Investigating the use of term recall and recognition tools in learning terminology and concepts in a senior biology classroom

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Abstract

This paper investigated the use of term recall and recognition tools for learning terminology and concepts in a senior biology classroom. The paper responded to a set of research questions from a teacher researcher perspective, making use of data collected from the teacher researcher's classrooms over several years, based on the implementation of two teaching strategies. Findings indicated that while looking for a teaching procedure to support a specific purpose may seem a simple task, in reality it was a complex task. However, the complexity lead to a greater awareness of the teacher researcher's teaching practice and inspiration to develop ideas for new and enhanced practice.

Introduction

A senior biology classroom can feel like a visit to a foreign country. A foreign language is spoken. The increased rate of technological and molecular applications in biology has resulted in the development of a multitude of new terms. In some cases, even the meaning of these terms change with new discoveries and scientific understanding.

Senior secondary school Biology requires students to recall key scientific terms and how they link together to describe or explain a variety of biological concepts. If students do not possess the required vocabulary, how can they express what they know and understand? This requires labelling, remembering and connecting vocabulary that may be very specific to the context in which they are working.

Students need opportunities to construct, develop and play with the biological vocabulary, so that they can understand the biological concepts and be able to communicate their understanding. How can classroom biology teachers assist their students in the journey of acquiring, applying and communicating this new biological knowledge? Is there a way in which this could be incorporated into a senior biology classroom? Which strategies would be most effective across the diverse range of abilities and learning styles within a senior biology classroom?

This paper responds to these questions from a teacher researcher perspective (see for example, Berry, Loughran, Lindsay, & Smith, 2009; Clarke & Erickson, 2003; Cochran-Smith & Lytle,

1990) based on the first author's extensive examination of her teaching and her students' learning in senior high school Biology.

Learning biological concepts

For decades, researchers have acknowledged the importance of language in science education. Wellington and Osborne (2001) noted that as learning the language of science plays a key role in learning science, an increased focus on learning scientific language may improve the quality of science education. Biological terms may be considered as one of the building blocks of biological knowledge (Schönborn & Bogeholz, 2013). The domain-specific vocabulary and terminology used to communicate molecular biology, genetics and biochemistry ideas, concepts and details can be a barrier for students learning these disciplines (Knippels, Waarlo, & Boersma, 2005; Lidbury & Zhang, 2008).

Yager (1983) noted that science textbooks can introduce more new terms than would be expected in studying a foreign language within a similar time frame. As significant time is devoted to vocabulary and grammar when learning a foreign language, Lidbury and Zhang (2008) were of the view that science education should aspire to immerse students in scientific language. Spencer and Guillaume (2006) suggested that rather than learning about a new word in a single exposure, learning should occur in small steps over time with the word being encountered in different contexts. They proposed that word knowledge is multidimensional. Rather than just recalling or knowing the meaning of the word, it involves knowing what the word means, how it relates to other words, how it is pronounced and how it can be used in a sentence. Further to this, Blachowicz and Fisher (2008) suggested that learners need anchor concepts (e.g., knowing what circle means assists learning terms like radius and circumference) as well as vocabulary to learn new words and connect them to concepts already known.

Teaching scientific language

Studies indicate that while teachers realise vocabulary to be important to understanding text and to allow time for vocabulary instruction, they usually do not address the complexity of word knowledge and do not always incorporate best practice into their instruction (Blachowicz, Fisher, Ogle, & Watts-Taffe, 2006; Flanigan & Greenwood, 2007; Spencer & Guillaume, 2006). Even when research provides teachers with useful general principles and methods of vocabulary instruction, its translation from theory into the practice of specific classroom contexts has proved difficult (Flanigan & Greenwood, 2007).

Over sixty years ago, Deck (1952) identified that the specific technical vocabulary of each field of science contributed to difficulties in learning science. He believed that it was necessary for the teacher to identify the new or difficult terms and to develop learning activities that would support student meaning-making and understanding of these terms. Likewise, Blachowicz (1986) identified highlighting key vocabulary terms to be encountered and the development of strategies for students to focus on and hypothesize about words. She suggested that such predictive strategies supported the active learning of new words, their connections and varied usage.

The requirement to understand scientific terms that are used to describe and explain scientific concepts supports the need for reflective and active reading skills to be explicitly taught in the science classroom (Wellington & Osborne, 2001). Research on effective reading instruction has demonstrated that effective teachers directly and explicitly teach students what they need to know. Direct and explicit instruction of phonemic awareness, phonics, fluency, vocabulary and comprehension needs to be an integral part of student learning (Rupley, Blair, & Nichols, 2009).

Effective vocabulary instruction, Blachowicz et al. (2006) advised, requires a context-related repertoire of teaching activities and instructional strategies that are embedded within the curriculum. They also proposed that students be repeatedly exposed to the words and provided with opportunities to be actively engaged in exploring semantic connections and in the development of their own independent strategies for dealing with future new words.

Lombardi (2008) suggested activities that assist the brain's search for meaning through patterning. Effective English language teachers, she noted, used graphic organisers, prediction strategies, and introduced vocabulary to prepare the brain for the new knowledge to come. Kessler (1999) also promoted student awareness of root words to predict the definitions of unfamiliar words. Recognition of patterns such as these and making connections assists the incorporation of new memories into the brain's long term storage (Bellanca & Fogarty, 2005; Fogarty, 2005).

Vocabulary instruction within a science classroom is more than just teaching scientific terms or the strategies that will be used to teach them. Vocabulary instructional decisions also need to consider the particular nature of the words, the purpose for teaching them and the particular students being taught (Flanigan & Greenwood, 2007). While many teachers intuitively incorporate brain-compatible strategies in their instruction, Wolfe (2006) suggested that they need to move these from the intuitive to the conscious level, so that such knowledge may be articulated. Once articulated, it may contribute to reducing the gap between vocabulary instruction research theory and practice, and an understanding of how scientific terminology may be more effectively taught in science classrooms.

This paper examines an attempt to articulate strategies to support the learning of scientific terminology with senior high school Biology students across cohorts over a five year period.

Research approach

Two teaching procedures that focussed on term awareness and recognition were researched for this paper, those procedures were: 1) *Term Recall* - now and before worksheets; and, 2) *Term Recognition* cards and worksheets. (Please note, the development of these procedures will not be discussed as it is beyond the scope of this paper however, please contact the first author should you require further details.)

Student responses to both teaching procedures were collected from the first author's senior secondary Biology classes at the same school over a five year period. Student responses were examined and the effectiveness of the procedures in exploring student term awareness and familiarity considered in conjunction with systematic teacher reflection documented through journaling.

Context

Units 3 and 4 VCE (Victorian Certificate of Education) Biology are final secondary school science subjects in Victoria, Australia that include both internal and external assessment. The internal assessment score (worth 34% of the total final end of year score) is moderated against students' external examination score. VCE comprises the final 2 years of secondary (high) school education. Traditionally Units 1 & 2 are in the second last year (Year 11) and Units 3 & 4 are in the final year (Year 12). However, students can accelerate their study and complete some Units 1 & 2 in Year 10 and therefore study some Units 3 & 4 in Year 11. The school year is a calendar year comprising four 10 week terms with two week breaks between each term across the year. Within the research study time period, there were two external exams worth 33% each, the first after 16 weeks of study in June and the second after the next 16 weeks of study in October; the same applied to each cohort each year for the five years of the study.

