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Jointly constructing semantic waves: Implications for teacher training

Lucy Macnaught
University of Sydney

Karl A. Maton
University of Sydney, kmaton@uow.edu.au

James Martin
University of Sydney

Erika S. Matruglio
University of Wollongong, erikam@uow.edu.au

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Abstract
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Keywords
training, waves, teacher, semantic, constructing, jointly, implications

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Jointly Constructing Semantic Waves: Implications for teacher training

Lucy Macnaught, Karl Maton, J.R. Martin & Erika Matruglio

The University of Sydney

Corresponding author:

Lucy Macnaught

University of Technology, Sydney

Blg 10.9.203

P.O. Box 123

Broadway, NSW, 2007

Australia

Lucy.macnaught@uts.edu.au

Abstract

This paper addresses how teachers can be trained to enable cumulative knowledge-building. It focuses on the final intervention stage of the *Disciplinarity, Knowledge and Schooling (DISKS)* project at the University of Sydney. In this special issue, Maton identifies 'semantic waves' as a crucial characteristic of teaching for cumulative knowledge-building; and Martin explores a 'power trio' of intertwining linguistic resources which contribute to the creation of these waves. This paper draws on these complementary theoretical frameworks from Legitimation Code Theory and Systemic Functional Linguistics to explore their implications for teacher training. Specifically, it links one Year 11 Biology teacher's experience of new

metalanguage and explicit pedagogy, in teacher training, to first attempts at classroom Joint Construction, a form of collaborative text creation. This paper then raises important issues regarding collaborations concerned with classroom interaction and knowledge-building practices.

Key Words

Systemic Functional Linguistics; Legitimation Code Theory; teacher-training; Biology; semantic waves; classroom interaction.

1. Introduction: Semantic waves in knowledge-building practices

The 'Disciplinarity, Knowledge and Schooling' project (DISKS) was concerned with knowledge-building practices in secondary classroom interaction and comprised three main stages. Stage 1 focused primarily on the collection of classroom video data from Biology and History classrooms in order to document a range of current practices from contrasting disciplines, at different year levels. Stage 2 drew on theoretical tools within Legitimation Code Theory (LCT) and Systemic Functional Linguistics (SFL) to analyse instances of teaching. Using data from this stage, Maton (this issue) conceptualizes a crucial characteristic of cumulative knowledge-building in terms of 'semantic waves'. This involves recurrent movements in the strengths of 'semantic gravity' and 'semantic density', or (crudely put) context-dependence and condensation of meaning. As Maton discusses, these concepts can be used in a variety of ways, including to trace changes in knowledge through time as *semantic profiles*. As he explains, for simplicity we have here focused on describing semantic profiles using a 'semantic scale' where semantic gravity and semantic density are moving inversely. Figure 1 illustrates a single semantic wave using such a scale: this one involves a downward

shift from abstract, generalised and condensed meanings to concretized, specified and simpler meanings, and then an upward shift to complete a single wave.

[INSERT FIGURE 1 & KEY HERE]

Analysis in Stage 2 of the project highlighted that a dominant pattern in classroom teaching was a recurrent 'downward shift', or 'down escalator' profile, i.e. repeated movements from generalized, abstract and highly condensed meanings, often in technical language, towards more context-dependent and simpler meanings, often in everyday language (see Figure 3 in Maton, this issue). One aspect of this downward movement is 'unpacking' technicality into more familiar commonsense language for students. As one Year 11 Biology teacher in our study reflected:

> Like many, I thought, I was actually very good at the unpacking aspect...taking it from highly-packed word and unpacking it. And in many instances, upon reflection, felt that, at that point, I had done my job - that students had been taught.

While this downward shift is vital to connect with students' everyday language and lived experience, Maton argues that the inverse 'upward shift' is also important. 'Repacking' knowledge in classroom interaction can begin to attend to the 'constellations of meanings' that abstract and condensed terms are positioned within and from which they accrue their meanings. As both Maton and Martin (this issue) demonstrate, specialised discourse of academic subjects comprise complex webs of meaning involving compositional structures, taxonomic structures, and processes. It is these webs or constellations that give the specialised terms meaning, and which students must demonstrate mastery of in their assessments. In other words, an upward movement towards weaker semantic gravity and stronger semantic density

reconnects concrete examples and specific instances to these more complex 'semantic structures' which comprise the pedagogic discourse of subject areas. Taken together, downwards and upwards shifts enable the recontextualisation of knowledge through time, a crucial condition for cumulative knowledge-building.

