Optimising Accurate Academic Language Skills for Engineering Higher Degree by Research Students

Alison-Jane Hunter, Professor Colin Kestell and Dr Margaret Cargill
The University of Adelaide
Corresponding Author Email: Alison-Jane.Hunter@adelaide.edu.au

CONTEXT
Engineering HDR students (EHDRs) with low level language skills contribute disproportionately to low completion rate statistics and high supervisor workloads. The research presented here is investigating a novel, tri-partite approach to language learning, in the distinctive context of engineering modes of cognition, designed to accelerate the development of EHDRs' language learning skills. Drawing together threads from Systemic Functional Linguistics (SFL), Editing Practice (EP), English for Academic Purposes (EAP) and Gifted and Talented Education (GATE), it builds around a needs analysis conducted with EHDRs at the University of Adelaide, which include a significant cohort of international students at this level of study. The solution seeks to engage at both intellectual and emotional levels, creating flow or intense learning experiences.

PURPOSE
The purpose of this research is two-fold: to explore how engineers learn and to align language teaching pedagogies to engineering modes of cognition (EMoCs).

APPROACH
This early research uses Participative Action Research (PAR) spirals to ensure that learning and outcomes are egalitarian in nature and constantly refined in the light of all possible information. The spiral components are a) purpose-designed Language Trees, b) a Concordancing tool using a new corpus fashioned from extant, recent, published Mechanical Engineering journal articles and c) a Systems Engineering tool: a new app using Boolean logic to enhance self-editing skills. The evaluative data is both qualitative and quantitative, collected using a mixture of specific questions which require responses on a seven point Likert scale and semi-structured interviews/questions to enrich the numerical data.

RESULTS
Early results are currently available from the first two spirals, evaluating the use and impact of the Language Trees and the Concordancing tool for Mechanical Engineers. These results show high levels of engagement, the transfer of skills from the research workshops to free writing and support in dealing with both perfectionism and imposter syndrome, leading to an improvement in engagement and flow in the students' own work.

CONCLUSIONS
Tentative current conclusions include 1) that the approach is working effectively to lift engagement and up-skilling of students; 2) that the physical-tactile, visual-spatial nature of the Language Trees is highly engaging for self-editing purposes and 3) that the Concordancing tool is solving both specific collocation issues and issues surrounding noun phrases in expository writing, using a headword system for phrase generation. We are hoping to have completed very early trials of the Systems Engineering tool (an online grammar device using both SFL and Traditional Grammar (TG) approaches) by the time of final full paper submission.

KEYWORDS
Self-editing skills, Accelerated Language Learning.

Context

It is acknowledged in Universities across the world (AARE, 2004) that failure to complete is a significant issue for Higher Degree by Research (HDR) students and their supervisors. Internationally, some 50% of HDRs fail to complete. Coupled with this damning failure rate, students are becoming more litigious in their approach to study, adding to pressure on Universities to graduate their students (Hodges, 1997). The funding rules are changing to tighten timeframes for completion, challenging both supervisors and students. This is a direct, governmental and administrative response, using funding mechanisms to try to drive up low completion rates (AGC, 2016). Schools and Faculties are therefore looking urgently for positive, evidence-based solutions to completion issues, notably (but not exclusively) in terms of language issues for non native speakers of English (NNSEs).

The student group recruited for the research was drawn from the first and second year of candidature from the Faculty of ECMS. 16 students were recruited. Of them, 9 are NNSEs, 2 are NSEs and 5 are NSEs with background EAL/D. Regular, full attendance at the monthly workshops has been an issue, despite reminders and catch up workshops being offered.

Beyond the practical issues associated with non-completion, there is the ethical issue of how to support students accepted by universities to high-level courses, who struggle with language issues. There is a range of outcomes when students feel out of control with language. These include the destruction of confidence through the inability to express themselves effectively in speech and writing, reinforcing Imposter Syndrome (a crippling fear of failure due to high expectations) and damaging well-being (Caltech Counselling Centre, 2016); lowering of acceptance rates for journal articles (Elsevier, 2015) and theses; take up of supervisory time for writing accuracy issues rather than conceptual development and the impact of failure to complete which leaves students some three years older and significantly poorer than when they started the process (Times Higher Education, 2011).

