

# COMPREHENSION OF SCIENTIFIC LANGUAGE AS A STRATEGY TO ENHANCE LEARNING AND ENGAGEMENT FOR MOLECULAR BIOLOGY STUDENTS

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The English language dominates the world today and is particularly influential as the global *lingua franca* for modern science. However, within this influence of English, it can be easily forgotten that many 'Englishes' exist. Through the advancement of scientific knowledge and the associated development of new specialisations, comes the emergence of new scientific or technical languages, based on modern English language, but distinct nevertheless. These specialised languages are aligned to particular speciality groups, for example, biochemists and molecular biologists, and are largely unintelligible to people outside these disciplines. Such languages can be considered to be foreign languages. Students studying biochemistry or molecular biology at university are initially outside these disciplines and a requirement to entry into the biochemical/molecular community is to learn the language. A focus on the specialised discipline language can enhance student learning through superior comprehension of the scientific concepts and ideas explored during their education at university.

## Introduction

Studies have previously identified that first-year biology students encounter more new words and terminology than students studying a foreign language during their first year of university (1,2). This evidence immediately identifies a possible learning barrier to students entering a science degree. When learning a foreign language, there is significant time devoted to vocabulary and grammar, and through this, translation of the foreign language to a form that is comprehensible to the student. In the long term, and after some immersion in the foreign language, it is hoped that utility in the language becomes embedded in the student, and the need to first translate the foreign meaning into the first language is no longer required. This should also be aspired to for science education. According to Wellington and Osborne (3), "... one of the major difficulties in learning science is learning the language of science... attention to language is one of the most important acts that can be done to improve the quality of science education..."

The science educator's views on the marginal role of language in learning reflect a number of assumptions about the student's and lecturer's experiences. For example, for

our first-year students, we assume that they have studied and understood high school biology, physics, chemistry, mathematics, or some combination of these disciplines. This attitude flows on into the university setting, with the assumption that students have passed the prerequisites for a particular second- or third-year subject, and hence have acquired the skills to move seamlessly into advanced undergraduate science subject areas. Another assumption is simply that if we as lecturers have managed to learn effectively at university as students, so will our current students. When entry to university was more selective, this may have been a useful assumption, but with increased numbers of students currently attending university in Australia, this can no longer be assumed. A focus on language is not about diluting the rigour of university science curricula, but developing an awareness around language that helps more students comprehend scientific concepts, encouraging them thereafter to continue towards a scientific career or further study after graduation.

## An Example of Language Interventions that Assist Comprehension in Molecular Biology

Science education provides an ideal environment for learning, with combinations of words, symbols, charts, tables, diagrams, measurements, physical movement (i.e., laboratory practicals and field trips) and so on. In other words, there is a vast range of modes and learning tools in science for communicating ideas and concepts. However, some education researchers suggest that there is over-emphasis on words only (3,4), and that ironically, science language comprehension will benefit from using other modes of representing ideas. This is encapsulated by Lemke's 'Words, Symbols, Images, and Actions' analysis of science education and communication (4). In terms of symbols and words, a useful taxonomy of scientific words has been constructed (3) and ascribes words to levels of simplicity or difficulty, with simple names at level 1, and mathematical words and symbols at level 4 (3). Of course, biochemistry and molecular biology comprise an extensive range of symbols and acronyms, which, following the logic of the above-mentioned taxonomy, introduces a high level of sophistication to our language that will confound our uninitiated students.