From the complementary perspective of Systemic Functional Linguistics, Martin (this issue) also draws on data from Stage 2 to explore the language resources that contribute to creating these semantic waves. Specifically, he introduces a trio of concepts for making more accessible the linguistic features that construe and organise what SFL refers to as 'field', i.e. the representation of reality, and 'mode', i.e. the organisation of information flow depending on the channel of communication (e.g. speaking vs writing). In secondary school contexts, the term 'field' is often translated as disciplinary 'subject matter' or 'content'. These represent not the linguistic equivalents of LCT's concepts of semantic gravity and semantic density, since charting semantic shifts in linguistic terms is a highly complex and ongoing task involving complexes of language resources that differ across subject areas. Rather, as Martin discusses, the 'power trio' represent those language features the project chose as a crucial *starting point* for training teachers how to teach in semantic waves in our pedagogic intervention. These comprised highlighting the semantic power of technical terms as 'power words', the knowledge construing power of grammatical metaphor as 'power grammar', and the crafting and organisation of whole texts as 'power composition'. Using this power trio, Martin explores disciplinary differences between Biology and History and the universal role of grammatical metaphor in connecting technicality with less congruent grammatical choices in order to construe complex field and craft powerful texts.

Analysis from Stage 2 also involved a closer examination of pedagogic strategies that enable semantic waves in History classrooms. Matruglio *et al*. (this issue) analyse the role of 'temporal shifting' (manipulating 'the temporal and spatial coordinates' of classroom

discussion) in cumulative knowledge-building. Collectively, these three aforementioned papers in this issue are concerned with the ongoing challenge of making educational knowledge accessible to students while retaining the complex meanings encoded in specialised pedagogic discourses. While 'semantic waves' and the 'power trio' provide a metalanguage for discussing dimensions of knowledge-building practices, one issue from the project, yet to be discussed, is their enactment in teacher training. This paper discusses how these concepts shaped a collaborative pedagogic intervention in Stage 3 of the DISKS project. This involved a teacher-training day where a key focus was the use of Joint Construction (Rothery 1994) as one way to make knowledge-building resources visible to students. To illustrate the challenge Biology teachers face in teaching students to construct a wide range of meanings *through* the language of Biology, this paper begins with a brief analysis of high and low scoring student exam responses. It then provides an overview of the teacher training day and subsequent intervention. This is followed by a discussion of the pedagogy teachers experienced and then enacted during the intervention, before reporting on one teacher's engagement with power words, power grammar and power composition, in a Year 11 Biology classroom. To conclude, important issues will be raised regarding future collaborations that are concerned with classroom interaction and knowledge-building practices.

2. Semantic profiles of low- and high-achieving assessments

The Biology teachers in our study faced the challenge of teaching students to construct a wide range of specialised biological meanings *through* the language of Biology. The dimension of Semantics, in LCT, offers one set of organizing principles of knowledge-building practices which can explore the scope of meaning-making in a wide variety of contexts and different kinds for texts, including classroom talk, text books, student writing etc. As Maton (this issue)

illustrates, the strengths of semantic gravity and semantic density of knowledge can be traced to map various 'semantic profiles' over time. In Stage 3 of the DISKS project, these concepts were used in teacher training for a variety of purposes, including analysis of low- and high-scoring student exam responses. The writing samples, presented in table 1, were collected during this stage, from the same Year 11 Biology classroom. In this practice exam question, students briefly describe the process and role of mitosis.