Universities recognise that they have an ethical and business interest in solving these issues and so they have instigated a range of administrative responses, including increased levels of milestones such as the new career and research skills training (CaRST) 120 hour requirements (AGC, 2016) at the University of Adelaide. Effectively, the CaRST framework gives an immediate reward for attending language training so that good habits are secured for future years. This initiative means that there is an opportunity to increase significantly the number of directly rewarded language skills training hours made available to students. To date, however, a formalized, researched approach to language development designed specifically to engage EHDRs is lacking.

Purpose:

The purpose of this project is to develop a positive remediation strategy for language issues, designed specifically for engineers and aligned with engineering modes of cognition (EMoCs), using an evidence-based, multi-faceted approach.

Approach:

The research uses Participative Action Research (PAR) Spirals (Pain, Whitman, Milledge, no date given) for its core methodology, as this is very early research. The research is egalitarian and positive in nature, driven by the needs of all participants and outcome-focused for engineers. The outcomes are evidence-based, as review happens consistently throughout each Spiral. The Spiral nature of the research enables the refinement of ideas through regular reviewing of the issues. The questions, approaches and outcomes are specifically designed for EHDRs.

The pedagogy used for delivery of the workshops is designed to match and facilitate this egalitarian, PAR approach, so all teaching uses the Harkness Model/Pedagogy, which

encourages equality of engagement and a co-operative, group-orientated response, in alignment with engineering skills. Harkness classrooms (Stevenson School, 2016) are characterised by operating around a large oval table, which invites quality discussion in an egalitarian environment. The researcher's responsibility is therefore to encourage focused, open discussion, without giving any direction as to outcomes of that discussion.

The PAR Spirals (see Figure 1) enable all the participants to both develop and revisit ideas in each spiral of the research. In Spiral 1, the MOG TREEs (Mechanics of Grammar with Theme and Rheme for Engineering Education) were introduced to the students. In Spiral 2, the Mechanical Engineering corpus was introduced using *AntConc* (Anthony, 2016a) as the Concordancing tool. In Spiral 3 the Systems Engineering tool for grammar (using both SFL and TG) is introduced. The aim is that all three elements are used in harmony as the students control and select which tool to use for each language instance. The testing runs from pre-testing to set a baseline, to continuous quantitative testing of the emotional responses of the students to the various elements of the research solution, to rich qualitative data generated by consistent interviewing of students throughout each element. This data is used to adjust the elements of each component in a feedback loop. Mid and Post Spiral testing will also be used to evaluate changes in writing through and at the end of the workshop series.

