on those terms and concepts that students are expected to know. Jones et al (2014) found that even the best A-level students forget more than half their subject knowledge in the four months between taking their A-level examinations and arriving at university. This is a further reason to reduce the content to allow time to improve retention of knowledge of key concepts.

There was a small number of terms which students said they were aware of, but which lecturers did not expect them to know (Section G Figure 1.). There could be a reason for keeping these terms in the syllabus because, although the majority of lecturers did not expect knowledge of these terms, students did not perceive these terms as difficult, and knowing them may assist in their understanding of related concepts. Brown and Ryoo (2008) suggest that unfamiliar vocabulary may be an obstacle to understanding concepts because unfamiliar vocabulary can induce anxiety in students; this then acts as an impediment to learning. Brown and Ryoo (2008) therefore propose teaching science concepts initially using common language. If specific terms are omitted from a syllabus it does not necessarily mean that related concepts need be omitted. Marintcheva (2012), however, reported that students find studying biology easier when they have prior knowledge of the vocabulary compared to when they do not.

In the present study students were asked if they knew and understood each term. Essentially they were being asked whether they could explain the term in common language, understanding the concept behind the term rather than just the term itself. However, students' concept of 'understanding' a term may vary widely and further study is required to find out their actual levels of understanding. But what is meant by 'knowledge' of a particular term? Knowledge of a term is based on the knowledge that an expert has of that subject; in this context it would refer to the lecturers. The same people write the science text books which are used in schools to provide students with science knowledge (Abimbola 1988). If students say they know a term it must be assumed they know the term in the context of the expert, since this is the basis of their knowledge. However, if students gain knowledge from other sources, experts can tend to devalue this knowledge. In the context of the present study, lecturers may give varying levels of trust to the students' perception that they know and understand a term. It should be noted that although the current scoring scheme asked students to indicate whether they understood each term, there was no evidence that a 'yes' actually connoted true understanding. It only meant that the students' perception was that they understood. This requires further investigation.

It is encouraging that there were no terms in Section C (Figure 1).These are terms that students did not understand but lecturers expected students to know. In other words, students did not fall short of staff expectations. Lecturers who have low expectations of students' knowledge of vocabulary should take heart that for every term more than 80 % of staff expect students to know, more than 80% of students will know and understand it. Kember and Kwan (2000) explored lectures' conceptions of the teaching process, and suggested it would be hard to change lecturers' teaching practices because of strongly help conceptions. The current data should provide some comfort to the lecturing community that their students arrive well prepared in terms of the vocabulary they claim to know.

Song and Carheden (2014) found students tended to rote-learn the scientific meaning of a term, without making a serious effort to understand it, for forthcoming assessments because that particular meaning had little relevance other than in the context of an exam. If students are able to perceive themselves as scientists they may be better able to develop the vocabulary of science. Song and Carheden (2014) suggest that developing the identity of a scientist is very important if students are to engage with scientific vocabulary. Perhaps this is an important aspect of induction for new undergraduates. If, during these first few crucial days, students begin to feel like biologists, they will find it easier to assimilate biology-specific vocabulary. Bahar et al (1999) suggest that subjects can be understood by students at three different levels, dividing them into macro, sub micro and symbolic; the macro being the large scale, practical and experimental side, the sub micro representing the vocabulary and concepts, and the symbolic where students put knowledge into context. Understanding what vocabulary means involves students working within all three levels, and perhaps this is what lecturers are expecting students to be able to do with the terminology they believe them to be familiar with. Students come into university knowing that they are entering an institute of higher learning, with the anticipation of learning more vocabulary and acquiring more knowledge. However, higher learning is more to do with the use of the knowledge, and so this further exacerbates the skills gap between school and university (Briggs et al 2012).

Surgenor (2013) studied the relationship between student and lecturer expectations in relation to assessment. He found serious mismatches between student perceptions and lecture expectations and suggests that it is the lecturers who, in his words 'are to be found wanting'. There have been studies that attempt to categorize the approach to teaching by lecturers. Abimola (1988) discusses 'evolutionary' vs 'revolutionary' approaches. The lecturer with a 'revolutionary' approach would be uninterested in students' prior education and in our present context, would have lower expectations of students' knowledge and understanding of terminology. Lecturers with an 'evolutionary' approach will expect students to be familiar with terms, but may need them to adapt their knowledge to a higher education setting. Kember and Kwan (2000) categorized different styles of teaching: content-centered or learning-centered. Lecturers that were in the 'content centered' category concentrated on the material that needs to be taught, while the learning centered lecturers focused on the comprehension of their students. These are sometimes referred to as surface or deep learning approaches respectively. The approach that teachers had to their teaching was strongly determined by their conceptions of the teaching process. The current study is one of the very few studies which compare lecturer expectations with students' perceptions of their educational achievements, and knowledge of this could help lecturers develop a deeper, learning-centred approach to teaching.