Short answer question: Describe the process and role of mitosis.	
Student A: Low-scoring text	**Student B: High-scoring text**
Mitosis is when the two parent cells come together, their DNA replicates and all these cells then replicate again which go onto forming two diploid cells. The 23 pairs of chromosomes combine to make all up. All chromosomes contain the same genetic material that help generate the body. The mitosis replicates the chromosomes which create enzymes.	Mitosis is one of the two forms of **cell division** that occurs in our body, the other being Meiosis. Mitosis is the process in which a cell divides into two cells identical to the original cell. Mitosis begins with DNA **Replication**. This is when the cells chromosomes replicate and split. The cell then divides into two cells each with 46 Chromosomes; otherwise known as diploid cells. Mitosis is used for many processes in our body involving **growth** and **repair.**

Table 1. Low- and high-scoring student responses in a year 11 Biology exam

As Figure 2 traces, Student B starts relatively high on the semantic scale by not only introducing the term mitosis, but also locating it as a more general 'type of' process, i.e. *one of the two forms of cell division.* After identifying mitosis, the student strengthens semantic gravity and weakens semantic density to outline what mitosis involves and the visible end result (*cells dividing into two*). A similar pattern is repeated as the student begins a more detailed explanation of cell division. The first stage of this process (*DNA replication)* is identified, followed by a more detailed description of cell components and processes involved (*chromosomes replicate* and *cells then divide*). Student B's text finishes with a movement back up towards weaker semantic gravity and stronger semantic density by stating the general functions Mitosis contributes to (*growth and repair).* As student B's text unfolds, the semantic profile can thus be heuristically illustrated as making semantic waves (Maton, this issue). In contrast, the lower scoring response of student A cannot form semantic waves because only a limited range of meanings are created: the student writer attends to specific types of cells and their components (*parent cells, diploid cells, DNA, chromosomes, enzymes)* and various processes (*replicates, forming, create)* but does not deploy language resources to enable upward movement. In short, LCT terms, student A's semantic profile can be described as a 'low semantic flatline', because the writer is stuck in a semantic range limited to stronger semantic gravity and weaker semantic density.

[INSERT FIGURE 2 & KEY HERE]

From the perspective of Systemic Functional Linguistics, a key reason why student B is able to craft the response into semantic waves is the deployment of 'power grammar', in particular experiential grammatical metaphor. As Martin (this issue) explains, grammatical resources

involving logical relations or experiential meaning are described as 'metaphoric' when there is 'stratal tension, i.e. a coding mismatch between levels of language'. This results in 'two layers of meaning, one symbolising the other'. To differentiate levels of language that are involved in grammatical metaphor, Martin (this issue) identifies: '**elements**', or individual constituent groups; semantic '**figures**' which consistent of several connecting constituent groups, i.e. Participants +Processes + Circumstances; and semantic '**sequences**' which consist of a series of connected semantic figures. As Figure 3 illustrates, student B, unlike student A, deploys experiential grammatical metaphor to package complex processes as elements within the clause, e.g. *cell division, DNA replication, growth* and *repair*.

[INSERT FIGURE 3 HERE]

In functional linguistic terms, at one level the nominal group, *one of two forms of cell division,* functions as a Participant within an identifying relational clause. In this example, a specific relational valeur is ascribed to the technical term Mitosis and encoded in a more complex nominal group:

Mitosis (Token) is (Process) one of two forms of **cell division** (Value).

The second layer of meaning arises because the core of the nominal group (or 'Thing' in functional terms), *cell division,* is not directly encoding an entity (i.e. a person, place or thing), but rather symbolizing and drawing together clause range of meaning beyond this single clause (Martin, this issue). In this example, the full nominal group, *one of two forms of cell division,* encapsulates the complex series of actions that multiple entities engage in and simultaneously positions Mitosis in a classifying taxonomy. The important point here is that

only student B effectively manages *both* congruent (*a cell divides into two)* and metaphorical (*one of two forms of cell division)* encodings in grammar to create different kinds of meaning: the former manages one step in the chronological sequencing of events, while the grammatically metaphorical encoding enables classification. This is indicative of the fact that higher scoring texts do not simply 'dress up' the meanings of lower scoring answers, or conversely, lower scoring texts are a not watered-down, crude, or rudimentary version of higher achieving ones; rather the different texts build *different* kinds of meaning. The specialised biological meanings, not found in student A's text, relate to the way knowledge is built in the discipline of Biology (Martin, this issue), i.e. through creating relationships of classification, composition and precise chains of logical relations, or 'implication sequences' (Martin & Rose 2008). It is therefore unsurprising that student B's answer will obtain higher marks from examiners.