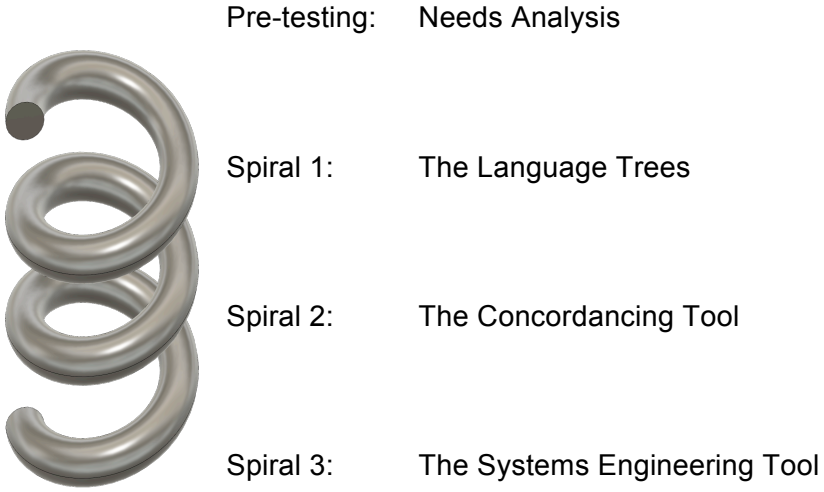

Figure 1: The Spiral Approach for PAR

This work is based on key ways in which Engineers learn. Engineering modes of cognition (EMoCs) are a key focus: that is, learning which is tactile, kinaesthetic, visual, spatial and highlights practical problem solving (Royal Academy of Engineers, 2014). By replicating these modes of learning in the target domain of language learning, the research designs a solution which is engineering driven, practical and should accelerate learning in a way that is familiar for the EHDRs, enabling them to move from the known to the new (Johan Herbart *cit* Egan, no date given).

There are four methods of collecting data derived from the research workshops: a) test type 1: a detailed SFL analysis of a sample of language in Workshop 1 to give a baseline outline of skills, b) test type 2: continuous testing of how the participants respond to each element of the workshops using a 7 point Likert scale which creates a set of responses to give quantitative data to review emotional response and flow, c) test type 3**:** semi-structured questions to give the rich data of qualitative responses to the mechanisms and outcomes of learning and d) test type 4: a detailed SFL analysis of a sample of language in Workshop 10 to give a measured outcome of the application of learning

The kind of language that is the focus of this research is formal, academic engineering language. It works at four levels: a) word level e.g. word choice, word form, word order, b) sentence level e.g. syntactical connections, grammar, here SFL, which is a dynamic, descriptive approach to language, alongside traditional grammar (TG), which is more familiar to some EHDRs, c) paragraph level e.g. cohesion between and across paragraphs and paragraph structure and d) genre level, sometimes called *text type*, that is the form and style of writing required for a particular kind of writing such as an article, report or thesis.

The identification of the language issues (see Table 1), which lie at the heart of this project, is derived from the needs analysis, where the students identified four key approaches to language and learning with which they needed support:

Table 1: Student-perceived requirements, based on the needs analysis (N=16)

Help at word, phrase and sentence level	Help at genre level
Support with the clarity and consistency of the requirements for writing across the School and, ideally, Faculty	Greater help for non native speakers of English (NNSEs) and recognition of their social and cultural needs within the teaching of English

These results from the open-ended questions in the needs analysis became the first set of benchmarking targets for the project. If the tri-partite system can support these targets, then the research will have been successful at a socio-affective (that is, a social-emotional) level.

The pre-test of writing was designed to analyse real error types and rates made by our EHDRs. The language analysis shows three key areas that strongly align with these requests. The most significant errors fall in three key areas: errors with word form, word order and genre. This reinforces the need for a solution to these particular error types.

Each workshop followed the four-part lesson model, which has been shown to be the most effective in terms English as an Acquired or Additional Language or Dialect (EAL/D) learning (Martin and Rose, 2005). This model requires the following sequence to encourage language learning: a) understand the context of the writing, b) deconstruct example texts, c) jointly construct and/or critique texts and d) construct new language instances, independently.

Spiral 1: the Language Trees

Using an Engineering Design approach to the requirements for language identified through the needs analysis, an optimised tactile, visual, spatial approach was sought. The Language Trees (see Figure 2) are visual-spatial, physical-tactile objects that echo Engineers' favoured modes of cognition, that is, learning which is tactile, kinaesthetic, visual, spatial and highlights practical problem solving. They have hexagonal trunks, which are large enough to use for building paragraphs, with individual branches that can hold titles, thesis statements or any other element of writing on their leaves. They are specifically designed to engage the students actively and encourage movement from the known (problem solving) to the new (this problem to be solved) (Johan Herbart *cit* Egan, no date). Furthermore, they are easy to edit, inviting students to optimise their skills without fear of failure.