There have been concerns in the past that an assessment-driven curriculum leads to rote-learning and a lack of understanding (Lock 1998). In much A-level marking, points are awarded for specific terms used, possibly fostering an approach where students memorize terminology rather than understanding the concepts. Explaining a concept correctly but in common language would not be given marks, whereas providing appropriate scientific terms would. This approach is germane to the AS/A2 structure and modular courses being introduced in a short time frame. With the removal of modular courses and the introduction of linear A levels (first examined in 2017), might there be less rote learning in the future? Changes to assessment patterns to encourage more understanding and less memory of specific terms (Ofqual 2014) may be a step in the right direction but unless the content of A-level biology courses is significantly reduced, these changes will do little to diminish the rote-learning aspect of these courses. This study provides evidence-based information for exam boards to use. If exam boards discontinue the use of terms listed in Section A of this study (Table 1), for example, this could start a process that may go some way to allow more space in the curriculum for skills and concept development.

There were differences between exam boards in terms students remembered (Figures 2 and 3), similar to differences found in Jones et al (2014). For all the examination boards, though, plant science was the least well-understood of the biological sub-disciplines, with only approximately half the terms being understood. This could be a result of ineffective teaching or of lack of student interest. Lock (1998) recorded a worrying lack of interest in plants in the teaching of A-level biology and even though this was almost 20 years ago, the current data suggests this may still be the case. There was no significant difference in knowledge of plant science across categories (Figure 2) even including those who did not have biology A-level. As a caveat though, the number of students in this category (n=3) was too low for meaningful statistics. However, Spurgin (1975) found medical schools prepared to take students with mathematics at A-level rather than biology and these students without A-level biology were not found to be disadvantaged on the course.

A commonly encountered problem for lecturers is motivating students to learn vocabulary. Students find it particularly difficult to deal with words that have a dual meaning. Song & Carheden (2014) found that chemistry students reverted to their every-day understanding of a term rather than its specific scientific meaning. Terms in Section D (Figure 1) included the word 'community'; only some students said they knew and understood this term. Nearly 10% maintained that they had never heard the word. It is highly unlikely that they had never heard the word used in an everyday context so it seems that these students were aware that the word had an alternative scientific meaning but had never heard it used scientifically. A further 10% claimed that they had heard the term but did not know its meaning. Again, it is very unlikely that they were unaware of its general meaning although its scientific meaning remained obscure. These complexities highlight the difficulty in collecting information on this subject and highlight the need for further studies using a more sophisticated methodology.

These data provide evidence to help exam boards reduce the number of terms in A-level biology syllabuses. This will enable teachers to spend more time helping their students understand concepts rather than rote-learn terms. The data also show that lecturers are underestimating their students' knowledge and understanding of biological vocabulary. This is the first study matching students' perceptions of knowledge to lecturer expectation. How students can use their knowledge of vocabulary in a Higher Education environment will require further study.

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References

Abimbola I.O. 1988. The problem of terminology in the study of student conceptions in science. Science Education 72(2): 175-184

Bahar M., Johnstone A.H. & Hansell M.H. 1999. Revisiting learning difficulties in biology, Journal of Biological Education, 33:2, 84-86, DOI: 10.1080/00219266.1999.9655648

Barrass R. 1979. Vocabulary for introductory courses in biology: necessary, unnecessary and misleading terms. Journal of Biological Education13:

Briggs A.R.J., Clark J.& Hall I. 2012. Building bridges: understanding student transition to university, Quality in Higher Education, 18:1, 3-21, DOI:10.1080/13538322.2011.614468

Brown B.A. & Ryoo K. 2008. Teaching science as a language: A 'content-first' approach to science teaching. Journal of research in science teaching 45(5) 529-553

Curzon L.B. 2004. Teaching in Further Education, and outline of principles and practice. 6th edition. Published by Continuum in US and MPG Books Ltd in UK.