Finding a way to demonstrate and teach these crucial differences became the point of departure for the practical workshops in the teacher training day. This paper argues that many students, like Student A, do not intuitively gain control of specialised meanings across disciplines. In particular, the affordances of grammatical metaphor often remain a mystery. As the representative writing sample shows, without these resources, students are limited to a narrower semantic range which hinders their ability to craft power texts and more fully access specialised meaning-making. Therefore, this paper argues that classroom interaction needs to explicitly teach students the linguistic resources that enable semantic waves and, ultimately, the possibility of cumulative knowledge-building.

3. Training and planning pedagogy for knowledge-building

3.1 Overview of the training day and pedagogic intervention

The final year of the DISKS project involved a teacher day and a collaborative pedagogic intervention. It involved eight teachers, half of whom had participated in the first two years of the project. They are employed in various Secondary Schools that are situated in either inner city, outer suburban or rural areas. For pragmatic reasons of restricted funds and time, the teacher training was limited to one day. There were several aims for the day: first, to introduce semantic waves and the power trio using data and analysis from previous stages (video recordings, transcripts and textbook images); secondly, to introduce pedagogic strategies for operationalizing these ideas within classroom practice; and thirdly, to provide teachers with time to begin planning for the intervention.

The intervention extended for one school term (approximately ten weeks) and our support needed to keep pace with current curriculum. Within this time frame, we aimed to capture three Teaching and Learning Cycles (TLC) (see section 3.2, below). Planning for the intervention commenced during the training day where teachers began to consider their current teaching units, curriculum outcomes and accompanying written assessment tasks. Through continued email correspondence and analysis of curriculum documents, three suitable exam questions were identified for each class. Each exam question then became the focus of one TLC cycle. As the intervention unfolded, teachers provided model exam responses which the research team then annotated for power words, grammar and power composition. Once satisfied with the models, teachers analysed them with students and used them as the basis for teacher-led collaborative writing (see section 4).

Data collection, during the intervention, involved six classrooms and teachers from either Year 11 Biology or Ancient History. From these six case studies, four partial sets of data and two complete sets of data were collected. A full set of data included the following for each

cycle: samples of student writing prior to support, curriculum outlines for the units of work, annotated model texts, classroom video recordings of collaborative writing, students' independent writing samples and an audio recording of a post-cycle teacher interview. Section 4 of this paper draws on data collected from one Year 11 Biology classroom, while the remainder of section 3 focuses on teacher training prior to the intervention.

3.2 Pedagogy for knowledge-building

As Maton (this issue) highlights, though cumulative teaching in different subjects areas, such as Biology and History, may share similar semantic wave profiles, this does not negate their disciplinary differences: their semantic waves may be themselves driven by different organising principles. Thus, to provide discipline-focused training, teachers were divided into their respective disciplines of Biology and History. The practical workshops, which both teacher groups experienced, focused on introducing the Teaching and Learning Cycle (TLC) (Rothery 1994), featured in Figure 4. It is important to reiterate that the primary goal of the pedagogic intervention in stage 3 was supporting teachers with making discipline-specific, knowledge-building resources visible to students. The TLC was introduced as one way to interactively engage with these resources through focusing on written exam responses.

[INSERT FIGURE 4 HERE]

The Teaching and Learning Cycle (TLC) was first developed in the Metropolitan East Region Disadvantaged Schools Program in Sydney. (See Martin 2009; Rose & Martin 2012 for various stages of development, including the integration of reading.) It can be classified as a curriculum macro-genre (Christie 2002) designed to attend to the semiotic resources that create and manage the movement of knowledge across texts. The TLC is a macro-genre

because the three main steps, Deconstruction, Joint Construction and Independent Construction, are each elemental genres (Martin & Rose 2008). As Humphrey & Macnaught (2011), Dreyfus et al. (2011) and Martin & Dreyfus (forthcoming) explore, these genres unfold with their own structure and provide different kinds of literacy support.