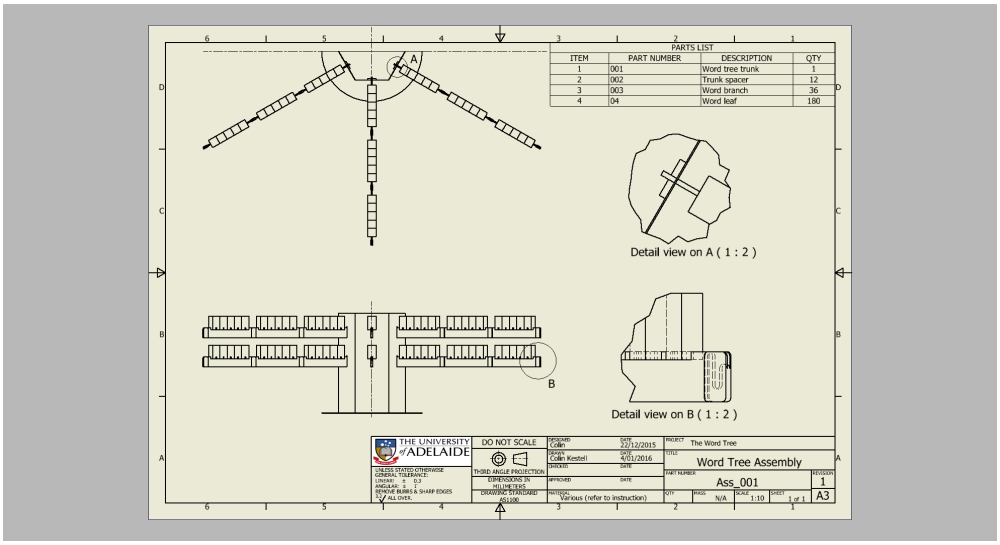

Figure 2: Envisaging the Language Trees

When using the trees in the joint construction phase of the workshops, the participants worked with extant sentences taken from published writing from our own staff. Knowing these were good, we then explored variant forms of the sentences to consider the effects of different movements of the language involved. The participants then moved into independent construction and worked with their own writing, considering both accuracy and impact. Interestingly, the participants report in the semi-structured interviews that they are taking this learning into their own free writing. This is extremely difficult to achieve using traditional teaching and learning methodologies (Day and Goldstone, 2012; J. Counsell, 2005).

Key results to date

The total, original number of student participants is 16. Of these, 9 are NNSEs, 2 are NSEs and 5 have background EAL/D. The number attending each workshop varies significantly. The number completing the feedback is given for each section of the responses.

Spiral 1: The Language Trees

The students have offered the following reactions to the Language Trees on being asked the open-ended question *are the Language Trees useful:* a) they're flexible for deciding and instituting large changes, b) they make language clearer and easier to follow, c) the work feels compact and focused, enabling important information to be placed (literally) at the beginning and the end of sentences and paragraphs, d) the Language Trees make the flow of the original sentences move into more, clearer sentences and e) the Language Trees encourage changes in meaning.

The students were then asked the open-ended *in what ways are the Language Trees useful*. The students felt that a) the Language Trees are a strong visual aid, focused on sentence structure, b) the Language Trees help students to focus on the structure and order of individual words, c) that changing words on this scale across the Branches had an impact on how they saw words on a bigger scale, elsewhere, d) that the Leaves encourage evaluation of every single word, ensuring the 'little' words which are so often inaccurate are also considered and e) that the process intensifies and re-values the experience of writing.

A workshop on basic grammar was included, prior to the development of the Systems Engineering tool to check whether it was seen as important (this is an instance of where the Spiral system enables the students to take an active role in determining the research direction). The results to the question *how useful is the teaching of grammar as a discrete course* affirm (see Tables 2 and 3) the need for a separate, interactive grammar support

system. The students were asked the open-ended question *would knowing about grammar helped you to edit your own work*. They felt that a) it made it easier to make the words flow, b) that grammar is essential for self-editing as it gives control to the user, c) that a grammar workshop still had limitations as the level of facility with grammar limited the accuracy of the writing and d) that grammar alone is not sufficient to ensure natural language use. This supported the construction of the SE, grammar tool for Spiral 3.