Throughout the time of the study, Unit 3 VCE Biology consisted of two Areas of Study. Area of Study One included content on the chemical nature of the cell, role of organelles and plasma membranes in the packaging and transport of biomolecules and the nature of biochemical processes (such as photosynthesis and cellular respiration). Area of Study Two included content related to control and regulation (e.g., homeostasis), infectious diseases and the immune response.

Unit 4 VCE Biology also consisted of two Areas of Study. Area of Study One focused on heredity and included molecular genetics (such as protein synthesis), genetic tools and techniques, transmission of heritable characteristics, cell reproduction, variation and patterns of inheritance in sexually reproducing organisms. Area of Study Two included population genetics, evolution and human intervention in evolutionary processes.

Data was collected throughout both Unit 3 and Unit 4 VCE Biology and representative data has been selected for presentation from across all data sets. The topics and terms selected as part of the study were chosen because they were part of the outlined for curriculum (as described above) and had terminology that was suited to the study.

Data sets

In this study, four key data sets were collected: 1) the identification and development of the teaching procedure; 2) student responses related to using the teaching procedure; 3) teacher responses related to using the teaching procedure; and, 4) teacher journal entries and reflections based on the ongoing teaching and learning experiences of the teacher-researcher.

Teacher journal

Throughout the planning and delivery of lessons, teacher-researcher thoughts and reflections were recorded and reflected upon. Teacher journal entries included reasons for developing the teaching procedure and the perceived influence of the procedures on student learning.

Teaching procedure 1: Term recall– before and now?

Students reflected on the topic recently studied. They then used a modified version of Osler and Flack’s (2008) Linking Circles. The adopted form of Linking Circles (see Figure 1) were referred to as a *Term recall - before and now?* and used as worksheets to record the key terms that students knew: 1) at the beginning of the course; 2) terms that they now knew; and, 3) types of activities they identified that helped them to link their learning.

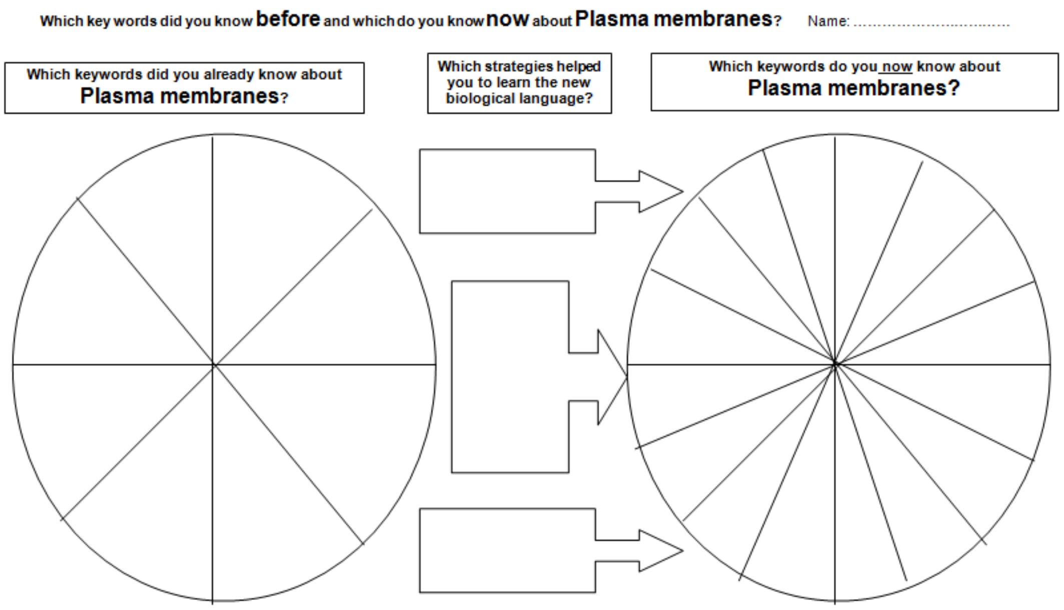


Figure 1. Term Recall - before and now? Worksheet

Teaching procedure 2: Term Recognition cards and worksheets

Teaching procedure 2 incorporated the use of term-recognition response cards to ascertain students' familiarity with the relevant biological terms of a specific topic of study. The Term Recognition cards and worksheet (and mapping of the links) procedure was often repeated either later, during, or at the end of the topic, to determine where the students were 'at' in their recognition and linking of the terms. This 'retesting' was used to determine if there were any gaps or areas that needed to be addressed before moving on to the next unit of work.

As a new biological concept was introduced, the familiarity with the relevant biological terms was ascertained. Information was obtained by students scoring each term against the criteria of a scoring sheet (see Figure 2) and by using coloured cards to quickly respond to teacher queries during class.

Photosynthesis 2011 Evergreen

How do these words fit into your current 'neural wiring'?

0	=	RED	=	Never seen the term before
1	=	ORANGE	=	Recognise the term
2	=	YELLOW	=	Recognise & can give definition or description of the term
3	=	GREEN	=	Recognise & could help others to understand the term

Term	Term comfort zone (please circle)			
autotroph	0	1	2	3
Photosynthesis	0	1	2	3
Light energy	0	1	2	3
Chemical energy	0	1	2	3
Glucose	0	1	2	3
ATP	0	1	2	3
ADP	0	1	2	3
Pi	0	1	2	3
Carrier molecule	0	1	2	3
Loaded carrier molecule	0	1	2	3
NADP	0	1	2	3
NADPH	0	1	2	3
Light dependent stage	0	1	2	3
Light independent stage	0	1	2	3
Grana	0	1	2	3
Thylakoid	0	1	2	3
Stroma	0	1	2	3
Stoma	0	1	2	3
Chloroplast	0	1	2	3
Chlorophyll	0	1	2	3
Calvin cycle	0	1	2	3

Figure 2. Example of term recognition worksheet

Participants

The student participants of this study were all studying Unit 3 and 4 VCE (Victorian Certificate of Education, VCE comprises the final 2 years of secondary (high) school education. Traditionally Units 1 & 2 are in the second last year (Year 11) and Units 3 & 4 are in the final year (Year 12). However, students can accelerate their study and complete some Units 1 & 2 in Year 10 and therefore study some Units 3 & 4 in Year 11. The study was conducted in Biology classes at a coeducational K-12 independent suburban college in Victoria, Australia, where classes were generally 1/3 male: 2/3 female and year levels studied were approximately 25% year 11 students and 75% year 12 students. The students were mostly of Caucasian heritage aged between 16-18 years. The class sizes ranged between 12 –

20 students. Most of these students had studied 'preparatory' Units 1 and 2 VCE Biology in the previous year.

Over 500 student responses were collected for each teaching procedure across the five years of the study. Using teaching procedure 1 (Term Recall – before and now?) responses to three topics were analysed: *Plasma membranes; Inheritance;* and, *DNA structure*. The same applied for teaching procedure 2 (Term Recognition cards), the three topics being: *Plasma membranes; Biomolecules; and, Photosynthesis*. (For details of the participants and timing of collection of data see Table 1.)

