Deconstructing scientific vocabulary for low-literacy students: an action research study

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Abstract This article reports on how increasing understanding of the morphology of science vocabulary, by introducing and using affixes, improved students' ability to recognise key words in examination questions and link these to prior knowledge. As a result, students attempted far more questions and the quality of answers they provided was significantly improved.

> *Words can have a power and influence quite out of proportion to their triviality as mere marks on paper or vibrations in the air* (Sutton, 1992: 1)

Low literacy levels are arguably the most significant challenge we face globally in developing understanding of science and its application (Sutton, 1992; Nunes *et al*., 2017). Many strategies have been introduced and employed across all subject areas that help to support both core and subject-specific literacy, or disciplinary literacy (Shanahan and Shanahan, 2014), with varying degrees of success (Ofsted, 2011; Pearson, Moje and Greenleaf, 2010; Grant and Fisher, 2010; DfEE, 2000; DfEE, 2001). Recent work by Ippolito *et al.* (2018) demonstrates well that disciplinary literacy can be developed in younger children, along with core literacy, using authentic outdoor science experiences.

The search for ways to improve students' scientific literacy is important, not only because we want our students to succeed in their examinations but also because we need a scientifically literate population. Abundant evidence shows that literacy is linked to individuals' prosperity and good health (Morriscoe, 2014; National Literacy Trust, 2011), and, in today's highly technological society, making informed lifestyle decisions requires a reasonable level of scientific literacy (Laugksch, 2000). Byrne, Johnstone and Pope (1994) considered language to be critically linked to reasoning and therefore fundamental for a person to conceptualise ideas. Understanding of how greater cognition and language acquisition can be developed and how verbal and written feedback can be utilised to support students' metacognition and their attainment in science is now becoming more commonplace in teaching (e.g. Quigley, Muijus and Stringer , 2018; Paivio, 1986; Morena, 2006; Bannert, 2002; De Jong, 2010).

This article reports on the impact that a small-scale action research project had on achievement in science for a newly formed low-literacy year 10 group (ages 14–15). It explores the explicit use of prefixes and suffixes in constructing meaning from science vocabulary.

Context

The action research took place in a large, mixed comprehensive school in Essex, England. The challenges posed by the study group were very significant. The group comprised 21 students aged 14–15: 9 girls and 12 boys. All students were registered with the SEN department, with 7 having statements of Special Educational Need and 14 recorded as Action Plus. Statements were for a range of needs: all included a learning need (e.g. slow development of literacy and/or numeracy, poor development of verbal communication) and many also had behavioural and emotional needs. Reading ages of students in this group ranged between 6 and 10 years, and 5 of them required support with speech and language, although this was a rare intervention despite this information being recorded in primary school transfer documentation.

Students' low literacy levels were found to be a major barrier to their learning, and deciphering the language used in examination questions was almost unachievable. This is not surprising, as text in examination papers often has reading ages of 15+ years (Paton, 2012; Richardson, 2012). Test results carried out at the end of topics showed that students made little or no progress over their first term of year 10 (ages 14–15), with many having regressed in terms of achievement from year 7 (ages 11–12), so it was decided to design and implement a range of literacy support strategies. These included:

- **a** starters that provided students with sentences based upon science taught in previous lessons, yet each containing grammatical, structural and scientific vocabulary errors. Students were asked to re-write the sentences correctly (Box 1);
- **b** asking students to write about equations (Box 2);
- **c** scientific text where students were asked to identify nouns, verbs, adverbs and conjunctions. Students were also asked to replace these words with alternatives, but without losing their meaning;

Box 1 Three examples of statements that students were asked to correct

1 carbohydrates can be found in foods such As rice and pasta they are need to mak energy

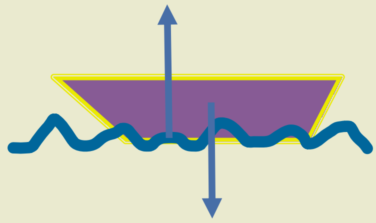
2 we use carboydrates to obtain energy the best energy fods contain starhc proteins are needed to help us grow and too repair tissues

3 The more concentrate a solution the more solvent particales thier are in a given volume

Box 2 Example of an image and an equation that students were asked to explain

Write a paragraph to describe what these images are showing:

$$F = m \times a$$



d giving students a title of a science-related article and asking them to discuss what the article might be about or, alternatively, students were given the article and ask to create a title (Box 3);

e using mnemonics to remember key lists, for example the range of colours in white light (ROYGBIV);

f providing students with a graph and asking them to explain what information the graph presented and what conclusions could be made from the graph; alternatively, providing students with a graph without axes, but with a simple conclusion; students were asked to label the graph axes appropriately.