Table 2: Sample responses to the question: how useful is the teaching of grammar as a discrete course? (N=5)

Pre-teaching of basic grammar course	1	2	3	4	5	6	7
Positivity		20%	20%		20%	40%	
Usefulness of Grammar				20%	20%	60%	
Engagement					65%		40%

Table 3: Sample responses to the question: how useful is the teaching of grammar as a discrete course? (N=4)

Post-teaching of basic grammar course	1	2	3	4	5	6	7
Positivity					50%	50%	
Usefulness of Grammar					25%	50%	25%
Engagement					75%	25%	

Clearly the grammar tool will need to address the issues identified in the open-ended questions in the needs analysis. By using both SFL and TG, contextual language learning can be supported to refine understanding of language in context. Boolean language will be used to reinforce the need for selection of language from the whole field of possible language choices and the detailed approach will enable students to narrow that field down for specific instances of language.

The numerical data shows strong approval ratings for the use of the language trees amongst the research group. The engagement levels are very high and the focus on language leads to a wider engagement with language issues. This engagement is vital as it leads to flow (Csíkszentmihályi, 2008). Flow is a state of positive engagement with work, to the exclusion of all distractions.

Spiral 2: the Concordancing Tool

The purpose of Concordancing is to consider language-in-context, by examining significantly sized corpora of extant work on a specific subject. Concordancing is useful for looking at: a) the frequency of language use, b) collocations, that is, which words go with which others and c) the position of words within sentences. It is used to enhance fluency and idiomatic language usage (The British Council, BBC, 2016; Anthony, 2016; Boulton, 2012). The Concordancing tool (see sample search results: Figure 3) gives answers in terms of statistically driven collocation agreements and therefore supports the use of the Language Trees. A key observation for Concordancing is that it is essential that the corpus placed into the Concordancing tool (here, *AntConc* developed by Anthony, 2016a) must contain language that is appropriate for the purpose of the search. Thus to create a Mechanical Engineering Concordance, the Corpus here consists of some 750,000 words, taking from published articles by Mechanical Engineering teaching staff at the University of Adelaide.

The corpus is flexible and individuals can personalize it by adding in further articles of their choice.