The first step, **Deconstruction,** involves the contextualisation, analysis and annotation of model texts. In relation to other lessons, this step is an opportunity to revise and check students' understanding of concepts that have previously been introduced. Through a structural analysis of texts, the way specific language features (i.e. power words and power grammar) contribute to predictive information flow (power composition) can be introduced and discussed. The purpose of this stage is to build shared understanding about texts – including a shared metalanguage – which subsequent guided interaction draws upon.

The middle step, **Joint Construction**, involves teacher-led collaborative writing. In this step, the teacher and students use shared knowledge from the Deconstruction to co-create another text, such as a similar short-answer exam question, or part of an extended-answer response. From an LCT perspective, this step is a further opportunity to consider how shifting strengths of semantic gravity and semantic density create semantic waves. Both these steps are designed to prepare students for successful individual writing, in the third step, **Independent Construction**. This model is represented as a cycle because there is the potential for varied entry points, back and forth movement between steps and also iteration – depending on the needs of students.

The careful sequencing of support in this cycle privileges the central role of interaction in language development (Halliday 1993, Painter 1984). In the secondary school context, this

means that students' understanding of power words and development of power grammar and power composition is not viewed as students' individual responsibility, nor as an independently developed 'skill' that will gradually be picked up through exposure to curriculum documents, such as textbooks and past exam papers. The design of the TLC emphasizes the role of the teacher in providing anticipatory explicit guidance, i.e. tailored support prior to practice exams, rather than retrospective feedback. The principles behind this approach have been encapsulated as 'guidance through interaction in context of shared experience' (Martin 1999). Shared experience refers to shared knowledge of field, specific texts and knowledge about language. This common ground of new knowledge enables teachers to know what can be asked. It forms the basis of interactive guidance that can be freed of the quizzing and guessing routines which have been shown to dominate classroom interaction (Sinclair & Coulthard 1975; Mehan 1979; Edwards & Westgate 1987; Tharp & Gallimore 1991; Nystrand & Gamoran 1991; Nystrand 1997; van Lier 1996; Wells 1999; Nassaji & Wells 2000; Christie 2002; Rose 2004; Gibbons 2006).

An on-going concern for teacher-trainers is that while considerable teaching resources and documentation exists for the first step of the TLC, there is far less around teachers providing interactive guidance through writing with their class (Humphrey & Macnaught 2011). The concern here is that text analysis with students privileges the end product. While it demystifies and makes transparent what is valued, it does not reveal the process needed to get there. In time-pressured classrooms, where time for one-on-one interaction with students is limited, writing with the whole class, or groups of students, provides the opportunity to discuss and debate decisions about how knowledge is created through language and other media. Additionally, Joint Construction is also where variation from model texts can be creatively, yet discerningly explored (see Table 3 where brackets in the scribed text capture

alternate choices). This is why the steps of Deconstruction and Joint Construction are designed to work in tandem. Over time, the combination of guided analysis and crafting of text aims to prepare all students to be powerful meaning-makers. Given that Joint Construction was new to our teacher group and its pivotal role in the TLC, the training day workshops provided teachers with the opportunity to experience this methodology as text-creating participants.

3.3 Jointly constructing exam responses in semantic waves

The training day workshops engaged teachers in one sequence of Deconstruction and Joint Construction, within the Teaching and Learning Cycle. The texts focused on specific Year 11 exam questions. For example, the Ancient History group analysed and annotated a factorial explanation on conservation issues in Pompeii, and constructed a consequential explanation about new research methods and everyday life in Pompeii and Herculaneum. Similarly, in Biology, teachers analysed a sequential explanation about phagocytosis and immunity and then, in the same genre, jointly constructed a text about the third line of defence in relation to organ transplantation. (See Martin & Rose 2008 for explanations and analysis of these genres.) Following these sessions, preparation and workshop notes were provided as post-training day summary documents for teachers' future reference. This section focuses on the step of Joint Construction, with the Biology teacher group, to explore its potential to make knowledge-building resources visible.