Table I. Term recall and recognition: Participants and timing of data collection

Type of data collection (What)	Topic (Which content?)	Participants (Who) *	Timing of data collection (When)
Student biological *Term recall - before and now*? responses	Plasma membranes	Unit 3 VCE Biology students Classes Yr3A &Yr3B (n=30)	During class at various times throughout instruction
	Inheritance DNA structure	Unit 4 VCE Biology students Classes Yr2A & Yr2B (n=26) Yr2A (n=13)	During class at various times throughout instruction
Student biological *Term recognition* cards and worksheet responses	Biomolecules Plasma membranes Photosynthesis	Unit 3 VCE Biology students Classes Yr3A (n=17); Yr3B (n=14) Yr4A (n=15); Yr4B (n=13) Yr5A (n=18); Yr5B (n=12)	Collected in lessons at various times throughout instruction

Table Key: * Yr1= Year 1; Yr2= Year 2; Yr3= Year 3; Yr4= Year 4; Yr5= Year 5; A & B refer to different classes, for example, Yr3A is Class A in Year 3 and Yr4B is Class B in Year 4

In this study, the Term recall– before and now? and Term Recognition cards and worksheets were used as both teaching procedures and as data collection tools. Students responses to these procedures form the data that has been analysed.

As the data was collected as part of and during the teaching of topics, the procedures used were chosen to ensure they were appropriate for the content being taught and the learning needs of the students in the classes. The decisions made were both pedagogical and research driven. Thus, there is some difference in the procedures being used and the timing of data collection across different topics, however, the procedures and collection are the same across the years, (see Table 1, row 3 for clarification).

Data analysis

In the *Term recognition card and worksheet* teaching procedure, while the students' response cards (coloured cards related to level of recognition − see Figure 2) provided immediate feedback to the teacher during class, completed student worksheet responses were collated and analysed after class. Familiarity scoring (i.e., combining responses for 'Never seen the term before' and 'Recognise the term'; and combining responses for 'Recognise and can define/describe' and 'Recognise and could help others understand the term') offered data for analysis of terms as well as opportunities to discern student patterns.

Although the learning of every individual student is important, and their individual responses valued, an arbitrary boundary percentage was set for analysis of the student response data. This enabled comparison across classes and topics to be more easily focused upon. For example, a figure of 33% of the students within a class was used as a 'cut off' point in interpretation for the familiarity of specific terms for both the *Term recall worksheet* and the *Term recognition card and worksheet.* In other words, terms were included for analysis once at least 33% of the students "recognised the term" (refer to Figure 4 for an example).

The 33% figure was adopted because it provided a useful visual representation that was easy to 'get a handle on' when teaching and making judgements about discernible 'response rates' in the class. It also provided a simple indication of issues that may be associated with particular terminology. The quantitative data from these 'recognition surveys' was tabulated and graphed in order to be used for interpretation and analysis.

No statistical analysis of the quantitative data was employed beyond conversion to percentages. In terms of a teacher research project and the need for efficient and meaningful feedback on practice, the quantitative data (as percentages) was used to specifically determine patterns of recall within classes and was sufficient for shaping development of, and adjustments to, both ongoing teaching and the perceived value of the teaching procedure itself in relation to the pedagogical purpose it was designed to serve. There were no expectations of generalizability, hence quantitative data served to inform the teacher rather than suggest outcomes that might be applied to broader cohorts or contexts. The qualitative data (teacher learning through the teacher journal, student learning through feedback and 'reasons for change') were the major shaping factors influencing understanding and value of the teaching procedures for practice; the formative feedback in shaping researching teaching and learning as a teacher.

Results

For each of the topics within Units 3 and 4 of the VCE Biology course that were investigated through the teaching procedures and students' responses, data sets comprised those outlined in the research design (above). For reasons of space, graphical representations and students' responses are purposely kept to a minimum in this section with exemplars being used to illustrate the nature of the data and the approach to analysis. Discussion of the data follows in each section following initial exemplars.

Teaching procedure 1: Term Recall - before & now

DNA Structure

A Unit 4 VCE Biology class (Year 2, 13 students) was asked questions regarding key terms they already knew about DNA structure and terms that they now knew, and strategies that helped their learning of the new biological language (e.g., Figure 3). The frequency of DNA structure terms mentioned by students was calculated and as only three terms scored above 33% familiarity, the 'top ten terms' were graphed (see Figure 4). It was interesting that while almost 80% of the students recalled double helix, the next most familiar terms trailed significantly behind and were the symbols 'C-G' and 'A-T' (38%). This suggested that the students were aware of the complementary base pairing of the nitrogenous bases in DNA. Although not mentioned by many students, some students (31%) recalled the names (adenine, thymine, guanine and cytosine) of these bases.

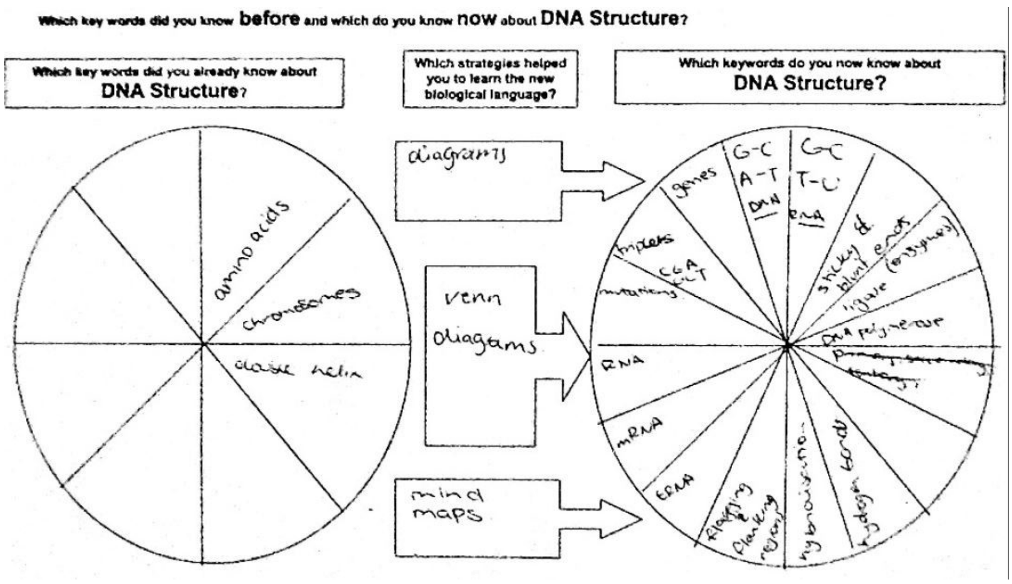


Figure 3. Year 2 Student A2 example: DNA Structure term recall worksheet

Less than a quarter of the class (23%) mentioned the terms nucleotides and chromosomes. It is interesting to note that the next most frequent terms (all 15%) recalled were phosphate, nitrogenous base, double stranded and complementary base pairing and that only one student (8%) mentioned either nucleic acids or hydrogen bonds. What was surprising was the number of students who had mentioned terms that had little relevance to the structure of DNA. The most common term was RNA (23%), followed by amino acids and uracil (15%) and finally, single stranded (8%).

In regards to new terms learned, the highest scoring terms associated with DNA structure were sugar (31%) and the bonding of complementary nitrogenous bases, C-G (38%) and A-T (31%). Surprisingly, terms related to the specific types of bonds in DNA ('hydrogen bonds between the bases' and 'covalent bonds between the phosphate and deoxyribose') were only mentioned by two students.