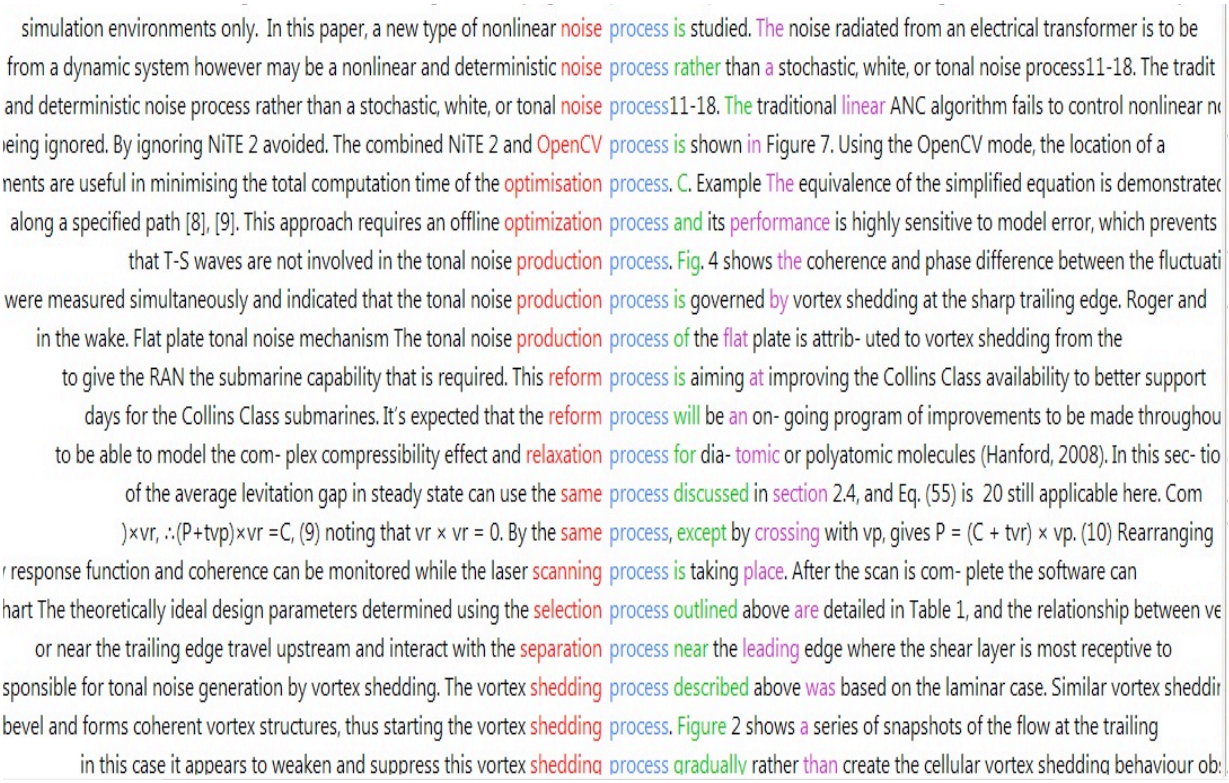

Figure 3: Example of output from a Concordance search of the Mechanical Engineering Corpus showing collocations with the search term "process"

It has been very challenging to engage the student participants in the Concordancing workshops. There proved to be great resistance to this tool for self-editing. Despite evidence that Concordancing can lower error rates by some 50% (Kaur, 2004), only a small group attended the workshops, despite multiple opportunities to engage with Concordancing. Whilst those who attended approved of the Concordance in specific instances, it would appear that this tool misaligns with the EMoCs and so, is less likely to be selected by the students than the Language Trees themselves. This is particularly true for the NSEs.

The cases in which Concordancing are particularly useful are a) glossing, which enables the enhancement of technical, academic language learning, b) signposting, which enables variety and accuracy with signpost words, c) use of technical terms, where language in context enables accurate, discipline-specific language learning and use, d) use of the corpus itself (the body of language placed into the Concordance) supports nuancing and phrasing through searching headwords in context, e) preposition use, where NNSEs find extreme difficulty in achieving accuracy, f) issues of typicality and repetition, through searching the corpus itself and g) the use of hyphens, by searching language in context.

In terms of glossing (that is, using the Concordance as an electronic version of a Glossary), the results were very mixed with only 40% of students responding at all positively. In response to the open ended question *how likely are you to use the Concordance tool now that you understand how it works* 60% felt that they were more likely to use a dictionary, with which they were more familiar. 20% understood that the Concordance offers *language-in-context* in a way that is inaccessible from a dictionary but familiarity won over this issue for the majority, notably the NSEs and those with background EAL/D.

In terms of preposition use, only the NNSEs students felt that it would be useful. However, they were particularly positive about using the tool for this purpose. They were clear that

dictionaries are unhelpful with collocations and therefore using a tool focused on language-in-context is a significant support. This aligns with previous research, as indicated above.

In terms of using the corpus itself to locate headwords and typical phrases (notably but not exclusively for introductory dependent clauses), the responses were mixed again. Once more the NNSEs were far more interested than the NSEs. Some students were very clear that this would enable them to vary their phrasing more effectively and accurately, avoiding repetition by increasing their options, whilst being confident that they were still retaining a formal, academic voice.

The NNSEs and background EAL/D students thought that Concordancing would be useful for checking hyphen use in noun-noun, adjective-noun and adjective-adjective phrases.

In terms of the Likert scale responses to the question of their emotional response to Concordancing and its potential use, the results were very scattered (see Table 4).