Box 3 Suggested titles for different articles that students were asked to read

The sugar that makes up DNA could be made in space

Waste not, want not

Apple plus helium equals trouble

These interventions supported good improvements in core literacy levels of students, enabling most to write coherent sentences with improved use of punctuation and accurate spellings, but performance in examination-style questions remained poor. Students were unable to understand what was being asked in examination questions and so most questions, predominantly those requiring extended writing, were not attempted. On examining the types of question students found most difficult, it was noticed that of particular challenge to students were:

- recognising command words such as explain, describe, compare and calculate, and understanding what they were being asked to do;
- but, more fundamentally, being able to identify the main areas of science being examined.

It was felt that as so many strategies supporting improvements in literacy had already been implemented, the initial focus would be to develop students' ability to recognise the science area that a question was focused upon, and later (year 11, ages 15–16), introduce the meanings of examination command words.

Examination questions often reveal their main scientific focus through the key vocabulary being used. For example, a question relating to thermodynamics (e.g. an energy change in a reaction) might use vocabulary such as exothermic or endothermic. Similarly, a question that expects students to provide answers related to respiration might use key vocabulary such as aerobic or anaerobic. From this stance, the hypothesis considered was, 'students who are able to recognise the vocabulary used in examination questions and link this to their prior learning of this topic, stand a much better chance of deciphering and answering the question'.

Making sense of scientific vocabulary

Before students can begin to unpick the meaning of many key scientific words, they must first understand how the words are constructed. Many commonly used words are constructed from a root word that could be used by itself, and an affix. An affix is a group of letters attached to either the beginning of the root word (prefix) or the end of the root word (suffix) that changes the meaning of that word. For example, the root word happy might be prefixed by 'un', this would change happy to unhappy. Alternatively, happy might be suffixed by 'ness', changing happy to happiness.

Many science words use prefixes and suffixes that are derived from the Greek and Latin languages. If students become familiar with the meanings of these affixes, they can work out the meanings of most scientific words. For example, the prefix 'photo' means light (Greek) and the suffix 'synthesis' means putting together or making (Greek). Joining the prefix and suffix together makes the word 'photosynthesis'. This word means making from light and we know this. The word 'polymorph' is also derived from Greek affixes. It is made from the prefix 'poly' (many) and the suffix 'morph' (shape/form). This new word formed by putting them together means 'many shapes'. Introducing students to the prefix and suffix fragments most commonly used to generate scientific words provides them with a potential strategy to deconstruct science vocabulary, and to then make some sense of the meanings.

Try it out using information in Tables 2 and 3

1 Making key words

Table 1 Key word construction

Prefix	Suffix	Word	Meaning
photo	graph		
tri	pod		three foot
	costal	intercostal	
	phobic		not liking water
iso		isotherm	
			carnivore
	ase	amylase	
chloro	phyll		
			telescope
		exothermic	

2 Understanding key words.
Try to work out what each sentence is referring to. Key words are highlighted for you.

- a The blood sample was **centrifuged** for 3 minutes.
- b A **cardiogram** was used to determine what treatment was required for the patient.
- c It was important to use **antiseptic** wash on the area.
- d Insects have an **exoskeleton**, whereas reptiles have an **endoskeleton**.
- e **Photosynthesis** could not occur without chloroplasts.
- f **Aerobic** and **anaerobic respiration** mean the opposite of each other.

3 For each of the following words: i) find the prefix and suffix, ii) explain the meaning of the word, and iii) write a short sentence using the word.

- a Symbiosis
- b Chromatography
- c Subatomic
- d Science

You may need to do your own research for some of these words.

Getting back to prefix and suffix

These words are also compound words that have two parts. 'Pre' means before, 'suff' means after and 'fix'

Table 2 Prefixes used in science

Prefix	Meaning	Origin (G = Greek, L = Latin)
a	against	G
acu	needle	L
adipo	fat	L
aero	air	G
acou	sound	G
amyl	starch	L
anti	opposite or against	G
bio	life or living	G
cardi	heart	G
carn	meat or flesh	L
centi	one hundred or one hundredth	L
center/ centri	mid-point of a circle	L
chlor	green	G
chromo	colour	G
di	two or twice	G
dent	tooth	L
endo	within or in	G
exo	out	G
equi	equal	L
grav	heavy	G
homo	same	G
hem/ haem	blood	G
hetero	different	G
hydro	water	G
hyper	over or beyond or greater	G
hypo	under or less	G
infra	below or beneath or lower than	L
Inter	between or among	L
iso	same or equal	G
kinetic	motion or moving	G
lact	milk	L
leuco	white or clear	G
lingual	tongue	L
macro	large	G
micro	small	G
mono	one or single	G
olfact	smell	G
nephro	kidney	G
noct	night	L
phago	eat	G
phono	sound	G
photo	light	G
poly	many	G
pre	before	L
re	again or back	G
ren	kidney	L
respire	breathing in and out	L
semi	half	L
sub	under or part or up to	L
tele	far away or distant	G
therm	warm (heat)	G
trans	across	L
tri	three	G/L
ultra	beyond	L