Less than a quarter of the class (23%) mentioned the terms nucleotides, phosphate and deoxyribose as newly learned terms. Although no students mentioned nitrogenous bases, one student mentioned nucleotide base - did they have the idea, but not the correct term? So many student responses were relevant to protein synthesis rather than DNA structure. The most frequent irrelevant terms mentioned were mRNA (23%), RNA (23%) and transcription (15%).

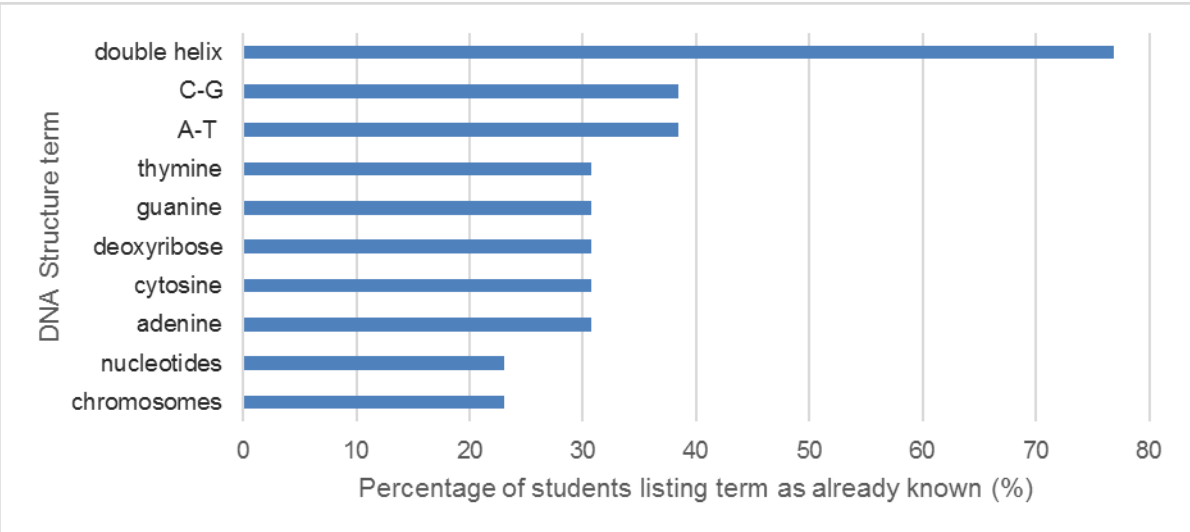


Figure 4. Term Recall: Year 2 Class A's 'Top ten already known' DNA Structure terms

Inheritance

Two Unit 4 VCE Biology classes (Year 2, 26 students) were asked to respond to the questions regarding what they knew about Inheritance before instruction, what they now knew and what helped them to link their learning. The frequency of inheritance terms mentioned by students was calculated and terms recalled by at least 33% of the students were identified and graphed (Figure 5). The two most frequently (62%) listed terms were dominant and recessive. At least half of the students across the classes, were also familiar with the terms Punnet squares, pedigrees, homozygous and heterozygous. Such a pattern was to be expected as all of these terms are included in the current Year 10 Science Genetics curriculum at the school.

What was surprising was that so few students recalled chromosomes (38%), DNA (27%), genotype (23%), phenotype (15%), and meiosis (12%), as these are also terms focused on in their earlier studies.

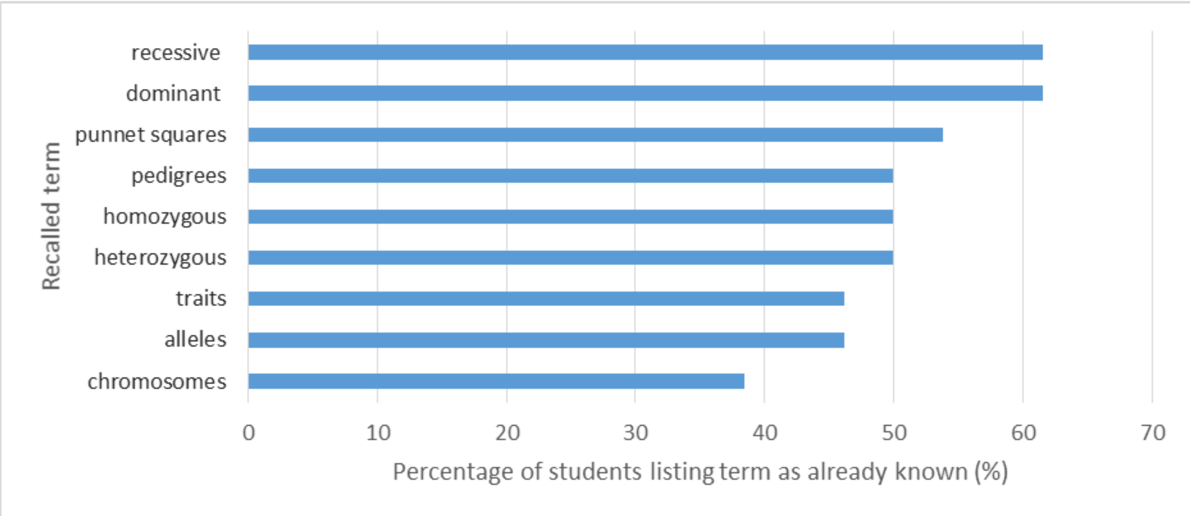


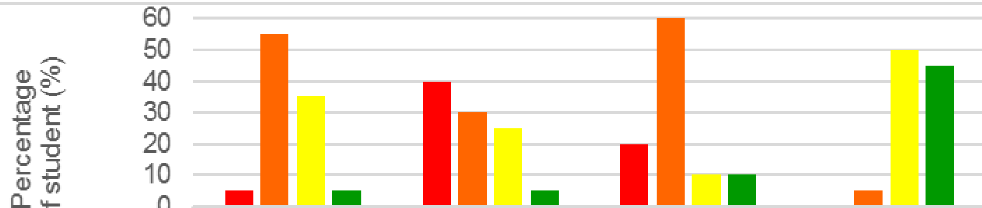
Figure 5. Term recall: Inheritance terms that as least 33% Year 2 Classes A/B students recalled

Teaching procedure 2: Term Recognition cards and worksheets

In this teaching procedure, students were provided with a list of key terms of which they ranked their familiarity, by initially circling the score on a worksheet and then sharing their response by using the appropriate coloured scoring card. Patterns in student familiarity responses could be viewed in various ways. For example, student familiarity response patterns could be used to identify which terms at least 33% of the students had never seen before, did not know the meaning of, knew the meaning of, or could explain the meaning of to others. Combinations of the student familiarity responses for groups of related terms within topics could also be used to look for patterns that provided information that could be used to plan and modify the teaching of these terms.