Table 4: Percentage of workshop attendees (N=5) selecting each scoring option after being introduced to Concordancing (1=of little use, 7=very useful)

Would Concordancing be useful to you?	1	2	3	4	5	6	7
		20%		40%	20%		20%

Despite some significant resistance to Concordancing, it is clear that for NNSEs and background EAL/D students, it has some clear benefits and produced a positive response. For NSEs, it is perceived as less useful and that is reasonable: language-in-context is far less of an issue for them and a familiarity with academic language and use of a quality dictionary would produce enough information for these students. It is perhaps worth noting that one of the NNSEs students was so excited about the benefits of using the Concordancing approach that, without asking permission in advance, she sent the entire corpus and the instructions on how to enter it into *AntConc* back to her home university on the grounds that her friends truly needed it.

Spiral 3: The Systems Engineering Tool

The final element in the package of solutions is the Systems Engineering tool (see Table 5). This is a brand new online resource being created as this paper goes to review, designed to use Boolean logic (Babbage, 2016; Oxforddictionaries.com, 2016) to lead the students through the maze of questions that confront the unconfident user of language. Its design responds to the student needs identified after a basic grammar workshop presented at the end of Spiral 1. Its purpose is to enable quality self-editing, thereby saving supervisor time and increasing skills and confidence in the student. It is envisaged that this tool will be used after the other two tools, in the refinement stages of editing. It asks and answers questions containing doubt (or nuance), just like having one's own editor in the room. This is why it depends on Boolean logic.

Question 1: Is a verb needed in every sentence?

Response 1: In formal, academic writing, a finite verb, i.e. a verb in a tense, is needed in every sentence. Sentences without verbs are known as journalese or sentence fragments. They are only acceptable in mass media, very spoken sentences and informal or colloquial language situations.

Question 2: What are the types of sentences used in academic writing?

Response 1: There are three types of sentences used in academic writing: simple,

compound and complex. No one type of sentence is better than the others: a well-balanced article will use a judicious mixture of each type.

Response 2: Simple sentences consist of an independent clause (a clause that will stand alone, grammatically): they consist of a subject, a finite verb and (possibly) an object (in TG) / a participant, a process and (possibly) a circumstance (in SFL). They are useful for making strong statements and for clarity.

Table 5: A sample of the Systems Engineering tool

Simple Sentence:	**The probe**	**was placed**	**in the cylinder.**
SFL description:	*Participant*	*Process*	*Circumstance*
TG description:	*Subject* *Definite Article, Noun*	*Finite verb (passive, simple past tense)*	*Prepositional phrase of location* *Preposition, Definite Article, Noun*

Conclusions to date and future work

This research is developing a novel, bespoke, evidence-based tri-partite language development solution for EHDRs, aligned with their modes of cognition. The students themselves have been an active part of the system being designed and tested and, so have ownership of the solution.

It is clear that the Language Trees are welcomed emotionally and used actively by the engineers. This fits with the premise that Engineers are looking for a solution based on familiar modes of cognition.

The EHDRs are more reluctant to use the Concordancing solution. Whilst some could see great value in the solution (indeed one participant sent the corpus and instruction guide over to their home country to help their friends at home), it was less popular as a solution for the NSEs, though it offered clear value to the NNSEs. This division in response is in alignment with the literature.

There is great interest in the new, computer-based grammar solution and testing will begin shortly. It is expected to be popular with the participants from the comments to date, in anticipation.

What is clearest of all is that a uni-directional solution approach is less useful than a tri-partite solution approach, which aligns with a greater number of issues and outcomes along with a greater number of students. A limitation of this study is the small numbers involved in this initial work; however, there seems to be strong alignment in the results with the EMoCs, which suggests that the prototype solutions are worth further exploration in larger, cross faculty and cross institution studies.

The tri-partite solution is a novel, engineering-orientated solution to authentic real-world problems in engineering. It is developing an evidence-based solution to language issues throughout the School of Mechanical Engineering, as a basis for a detailed Language Support program, created in full partnership with engineers, for engineers.