Evans JD. 1975. Technical terms used in school textbooks of human biology. Journal of Biological Education 9: (3-4): 118-122

Evans JD. 1976. The treatment of technical vocabulary in textbooks of biology. Journal of Biological Education. 10 (1): 19-30

Johnstone AH. 1991. Why is science difficult to learn?: things are seldom what they seem. Journal of Computer Assisted Learning7:75-83

Jones HLJ, Black B, Green J, Langton P, Rutherford S, Scott J and Brown S. 2014. Indications of Knowledge Retention in the Transition to Higher Education. *Journal of Biological Education*. 49: 261-273

Kember D & Kwan K. 2000. Lecturers' approaches to teaching and their relationship to conceptions of good teaching Instructional Science 28: 469-490

Krajcik J.S. & Sutherland L.M. 2010. Supporting students in developing literacy in science. Science 328: 456-459

Lock R. 1998. Advanced-level biology – is there a problem? School Science Review 80: 25 – 28.

Letts. 2008. Revise AS and A2 Biology. Letts and Lonsdale.

Marintcheva B. 2012. Motivating students to learn biology vocabulary with Wikipedia. Journal of microbiology and biology education 13(1): 65-66

Ofqual. 2014. GCE AS and A level subject content for biology, chemistry, physics and psychology . Department for Education.https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/593849/Science_AS_and_level_formatted.pdf (last accessed October 2017)

Surgenor P.W.G. 2013. Measuring up: comparing first year students' and tutors' expectations of assessment, Assessment & Evaluation in Higher Education, 38:3, 288-302, DOI: 10.1080/02602938.2011.630976

Song Y. & Carheden S. 2014. Dual meaning vocabulary (DMV) words in learning chemistry. Chemistry Education Research and Practice 15: 128-141

Spurgin C.B. 1975. Entry to medical schools with 'A' level in mathematics rather than biology. British Journal of Medical Education 9: 140-144

Yager RE. 1983. The importance of terminology in teaching K-12 science. Journal of Research in Science Teaching. 20(6): 577-588

Table 1. Terms that > 80% of staff expected students to not know

Terms that >80% of students didn't understand	Terms that between 20% and 80% of students did understand	Terms that >80% of students did understand
Section A	Section F	Section G
Action spectrum	*Allopatric speciation*	*Dynamic equilibrium*
Autosome	*Aneurysm*	*Refractory period*
Bordered pits	*Antidiuretic hormone*	*Relay neurone*
Chlorosis	*Antigenic variation*	*Reverse transcriptase*
Chordae tendonae	*Apoplast*	*Synaptic knobs*
Colostrum	*Atheroma*	
Cuticular transpiration	*Capillarity*	
Cytoplasmic connections	*Carbonic anhydrase*	
Cytoplasmic streaming	*Casparian strip*	
Edaphic factors	*Cell fractionation*	
Embolism	*Chemiosmotic theory*	
Gastrin	*Chiasmata*	
Glycoclyx	*Dehydrogenase*	
Graticule	*Differential centrifugation*	
Merozoites	*DNA hybridisation*	
Oligotrophic	*Emphysema*	
Osmium stain	*Endodermal cells*	
Oxidoreductase	*Erector-pili muscles*	
Pancreozymin	*Generator potential*	
Photoperiodism	*Geotrophism*	
Phytochrome	*Germ line gene therapy*	
Pinocytocis	*Globular head*	
Pleural cavity	*Glucose oxidase*	
Precapillary sphincter	*Glycoprotein*	
Proprioreceptors	*Grana*	
Secretin	*Haemoglobinic acid*	
Sequential effect	*Hydrolases*	
Single nucleotide polymorphisms	*Hydrotropism*	
Sporozoites	*Inner capsular membrane*	
Tetraploid	*Intergranal thylakoids*	
Thigmotropism	*Ligase*	
Tonoplast	*Mass transport*	
Tunica externa	*Mechanoreceptors*	
	Memory T-lymphocytes	
	Mesophyll cell	
	Micropropagation	
	Microtubules	
	Motor end plates	
	Myogenic	
	Open circulation	
	Osmoreceptors	
	Pacinian corpuscles	
	Palisade cell	
	Passive natural immunity	
	Phosphorylated nucleotide	
	Photoautotrophic nutrition	
	Phylogenetic system	
	Plasmolysis	
	Pleural membranes	
	Podocytes	
	Polygenic inheritance	
	Preferred respiratory substrate	
	Protoctista	
	Proximal tubule	
	Reaction centre	
	Reduction division	
	Reflex arc	
	Restriction endonuclease	
	Reversible inhibitor	
	Ribulose phosphate	
	Root pressure	
	Satatory conduction	
	Saprobiotic	
	Sarcoplasm	
	Sieve plate	
	Sieve tube	
	Somatic cell therapy	