Biomolecules

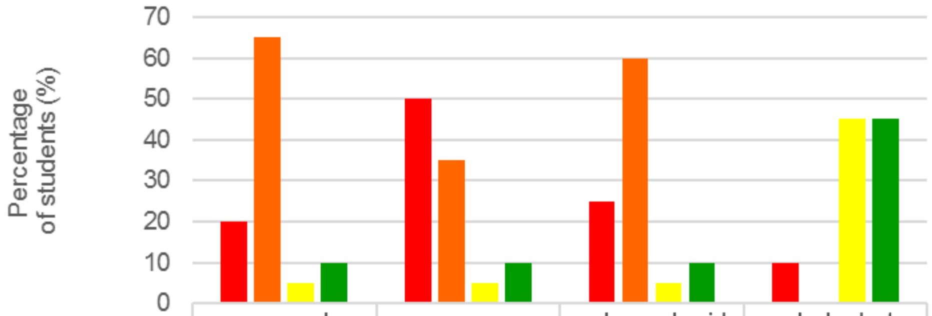
VCE Biology requires students to have a firm understanding of terms relating to carbohydrates, proteins and nucleic acids, as these are important to many of the topics studied. Figure 6 (Year 3 Class C) and Figure 7 (Year 4 Class C) show patterns of familiarity for carbohydrate-related terms. Disaccharide is the term shared by both classes as the least familiar with between 40-50% of the students having never seen it before. While many students in both Year 3 and Year 4 recognised the terms monosaccharide (95%; 80%) and polysaccharide (80%; 75%), more students in Year 3 (40% monosaccharide; 20% disaccharide) considered themselves to know their meaning than in Year 4 (15% for both terms). The carbohydrate term was the most familiar term across both years, with 90-95% of students either knowing what the term meant or could explain it to others.



	monosaccharide	disaccharide	polysaccharide	carbohydrate
never seen before (%)	5	40	20	0
can recognise (%)	55	30	60	5
can define/ describe (%)	35	25	10	50
can explain to others (%)	5	5	10	45

Figure 6. Recognition of carbohydrate-related terms (Year 3: Class C)

Analysis of patterns of familiarity for protein-related terms showed that dipeptide was the term shared by both classes as the least familiar with 45% of Year 3 students and 85% of Year 4 students having never seen it before. Polypeptide was the next least familiar term for both classes. Although 65% of students in both years recognised this term, only 40% of Year 4 students knew what it meant. In Year 3, not a single student was able to either define, describe or explain it. While 50% Year 3 and 85% Year 4 Class C students knew the meaning of amino acid, 90% of both classes could define, describe or explain proteins.



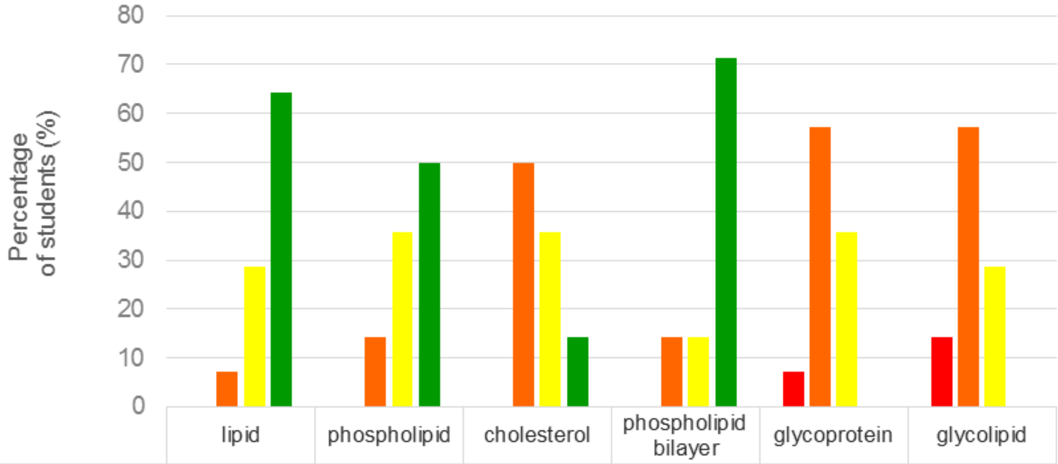
	monosaccharide	disaccharide	polysaccharide	carbohydrates
never seen before (%)	20	50	25	10
can recognise (%)	65	35	60	0
can define/ describe (%)	5	5	5	45
can explain to others (%)	10	10	10	45

Figure 7. Recognition of carbohydrate-related terms (Year 4: Class C)

Patterns of familiarity for nucleic acid-related terms illustrated that deoxyribose was the term shared by both classes as the least familiar with 35% of Year 3 students and 45% of Year 4 students having never seen it before. Ribose was the next least familiar term for both classes. Of all of these results, the most unexpected was that, in a class of twenty students in Years 3 and 4, five students responded that they had never seen the term deoxyribonucleic acid before and another five students responded that although they recognised the term, they could not define or describe it. Hence, at the start of this final secondary year biology class, 45% of the students could not define or describe deoxyribonucleic acid; a major term at the centre of their study.

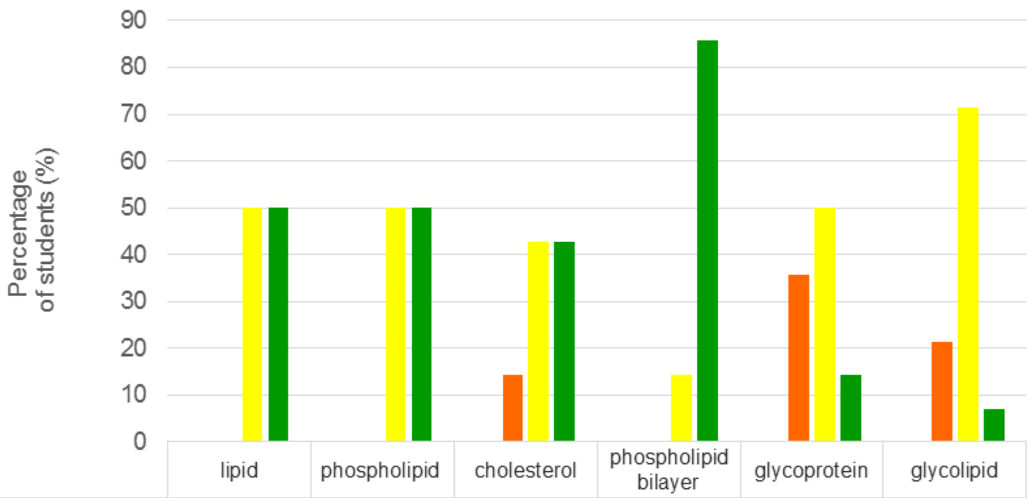
Plasma membranes

VCE Biology requires students to have an understanding of both the structure and function of plasma membranes. Figures 8 - 11 summarise changes in student familiarity with molecular-related and process-related plasma membrane terminology at the beginning of instruction (e.g., Year 4 Class A1; Year 5 Class B1) and again approximately a week later (e.g., Year 4 Class A2; Year 5 Class B2). These figures indicate changes in student familiarity with plasma membrane molecular structure-related terminology. Changes in the patterns of familiarity colours within the graphs show movement of student familiarity responses towards increasing awareness and understanding of the specific terminology. In Year 4, Class A after a week of instruction, all students felt that they knew the meaning of lipids, phospholipids and phospholipid bilayer. Student familiarity of glycoprotein and glycolipids also improved, although there were students who still required support in understanding these terms.



	lipid	phospholipid	cholesterol	phospholipid bilayer	glycoprotein	glycolipid
never seen before (%)	0	0	0	0	7	14
can recognise (%)	7	14	50	14	57	57
can define/ describe (%)	29	36	36	14	36	29
can explain to others (%)	64	50	14	71	0	0