In the context of 'Words, Symbols, Images, and Actions', the teaching of science can learn much from the teaching of foreign languages, including the use of 'action' to reinforce the learning of difficult language meaning and pronunciation. Pioneering work by Zhang has used somatic movement to teach Mandarin Chinese at university level (5,6). However, action does not need to be vigorous when teaching language. **Fig. 1** shows an example of the application of the *Cloze* technique (7) to learning molecular biology language. The exercise is based on the analysis of a primary journal article that describes plasmid cloning and PCR to construct anti-hepatitis B virus (HBV) DNA vaccines, by engineering multiple epitope and adjuvant sequences into the final vaccinating plasmid construct (8). Rather than simple, passive reading of the text, the exercise is designed to encourage students to construct the meaning of the work via filling gaps deliberately introduced into the text. To do this successfully, students need to actively read the journal article text (in this example, the Materials and Methods section) to find the actual words or terms, or to find clues to answer the gap-fill question. This task is supported by *Hot Potatoes*<sup>TM</sup> software (9) and allows the designer to embed clues into the exercise (see **Fig. 1C**).

Student action, therefore, completes the passage by extracting meaning from the journal article. As described by **Fig. 1**, the exercise comprises four sections. Part A is a 'chunk' of text copied from the original journal article unchanged; this represents the 'foreign language' to be interpreted. Part B is the lecturer's overview and summary of the article, and is intended to present the core purpose of the article in accessible and clear language. The early phase of the gap-fill (*Cloze*) exercise, Part C, introduces language gaps about the biological question being addressed by molecular biology (in this case, the immunology of vaccines), while Part D addresses the fundamental molecular biology applied to the question. The students need, therefore, to make sense of the passage in terms of PCR and cloning strategies used in the study to make the DNA vaccine (8).

Online activities like that described above can also be undertaken offline, in lectures or tutorials and in a group format. Other language interventions can be used in tutorials, such as group 'mix-and-match' exercises, text translation and deconstructing scientific words, expressing concepts in pictorial form and so on. Again, these examples use student action in some way to encourage learning; this includes having students leave their seats and move around the tutorial room. But does such language focus and intervention ultimately help students understand the science?

## Fig. 1. An example of a Cloze (gap-fill) exercise used to promote language comprehension for molecular biology students.

The exercise is focussed on the Materials and Methods section of a journal article describing the application of PCR and the genetic engineering of plasmids to create a DNA vaccine construct for hepatitis B virus (HBV) (see ref. 9). **Part A** of the exercise is the reading "chunk" taken from the journal article unaltered (Materials and Methods) and requires translation by students. **Part B** is an overview of the journal article in simpler language and explains the purpose of the study. **Part C** represents the early section of the *Cloze* exercise that features the biological problem being addressed by molecular biology techniques, in this case, vaccine immunology and the role of helper T-lymphocytes. **Part D** is the section of the exercise where the students need to answer questions and complete sentences concerning the molecular biology techniques utilised by the authors to construct their anti-HBV DNA vaccine.

### DNA Immunisation for HBV using plasmids - Gao, Peng et al. MATERIALS and METHODS

#### The language of plasmid-based DNA cloning (Gap-fill exercise)

Read the original text from the Gao et al. paper (on the left) and then attempt the exercise. Fill the gaps with the appropriate words/terms to complete the story ...

#### Materials and Methods

MTE5 splicing and cloning: MTE5 was designed to consist of HTL epitopes from heat shock protein 65 of mycobacterium tuberculosis (aa1-20), E2 polyprotein of rubella virus (aa54-65), artificial epitope (PADRE), heat shock protein 60 of chlamydia trachomatis (aa35-48) and tetanus toxoid (aa830-843). These epitopes were translated into a 219-bp fragment of DNA sequence. Then, it was synthesized in four oligonucleotide fragments, which were linked together using splicing by overlap extension. The oligonucleotide fragments F1 and F2, F3 and F4 were spliced by PCR at first. The purified products were spliced together again to generate MTE5. The construct of pUMTE5 was generated by cloning MTE5 into plasmid pUC18 at the site between restriction endonucleases BamHI and Xba I. pcMTE5 then was obtained by sub-cloning MTE5 from pUMTE5 into mammalian expression plasmid, pcDNA3. The sequence of MTE5 in pcMTE5 was confirmed using automatic DNA sequencing ... HBV pre-S2/S gene cloning: Pre-S2/S fragment of HBV was obtained using pTZ19U-HBV as a template, and HBV-P1 and HBV-P2 as primers. The purified product