	Spirometer *Sputum testing* *Squamous endothelium* *Stage micrometer* *Suppressor T-lymphocytes* *Sympatric speciation* *Symplast* *Therapeutic cloning* *Thyroid stimulating hormone* *Thyroxine* *Tidal volume* *Totipotent* *Transgenic bacterium* *Triose phosphate* *Tropic hormones* *Troponin* *Ultra centrifuge* *Ultra filtration*	

Table 2. Terms that > 80% of staff expected students to know

Terms that between 20% and 80% of students did understand	Terms that >80% of students did understand
Section D	Section I
Bone marrow *Community* *Erythrocytes* *Nomenclature* *Staining* *System* *Testosterone* *Vitamins*	*Absorption* *Acid* *Adrenalin* *Alkaline* *Allele* *Amino acids* *Anaerobic respiration* *Antibodies* *ATP* *Axons* *Biodiversity* *Breathing rate* *Bronchioles* *Capillary* *Carbohydrates* *Carbon monoxide* *Carcinogens* *Cell cycle* *Cellulose* *Cholesterol* *Combustion* *Coronary heart disease* *Digestion* *Digestive enzymes* *Diploid* *DNA* *Ecosystem* *Eukaryotic* *Evaporation* *Fats* *Fertile offspring* *Gametes* *Genotype* *Global warming* *Glucose* *Greenhouse effect* *Guanine* *Haemoglobin* *Haploid* *Heterozygous* *Homogeneous* *Hormones* *Humidity* *Inhibitors* *Insulin* *Kilojoules* *Light microscope* *Lipids* *Magnify* *Mammal* *Mean* *Meiosis* *Metabolism* *Minerals* *Mitochondrion* *Mitosis* *Mutation* *Natural selection* *Nerve cells* *Nerves* *Nucleotides* *Obesity* *Oestrogen* *Oils* *Organelles* *Oxidation* *Pelvis* *Phenotypes*

	Photosynthesis *Plasma* *Plasma membrane* *Population* *Precipitation* *Predation* *Proteins* *Red blood cell* *Reduction* *Retina* *Ribosomes* *RNA* *Salts* *Sampling* *Saturated* *species* *Sperm cell* *Substrate* *Thymine* *Tissue* *Variation* *Vein*

Table 3. Terms that between 20% and 80% of staff expected students to know

Terms that > 80% of students know and understand	Between 20 and 80 % of students know and understand the terms.
Section H	Section E
Abiotic factors	*Absorption spectrum*
Action potential	*Accessory pigments*
Active transport	*Acetylcholine*
Anaphase	*Actin*
Anticodon	*Agar*
Antigens	*Anabolic reaction*
Arterioles	*Angina*
Atrioventricular node	*Anorexia nervosa*
Atrioventricular valve	*Antagonistic*
Axon membrane	*Artefacts*
Behavioural response	*Atherosclerosis*
Binding sites	*Autosome*
Biotic factors	*Autotrophic nutrition*
Bronchi	*Auxin*
Calvin cycle	*Bicuspid valve*
Cardiac cycle	*Binomial system*
Carrier proteins	*Biological oxygen demand*
Cell body	*B-lymphocytes*
Channel proteins	*Carrying capacity*
Cilia	*Catabolic reaction*
Climax community	*Centrioles*
Co-dominance	*Chemoreceptors*
Denatured	*Chemotaxis*
Denitrification	*Chi squared*
Depolarisation	*Chiasmata*
Dominant allele	*Climatic factors*
Effectors	*Closed circulation*
Electrical impulses	*Compensation point*
Endothermic	*Condensing lens*
Enzyme-substrate complex	*Cones*
Epithelial cell	*Cortex*
Gene pool	*Cytosine*
Gene therapy	*Degenerate code*
Genetic diversity	*Dendrons*
Genetic engineering	*Denitrifying bacteria*
Golgi body	*Density dependent*
Homologous chromosomes	*Diastole*
Hydrophilic head & tail	*Double circulatory system*
Interphase	*Ectothermic*
Interspecific competition	*Elastic fibres*
Intraspecific competition	*Electron carrier system*
Ion channels	*Endocrine gland*
Lactase	*Endocytosis*
Left atrium	*Erector-pili muscles*
Light intensity	*Eutrophication*
Lysosome	*Evolutionary relationships*
Messenger RNA	*Exons*
Metaphase	*Exponential rate*
Microvilli	*Fluid mosaic model*
Motor neurone	*Follicle stimulating hormone*
mRNA polymerase	*Genetic fingerprinting*
Myelin sheath	*Globular proteins*
NADP and NADPH	*Glomerulus*
Negative feedback	*Glucagon*
Niche	*Growth response*
Nodes of ranvier	*Guard cell*
Oxidative phosphorylation	*Habitat diversity*
Pacemaker	*Habituation*
Phagocytosis	*Heterotrophic*
Polarisation	*Homogenisation*
Polypeptide	*Humoral response*
Post-synaptic membrane	*Hydrogen peroxide*
Potential difference	*Hypothalamus*
Pre-synaptic membrane	*Intermediates*
Primary consumers	*Introns*
Primary succession	*Irradiation*
Prokaryotic	*Irreversible inhibitor*
Prophase	*Islets of Langerhans*