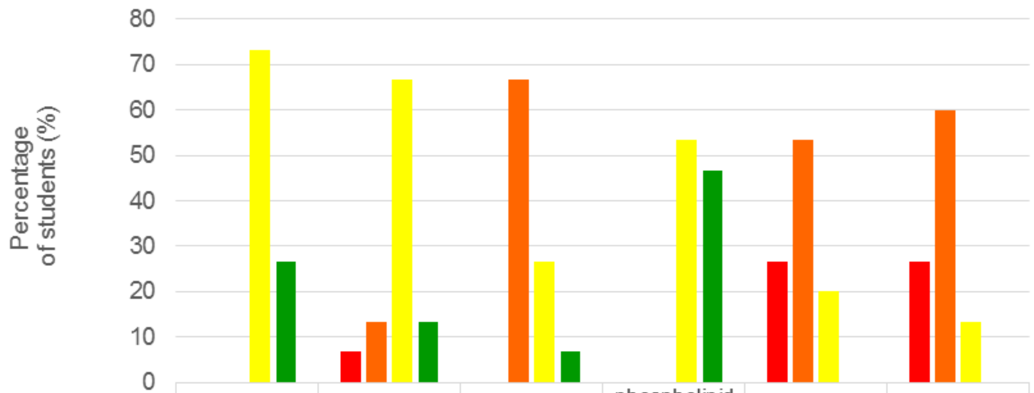
Figure 8. Recognition of Plasma membrane molecular terms (Year 4: Class A1)



	lipid	phospholipid	cholesterol	phospholipid bilayer	glycoprotein	glycolipid
never seen before (%)	0	0	0	0	0	0
can recognise (%)	0	0	14	0	36	21
can define/ describe (%)	50	50	43	14	50	71
can explain to others (%)	50	50	43	86	14	7

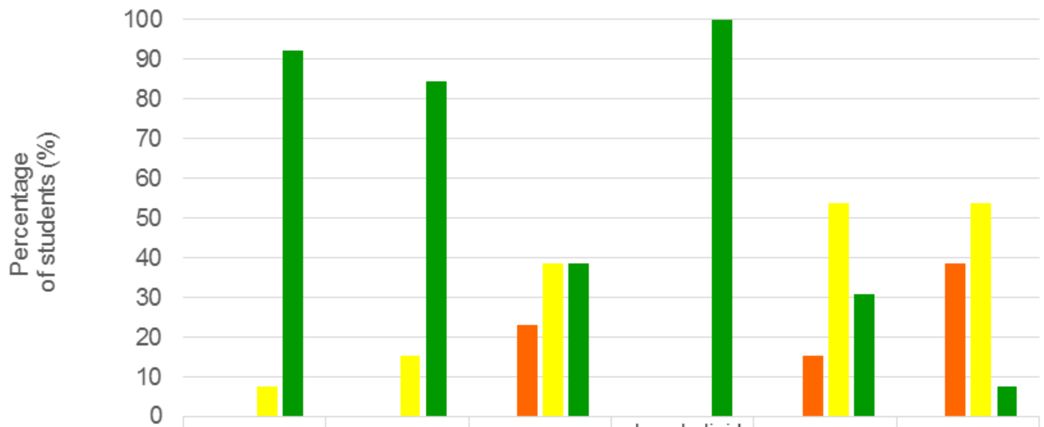
Figure 9. Recognition of Plasma membrane molecular terms (Year 4: Class A2)

In Year 4, Class B after a week of instruction (Figure 10), there was significantly more change (Figure 11) than observed in Class A. Not only did all students 'know' the meaning of lipids and phospholipids but all felt comfortable enough to explain the phospholipid bilayer to other students. As was the case with Class A, after a week of instruction, there were no terms on the worksheet that were not recognised.



	lipid	phospholipid	cholesterol	phospholipid bilayer	glycoprotein	glycolipid
never seen before (%)	0	7	0	0	27	27
can recognise (%)	0	13	67	0	53	60
can define/ describe (%)	73	67	27	53	20	13
can explain to others (%)	27	13	7	47	0	0

Figure 10. Recognition of Plasma membrane molecular terms (Year 4: Class B1)



	lipid	phospholipid	cholesterol	phospholipid bilayer	glycoprotein	glycolipid
never seen before (%)	0	0	0	0	0	0
can recognise (%)	0	0	23	0	15	38
can define/ describe (%)	8	15	38	0	54	54
can explain to others (%)	92	85	38	100	31	8

Figure 11. Recognition of Plasma membrane molecular terms (Year 4: Class B2)

Inclusion of term recall tools to probe students' perceptions of how they learn new terminology

The Term recall worksheets provided an opportunity for students to list activities that helped them to link their previous knowledge of the vocabulary (and concepts) to new learning. Figures 12 - 14 provide a summary of the top ten student strategy responses for Inheritance, DNA structure and Plasma membranes.

For the Inheritance worksheet, two Unit 4 VCE biology classes (26 students) responded, for the DNA structure worksheet, a single Unit 4 VCE biology class (13 students) and for the Plasma membrane worksheet, two Unit 3 VCE biology classes (30 students).

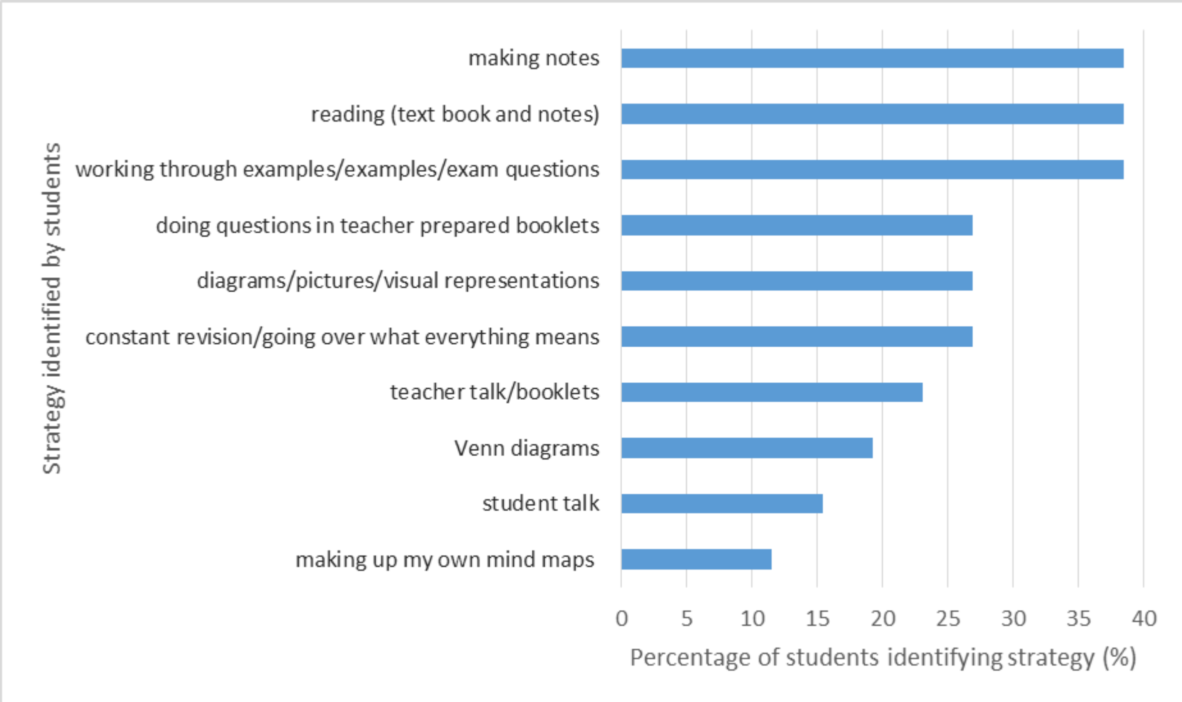


Figure 12. Inheritance recall: Student strategies used to link new knowledge to previous knowledge