References

http://www.adelaide.edu.au/graduatecentre/ (AGC, 2016)
http://www.aare.edu.au/publications-database.php/4104/Attrition,-completion-and-completion-times-of-PhD-candidates (AARE, 2016)

Boulton, A. (2012). Corpus consultation for ESP: A review of empirical research. In A. Boulton, S. Carter-Thomas, and E. Rowley-Jolivet (eds.), *Corpus-informed research and learning in ESP: Issues and applications* (pp. 261-91). Amsterdam, Netherlands: John Benjamins.
https://counseling.caltech.edu/general/InfoandResources/Impostor (2016)
Counsell, J., (2011), How effectively and consistently do international postgraduate students apply the writing strategies they have been taught in a generic skills-based course to their subsequent discipline-based studies? *Journal of Academic Language & Learning* Vol. 5, No. 1, 2011, A1-A17. ISSN 1835-5196
Csíkszentmihályi, M., (2008). Flow: The Psychology of Optimal Experience. New York, NY: Harper Perennial.
https://www.elsevier.com/__data/promis_misc/edurevReviewPaperWriting.pdf (2015)
Day, S.B., and Goldstone, R.L. (2012) Educational Psychologist. Vol. 47 Issue 3, p153-176.
Gagné, F., (2010), Motivation within the DMGT 2.0 Framework, High Ability Studies, Vol. 21, No. 2, Pp 81-99
http://www.independent.co.uk/news/education/education-news/education-hard-lessons-in-litigation-1273834.html (Hodges, 1997)
http://www.i-programmer.info/babbages-bag/235-logic-logic-everything-is-logic.html
Kaur, J., (2004) Thesis: ESL students' use of concordances and dictionaries in the transfer of academic word knowledge: a comparative study, Iowa State University.
Kiley, M., Mullins, G., (eds) 2004 Characteristics, degree completion times and thesis quality of Australian PhD candidates, published in Quality in Postgraduate Research: Re-imagining research education. Proceedings of the 2004 International Quality in Postgraduate Research conference, Adelaide, Australia, 22-23 April.
http://www.laurenceanthony.net/software.html (2016a)
Anthony, L. (2016). Introducing corpora and corpus tools into the technical writing classroom through Data-Driven Learning (DDL). In J. Flowerdew and T. Costley (eds.), *Discipline-Specific Writing: From theory to practice* (pp. 163-181). Abingdon, UK: Routledge.
Martin, J.R & Rose, D. (2005) Designing literacy pedagogy: scaffolding democracy in the classroom. In Webster, J., Matthiessen, C. & Hasan, R. (eds.) Continuing Discourse on Language. London: Continuum, 251-280.
Northcote, M., (2012) Selecting Criteria to Evaluate Qualitative Research. Avondale College: ResearchOnline@Avondale
http://www.oxforddictionaries.com/definition/english/logical-operation
Pain, R., Whitman, G., and Milledge, D., and Lune Rivers Trust, University of Durham: Participatory Action Research Toolkit: An introduction to using PAR as an approach to learning, research and action.
http://www.raeng.org.uk: Do you think like an Engineer? (2014)
Reinders, H. & White, C. (2010) The Theory and Practice of Technology in Materials Development and Task Design. In Harwood, N. (ed) English Language Teaching Materials. Cambridge University Press.
http://schools.yrdsb.ca/markville.ss/history/history/canadian_seminar_instructions.html
https://www.sfu.ca/~egan/HER.html
http://www.stevensonschool.org/academics/carmel/excellence/harkness_teaching_method/index.aspx
https://www.teachingenglish.org.uk/article/concordancers-elt
https://www.timeshighereducation.com/news/poor-english-a-key-diagnosis-for-failure-to-make-phd-grade/416018.article (2011)
http://www.trainingindustry.com/wiki/entries/addie-model.aspx