Quadrat	*Keratin*
Receptor protein	*Leucocytes*
Recessive allele	*Lignin*
Right atrium	*Linkage*
RNA polymerase	*Lipoproteins*
Root hair cell	*Lymphatic vessels*
Rough endoplasmic reticulum	*Lysis*
Schwann cell	*Malignant growths*
Selective breeding	*Mass screening*
Sinoatrial node	*Medulla*
Smooth endoplasmic reticulum	*Metabolic pathway*
Smooth muscle	*Microscope stage*
Sodium-potassium pump	*Muscle layer*
Specialisation	*Mutagens*
Speciation	*Myocardial infarction*
Species diversity	*Myoglobin*
Stomata	*Myosin*
Stroma	*Neutralisation*
Synapses	*Neutrophil*
Telophase	*Nitrogen fixation*
Tertiary structure	*Normal distribution*
Thermoreceptors	*Normal distribution*
Thylakoid membranes	*Oncogenes*
Tissue fluid	*Parasympathetic system*
tRNA	*pheromones*
Urea	*Photometer*
Vacuole	*Photoreceptor*
Vasoconstriction	*photosensitive*
Vasodilation	*Photosystem I and II*
Vector	*Phototropism*
Ventricles	*Pioneer species*
Vesicles	*Plasmodesmata*
	Pluripotent
	Polyploid
	Primary colonisers
	Progesterone
	Prokaryotae
	Pulmonary ventilation
	Purkinje fibres
	Renal vein
	Reproductive cloning
	Resolution
	Reticulum
	Retroviruses
	Secondary structure
	Secondary succession
	Sediment
	Semi-conservative replication
	Sensitivity
	Significant difference
	Single circulatory system
	Somatic cell
	Standard deviation
	Supernatant
	Sympathetic system
	Systematics
	Systole
	Taxis
	Taxonomy
	Threshold level
	Tissue culture
	T-lymphocytes
	Transgenic bacterium
	Transmission electron microscope
	Transmitter molecules
	Transpiration
	Tricuspid valve
	Tropism
	Turgidity
	Uranium
	Venule
	Visual acuity

Figure 1. Student evaluation of terms based on their perceptions of their own understanding. Each mark represents one term. Scales show % of staff expecting students to know a term and % of students saying they understood a term. Harder terms are those which fewer students understood and easier terms those which more students understood. Grid lines separate terms into categories based on student and staff evaluation of those terms. For example, section A is where >80% of students don't understand the term and >80% of staff don't expect them to know; section G is where >80 % of students say they understand a term, but 80% of staff don't expect them to know the terms.

Figure 2. Students' perceptions of their understanding of all terms in the vocabulary list, grouped by exam board. Error bars represent standard error of the mean. AQA n=76, OCR n=69, Edexcel n=27, no biology A-level n=3.

Figure 3. Mean percentage of terms, separated into ten sub-disciplines, which students recorded that they understood. Error bars represent s.e.

Figure 4. Comparison of mean percentage understanding of terms in five biological sub-disciplines between three examination boards and students who did not take Biology A-level. General biological terms $F_{2,72}$=0.736, NS Biochemistry $F_{2,246}$=8.823, P<0.001 Cell biology $F_{2,231}$=5.735, P<0.01 Anatomy $F_{2,309}$=5.552, P<0.01 Ecology $F_{2,153}$=4.239, P<0.05