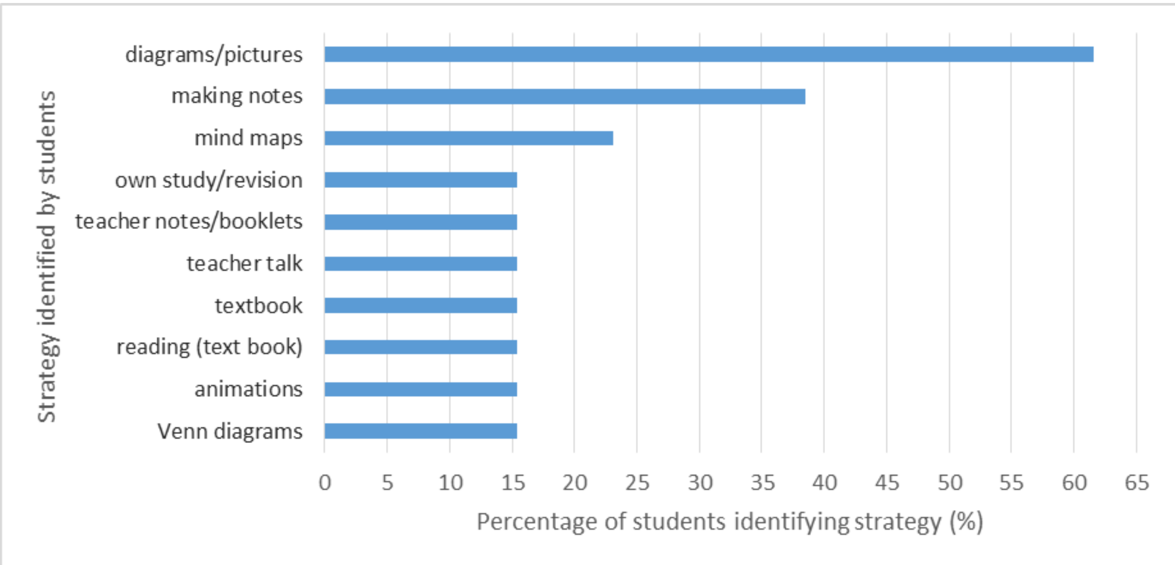


Figure 13. DNA Structure recall: Student strategies used to link new knowledge to previous knowledge

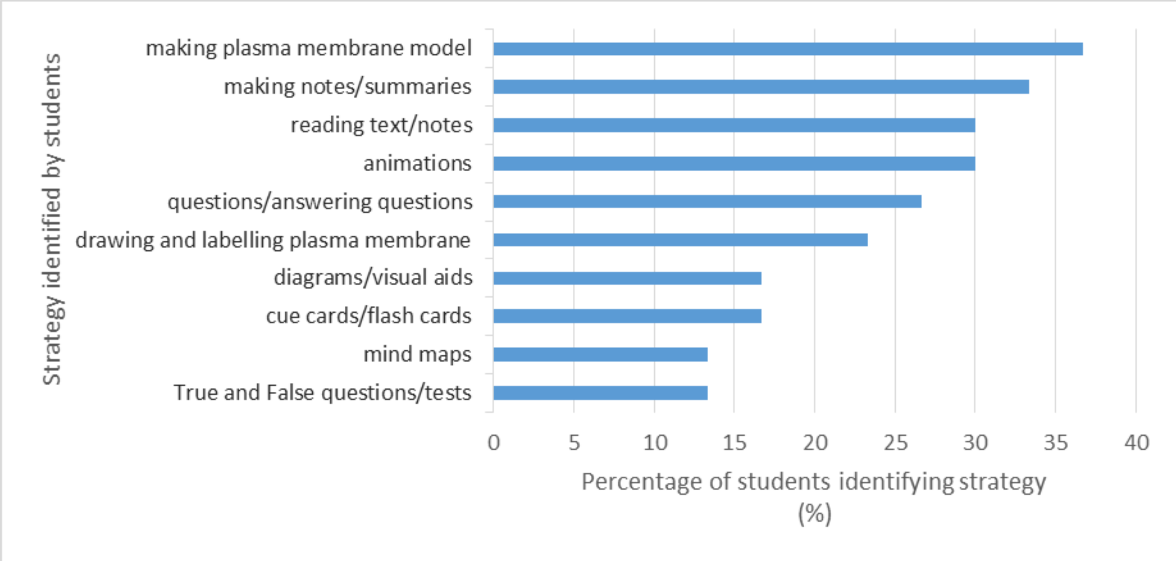


Figure 14. Plasma membrane term recall: Top ten student strategies used to learn new biological language

What are the implications for class instruction?

Figures 12 - 14 provide an opportunity to consider (in practice) Shulman's (2000) idea of 'putting the inside out' and enabling the teacher to look for patterns in it 'while it is out'. These patterns can be used to inform planning of future instruction for both classes and the individuals within them. Feedback in this small sample, suggests that many students found traditional note taking and text reading to be useful in their learning of new scientific terminology. A point that highlights an interesting issue related to the tension between knowing information and learning for understanding.

A limitation of this part of the Term Recall sheet was that it involved recall, rather than recognition. A selection of teaching procedures that students could have scored and commented on may have provided more information. A strength of this worksheet was that the teacher did not have 'control' of that which was being recalled, thus giving students the ability to recall their own choices rather than being confined to someone else's selection.

Throughout each year, variations of the 'traditional' strategies mentioned by the students were included in instruction, as were others that they may not have previously experienced. This further highlights that perhaps different activities (or teaching procedures) may be more effective when learning different types of content (e.g., structure compared to process), which appears to be the case in the views expressed through this data, and also supported in the literature (Carlson & Marshall, 2009; McTighe, 2005; Shulman, 1986). After experiencing these new 'foreign' ways of learning vocabulary and concepts, a number of students verbally mentioned that the new approaches were now their preferred ways of learning the new vocabulary. However, it must be noted that each class (even in the same subject, in the same year) appeared to develop its own preferred 'learning procedure' profile.

Finding out where students are 'at'

The term recall and recognition activities provided considerable feedback on which terms students already knew and which were foreign to them. Although the term recall worksheets provided some feedback on terms that they had recalled on Biomolecules, Inheritance and DNA structure, the feedback from the Term recognition worksheets was extensive.

The Term recognition worksheet activity on Biomolecules and Plasma membranes provided a coloured snapshot of those terms which students knew as well as those terms they had not seen before. Also, unlike the Term recall activity, they provided student perceptions of how well they 'knew' the terms.

Using a similar colour coding in the graphs as for the term recognition cards (RED = Never seen the term before; ORANGE = Recognise the term; YELLOW = Recognise and can give definition or description of the term; GREEN = Recognise and could help others to understand the term) simply browsing through the Term Recognition figure pages (for the full data sets) provided immediate feedback on student familiarity of specific terms.