Introduction: The theme of this paper is "DNA vaccination", and in this study the infectious agent of interest is Hepatitis B virus (HBV). It has been found that the injection of raw DNA can elicit a protective immune response. Recombinant plasmids can, therefore, be designed to carry genes or sequences that encode antigenic peptides or proteins. This paper shows how various DNA sequences were spliced together to produce a multi-epitope vaccine, which in theory, should prime for an enhanced and more vigorous immune response to HBV.

Exercise: MTE5 is a set of HTL (  Clue? T-lymphocytes) epitopes (structures that induce a cellular  Clue? response)

The DNA sequences for cloning were predicted from the protein sequences of the above epitopes. Four fragments, F1-F4 were amplified by \_\_\_\_\_ and the separate sequences joined together for cloning. MTE5 was first cloned into the plasmid \_\_\_\_\_ to make the new plasmid construct pUMTE5. MTE5 from pUMTE5 was then sub-cloned into the mammalian \_\_\_\_\_ plasmid pcDNA3.

(D)

## Does Attention to Language in Undergraduate Molecular Biology Assist Student Performance?

A language and comprehension study of second-year undergraduate genetics students was conducted and involved a number of foreign language interventions like those mentioned above, including the presence of the language expert in lectures and tutorials to guide teaching strategy and identify language issues. The results of this study have been published (10), and in short, showed no significant increase in performance for either the theory examination or overall performance across the collective student cohort, compared to earlier student cohorts who had traditional transmissive teaching. Nor was there significant movement of students from Pass to Credit, or Credit to Distinction/High Distinction levels of overall attainment in the language cohort compared to earlier, traditionally taught genetic student cohorts. For all student cohorts compared, the final theory examination was identical and the continuous assessment similar. Therefore, there was no significant impact on overall student cohort performance obtained from language-centred instruction.

However, when examining student performance at an individual level, an interesting association was found between performance in genetics and individual student performance across their whole degree, as measured by grade point average (GPA). There was a significant correlation ( $r=0.64$ ,  $p=0.045$ ) between student performance for genetics and degree GPA, but only for the Distinction students. Furthermore, this association between specific academic performance in genetics and overall degree performance (GPA) was only seen for the language cohort and not for previous genetics Distinction cohorts taught under a traditional regime between 2001-2004 (10). Teaching interventions such as those described here are generally aimed at assisting the less able students, hoping to increase the opportunity for failing students to pass. This was not the case for the genetics language intervention, with the best students appearing to benefit most through maintaining their high level of academic achievement in genetics, whereas Pass and Credit students had wide variation and no consistency when comparing success in genetics to their overall degree GPA.

While the quantitative analyses identified some issues on language-centred education that required further consideration, the qualitative survey data pointed to some very positive experiences of student learning in genetics when there was a language focus. The following feedback was received through open-ended questions: "...breakdown skills used to read journal articles were useful in every other subject"; "...develop(ed) skills in understanding scientific papers (using language exercises)"; and "...became much more dependent on finding answers for themselves rather than relying on being told all the time" (10). This is very encouraging, as these issues, identified via student feedback, show an enhancement of generic skills via language learning strategies.

An identical study was performed with a cohort of

molecular biology students. Again, interventions focussed on language learning were utilised, with direct input and guidance from the language expert collaborating on the project. The molecular biology unit teaching structure is different to the aforementioned genetics unit examined for the earlier study. Genetics is tutorial based, with no wet laboratory classes, while molecular biology has a significant laboratory practical component (36 hours over the semester) covering RNA and RT-PCR, plasmid-based DNA cloning, including the isolation and purification of plasmid DNA, and a PCR project on human genetics. For the molecular biology language study, transmissive lecture content was reduced, with time in lecture periods devoted to language tutorials, exercises and explanations. Exercises like that described in **Fig. 1** were often used in these sessions to promote discussion and explain concepts.