Table 3 Suffixes used in science

Suffix	Meaning	Origin (G = Greek, L = Latin)
able	capable of (or 'can do' or 'can be done')	L
aceous	composed of	G
ase	enzyme	Modern
costal	rib	L
cyte	vessel or cell	G
derm	skin	G
fuge	drive away	L
graph	record or write	G
gram	make a record by tracing, writing, drawing, etc.	L
ise	to become	G
morph	shape/form	G
ology	the study of	G
phobic	fear	G
philic	love	G
phoresis	being carried	G
phyll	leaf	G
plast	small body or structure or particle	G
pod	foot	G
respire	breath	L
rhine	nose	G
sclerosis	hard	G
scope	examine or to look at	G
septic	infection or decay or rot	L
sphere	globe or ball	L
stasis	same or no change	G
synthesis	putting together	G
therm	heat	G
trophic	food	G
vore	swallow or devour	L

means to attach. Older books sometimes call a suffix a postfix. What do you think 'post' means?

Discussion

Conversations with students included asking about their perceptions of using the prefix/suffix sheets. Student feedback showed that they enjoyed learning how to deconstruct and construct scientific words, and thought very strongly that this process helped them to understand science better. Responses often referred to them being able to better recognise science words and so be able to understand what a question was asking – for example, '*If I know a word in the question, I can tell what it's about*'.

Students found the process of working out word meanings engaging, and this initiated dialogue within the class, which was not observed before. It was also noticed that students' writing in class improved. Their responses to questions became more comprehensive and had fewer spelling mistakes, particularly for science vocabulary. Students began to write more without being asked to.

Data from end-of-topic tests and half-termly assessments clearly demonstrated a marked improvement in student achievement over the year. Before the intervention was introduced, progress measured by achievement in examination-style questions over the first term had been extremely limited; students rarely made any progress in terms of grades. However, by the end of the third term, progress had improved significantly with students attempting to answer more questions and provide greater detail in their answers.

(In the first term assessment, students attempted between 1 and 2 questions out of 6 and rarely scored more than 2 to 5 marks out of 60. In the third term assessment, students were able to attempt between 4 and 6 questions, including the 6-mark questions, and scored between 10 and 22 marks out of 60).

The analysis of assessment papers, along with individual conversations held in class with students, strongly suggested that a correlation existed between students' improved ability to recognise and understand the meanings of key vocabulary used in examination questions, and the increased number of questions attempted and the improved quality of their answers. The ability to recognise a topic within a question was given as the most important factor in students' increased confidence to tackle questions, which increased the chances that they would attempt more questions.

Conclusion

Although the introduction of affixes was used in combination with other strategies for improving literacy, the increase in the number of examination questions attempted by students, and the improvement in achievement after its implementation, strongly suggests that this intervention had a positive effect on learning outcomes, which, in part, supports the hypothesis.

Teaching students in this group how scientific words are constructed had a significant impact on their scientific understanding and ultimately their achievement in science. This small-scale project is supported by a more recent study that showed children of primary school age benefit greatly from learning how key prefix and suffix fragments inform scientific vocabulary (Markwick, 2018), and authors such as Ippolito *et al.* (2017) and Brock *et al.* (2014) strongly advocate introducing students to science literacy at a young age (key stage 1; age 5–7).

We know that good literacy, both core and subject specific, is vital for scientific understanding and therefore also for achievement in science, and ultimately for improving an individuals' scientific literacy. This simple strategy very quickly and significantly helped to improve outcomes for low-literacy students in science. We all search for effective ways to improve outcomes for our students; focusing upon scientific vocabulary in this way may be part of the answer.

Developing students' understanding of the morphology of scientific words is not a new idea. Often teachers will explain the root meanings of words such as photosynthesis and exoskeleton, but to be an effective strategy in developing a deeper understanding of scientific vocabulary meaning and the confidence to decipher meaning from text containing these words, greater emphasis is required on creating a comprehensive pedagogy that teaches word morphology in a consistent and meaningful way through a student's schooling.

At the beginning of year 10 and the GCSE course, these students were not expected to achieve a grade at GCSE, but continued literacy interventions through years 10 and 11 resulted in all of them passing two science GCSEs with grades between G and D.

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