Mitchell (2002) referred to the messiness of research conducted while teaching full-time. While it can sometimes be difficult to collect data around teaching commitments, it is easier if the data has immediate benefits to the direction of the lessons in which it is being collected. Such embedded data collection can lead to immediate 'informed' change to practice which may result in enhanced student learning. Collection of the student Term recognition worksheets enabled opportunities for further processing of the information. Categories or groups of terms could be considered in relation to student familiarity. The examples noted earlier in this section (i.e., carbohydrate, proteins, and nucleic acid groupings for Biomolecules; molecular structures and processes for Plasma membranes; and, chloroplast structure and molecular terms for Photosynthesis) provided very valuable information for planning for each particular class.

Once there was a snapshot of where students 'were at' with the terms at a particular point in time in their learning, other teaching procedures and activities could be used to increase their familiarity and understanding of those terms. The Figures in this paper illustrate an effective colour-coded snapshot of the Term recognition data and change in student familiarity in molecular structure and process related to plasma membrane terminology and chloroplast structure and molecular terminology for Photosynthesis.

Different types of teaching procedures and activities were seen to be more effective for teaching and learning different topics. Such a varied approach has the potential to increase the neural pathways (Gregory & Parry, 2008; Willis, 2009) in which links of the terms were incorporated and enhanced in long term memory and increase ease of retrieval as more cues may be available. Exposure of the terms to students in different ways and at different times increased their familiarity with them. This (as Spencer & Guillaume (2006) suggested), increases the likelihood of these terms moving into long-term memory.

Empowered with new awareness on student familiarity and learning from the Term recall and recognition worksheet feedback, new teaching procedures were developed to further increase student familiarity with the new terminology. (These included patterning using pre-fix and suffix cards, storytelling and predictive ‘Who am I?’; however, it is beyond the scope of this paper to go into the details of these procedures.)

Personal learning about recall and recognition teaching procedures

Teaching procedure 1: Term recall

By providing students with the time, opportunity and expectation to reflect on both previously known and new terminology and knowledge, the importance of the new language can become an explicit focus. As this study illustrates, such a focus encourages students to be more aware of connecting old and new terminology. The use of this procedure also provides students with the opportunity to focus on the specific language and to mentally link terms that they knew with new terminology.

By responding to the section of the worksheet about strategies that helped them to learn the new biological terminology, the students in this study were also reflecting on their own personal learning and that which was working for them. Such reflection, it can be argued, may increase the likelihood that they might continue to use these strategies. By allowing students to share their responses with each other, other students may become aware of, and even try out, new strategies to see how they work personally.

From a teaching perspective, analysis of these worksheets proved to be both difficult and very time consuming. At a quick glance (as is often required by teachers requiring quick feedback to inform and modify future class instruction), it was very difficult to see 'where students were' with the terminology. Some of this may be related to the design of the worksheet, the 'breadth' of the term used, the questions asked and the timing of when it was presented to the students.

In the second version of the worksheet, the wording was changed so that the students focused more on the biological terminology than their knowledge. The question at the top of the sheet changed from: "What did you know before and what do you know now about inheritance?" to "Which key words did you know before and which do you know now about DNA structure?" The first circle also changed to: "Which keywords did you already know about DNA structure?" and the second circle to "Which keywords do you now know about DNA structure?" The question between the circles also changed from "Which strategies linked your learning together?" to "Which strategies helped you to learn the new biological language?"

The design of the worksheet was also modified. 'Blank' circles were replaced with 'lined' circles. A total of eight segments were formed within the first circle by these lines and sixteen in the second circle. While this may seem a little 'slanted' in the direction of recalling more terms in the second circle, the intention was for the first circle to not be too threatening to the students and anticipated that they would know more terms after instruction. Also, while some students wrote a single term in each segment, others wrote numerous terms. This suggests that the format did not limit the number of terms that students included.

In terms of students' inclusion of strategies that helped them to learn, the rectangle was replaced with three 'arrowed' smaller rectangular shapes. Such a modification again made interpretation of the worksheets easier and also indicated to the student that a less threatening three strategies were expected. As these worksheets were given to the students towards the end of the study period on the topic, it is not clear if the students really did recall the terms that they had listed as already known. Unfortunately, it also does not provide an indication as to how well they knew the term.

While this was a useful reflection activity and provided feedback on student learning in terms of which activities helped them to learn the new language, it did not assist them in focusing on the key terms at the beginning of the topic. Such awareness, could help the students to focus on specific new terms when they were introduced or mentioned as they may then more explicitly recognise them. From this idea, came the development of the term recognition activity (Teaching procedure 2).

Teaching procedure 2: Term recognition

Students took the term recognition worksheets very seriously and used these to communicate areas that they wanted reviewed in class. On some occasions students even stayed back after the lesson to clarify their perceived ‘terminology gaps’. Occasionally, students who had scored the terms highly (‘can explain the term to others’) were asked to help others to understand them.

The recognition worksheet activity proved to be very informative as it provided very quick feedback as to where the students ‘were at’ in the beginning of the unit. It also provided the students with the opportunity to become aware of the key biological terms that they would encounter. The students took the activity seriously and appeared to be honest in their ‘recognition scoring’.

Conclusion

In her search to find a teaching procedure to determine and increase student familiarity of biological terminology, the first author of this paper thought that the answer would be simple. What she discovered was that the problem was more complex than she could have imagined. To summairse very briefly, the term recall procedure provided students with the time, opportunity and expectation to reflect on old and new terminology and knowledge and, as this study illustrates, encouraged students to be more aware of connecting old and new terminology. The use of this procedure also provided students with the opportunity to focus on the specific language and to mentally link terms that they knew with new terminology. However, this procedure did not provide the teacher with information about how well the students knew the terms and knowledge. This led to the development of the term recognition procedure, which was a quick way for the teacher to gauge where students 'were at' with biological terms.

As this research shows, while the idea of looking for a teaching procedure to assist students to learn biological terms may appear simple, putting it into practice is not so simple at all. In this research, the trial of one procedure (term recall) led to the development and implementation of another (term recognition) which led to the view that students needed help to make effective use of yet another teaching procedure (mind or concept maps). The challenges continue to present themselves and the complexity mounts, raising the question: "Is a solution even possible?"

Loughran (2010) suggested that teaching can be more professionally rewarding when it is viewed as problematic. The desire to search for simple solutions to complex problems is difficult to overcome, yet it does empower teachers to begin a journey that leaves them far better informed about their practice. While the first author had not recognised the complexity of the task that she had set for herself, the journey led her to develop and implement teaching procedures that support student learning of biological terminology and further, to increase her awareness of her own practice and inspired her to develop ideas for new and enhanced practice.

As a teacher researcher, Baumann (1996) captured the essence of the experience and illustrated why it is that teacher research matters, but also why it is perhaps under-represented and under-valued in the Educational research literature. He noted that:

> *It is through the very process of dealing with the realities of teaching while researching that [one experiences] … the costs and benefits of being [a] teacher researcher. [But there is an] inevitable, natural, and productive tension that arises when inquiry is infused with teaching. However, by struggling with ways to integrate inquiry into their work, teacher researchers come to know themselves better as teachers and persons, learn to understand their students and families in ways heretofore unknown, increase their professional esteem and credibility, share their learnings with colleagues locally and beyond, and, most importantly, help their students develop intellectually, socially, and emotionally. And that is what a dynamic, reflective, action-oriented research pedagogy is all about* … (p. 35)

We trust that this paper is a good example of Baumann's points (above) and is illustrative and helpful in terms of a strong example for students of teaching and the profession at large as to what a vision for being a teacher can mean and how it might be enacted.

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