Similar to the results from the genetics study (10), there was no significant improvement in academic performance for the total molecular biology language cohort compared to earlier student cohorts studying molecular biology. However, for higher performing molecular biology students, there was a significant correlation with GPA (**Table 1**). For this study, High Distinction and Distinction students were pooled, as were Pass and Fail students, because of low numbers in individual grade categories. Similar to the findings of the genetics study, the introduction of a scientific language focus enabled the Credit and Distinction/High Distinction students to maintain performance in accord with their overall degree performance, as measured by GPA. This suggests that the superior students are able to adopt new learning styles more readily and incorporate them into their study routines. Alternatively, the possibility exists that the less able students experience such a new regime as an encumbrance to their study patterns. Further examination on the link with GPA is required; correlation measures association only, and it is possible that many Pass/Fail students performed better under the language regime, but this was not consistent across the student cohort. This issue cannot be studied adequately at the moment because of low numbers, but in future, longitudinal results across Pass/Fail cohorts will be pooled to determine the impact of language teaching for less able students studying molecular biology.

## Conclusion

The language in which ideas, concepts and details are communicated by molecular biologists and biochemists is a foreign, specialised language for students entering these fields, and therefore, is a barrier to learning these disciplines. With a greater attention to teaching our language to students, the hope is that learning and comprehension of scientific ideas will be enhanced, leading to students being better equipped for university study, and a greater potential to retain students in science. The issues associated with language in scientific education have been a topic of investigation for around forty years (3), but have not been generally embraced by science educators.

**Table 1.**

A University of Canberra Molecular Biology student cohort taught with a language emphasis and ranked according to the final overall mark (all assessments) achieved at the end of semester. Within each range, each student's GPA was paired with their final overall molecular biology mark out of 100, leading to the calculation of a group correlation coefficient ( $r$ ) for each final mark category.

Overall Final Mark – Range (%)	Correlation ( $r$ ) of Final Mark (%) versus GPA <sup>†</sup>	Mean GPA	Mean Final Mark (%)
90-75 (n = 26)	0.41*	5.27	80.23
74-65 (n = 24)	0.46*	4.57	70.26
< 64 (n = 15)	0.16	4.03	53.55

\*  $p < 0.05$

A probability of  $p < 0.05$  indicates a significant variation from  $r = 0$ , or independence of the two variables.

<sup>†</sup> GPA = Grade Point Average. This is a measure of student's performance across their degree program. For example, a High Distinction contributes a score of 7.0 to the GPA, whereas a Distinction scores a 6.0, a Credit scores a 5.0 and a Pass scores a 4.0. These scores are averaged across the degree whether complete or partially completed. To be included in the above study, students needed to have completed an entire first-year study load (8 units). The maximum GPA score is 7.0.

Formal language intervention involving collaboration with an expert in tertiary language education and linguistics has been conducted for students studying undergraduate molecular biology and genetics. The results from these studies suggest that at a whole cohort level, language intervention and focus made no difference to student performance, but through correlational analysis, high-performing students benefitted most from introducing a language focus. Student feedback data, though, identified several very positive outcomes in the student learning experience through a language focus, particularly in the enhancement of generic skills essential for university graduates. Further longitudinal analysis is required to understand the learning dynamics of Pass/Fail students, with the intention of tailoring such teaching approaches to their needs as well. Investigation is also required to track whether students exposed to language learning improve their performance in subsequent science units. Through feedback, students reported that the language skills learnt were applied to other units in their degree (10). Therefore, the impact may not be immediate. Language intervention did not impact negatively on student performance, with similar Pass, Credit and Distinction rates found for language versus non-language cohorts. Further language focus and refinement of language teaching techniques will aim to ultimately benefit all students during their science education, in terms of grades and educational experience.

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