As previously discussed, Joint Construction is, amongst other interpersonal factors that are beyond the scope of this paper, dependent upon a platform of shared knowledge. This includes having sufficient knowledge of the field or 'subject matter'. In addition to revisiting deconstructed models, to prepare the teacher group for Joint Construction, summary notes and

diagrams, such as Figure 5, were used as revision. In teaching contexts where there is often a gap between consecutive lessons, revising shared knowledge forms an important preparatory stage between text analysis and writing. Humphrey & Macnaught (2011) have referred to this stage as *Bridging.* From the perspective of field-building patterns in SFL (Martin, this issue; Martin & Rose 2007), the stage of Bridging also has the potential to remind students of larger patterns which sequences of language choices contribute to. For example, the diagram in Figure 5 captures the 'implication sequence' (chains of cause and effect relations) relevant to the exam question about organ transplantation. The diagram illustrates key entities and their cause and effect relationships to each other. The vertical organisation also adds approximate chronological sequencing to these relationships. In addition to their use in preparation, these kinds of diagrams also provide a visible resource during the subsequent stage of *Text Negotiation* where the writing gets done.

[INSERT FIGURE 5 HERE]

The core stage of Joint Construction, *Text Negotiation,* involves eliciting and mediating suggestions as the text is gradually scribed. (See Dreyfus et al 2011, Martin & Dreyfus forthcoming, and Dreyfus & Macnaught forthcoming for SFL analysis of mediation during Text Negotiation.) As previously discussed, from an LCT perspective, this is the stage where the teacher leading the Joint Construction can provide explicit guidance about the strengths of semantic gravity and semantic density and craft semantic waves. As Maton (this issue) highlights, semantic waves take a host of forms. Figure 6 traces one semantic wave profile. It plots teachers' suggestions as they take on the role of text-creating participants.

[INSERT FIGURE 6 HERE]

Figure 6 relates to suggestions between turns 9-18 of the transcript in Table 2. At this point, the Joint Construction focuses on the connection between antigens and B and T cells. Suggestions start at approximately mid-range on the semantic scale, where antigens are identified as a kind of cellular structure (*molecules or proteins*) without more specific description. There is movement up the semantic scale as semantic gravity is weakened and semantic density is strengthened to state the general causal relationship between antigens and the entire complex chain of cause and effect relationships – abstractly and technically labelled as the *immune response.* At turn 13, there is then movement down the semantic scale as more site-specific processes and accompanying cell types are identified *(the production of B and T cells).* This is followed by further downward movement as the teachers debate the precise nuancing of causal relationships: they consider whether it is accurate to say that *the body activates B and T cells.* Through the use of gesture (clicking of fingers) and discussing what *activates* means in everyday language (*to switch it on),* against alternatives (*stimulates, initiates),* it is decided that *activates* is appropriate. Lastly, at turn 18, there is movement back up the semantic scale: semantic gravity weakens and semantic density is strengthened as one teacher reworks the previous suggestion to propose *the activation.* Now, in its more abstract, nominalised form, *activation* is less bound to a specific context. From a linguistic perspective, it has the potential to be connected to various cell types and subtypes through alternate post-modification, i.e. *activation of x; activation of y.)* In this text, the choice of *activation of B and T cells* allows the writers to start building a precise implication sequence (Martin & Rose 2007:102) that increases in complexity.

Turn	**Sample: Biology teachers' spoken suggestions**
1	T1: The third line of defence is a specific response, ahh, a specific response, or about

	in response to, or brought about by antigens, or specific antigens.
2	T2: Yeah we've got to say what it means.
3	T3: So isn't it now, what goes into the body? It's gone past the first two defences and it has (inaudible).
4	T1: Yeah, it's right, so it comes about as a result of the pathogen having passed the first and second line of defence."
5	T4: It's also a more effective way, like it's actually designed specifically to attack that particular kind ~~ of antigen..
6	T3: ~~ But, it's like the other way, sort of like, it's like I tell the students, your first line of defence is essentially like your infantry. It's the barrier *(gesture: fist to open palm).* Ya second line of defence is like your artillery. It just knocks out everything that is foreign. The third line of defence is like a sniper, it basically comes in and particular-.
7	T2: Say, 'your targeted'.
8	T1: Which targets.
9	T1: Antigens which have breached the first and second line of. Foreign particles all possess antigens, which are, are molecules or proteins that do not belong to the body, or-
10	T3: So it should start with Antigen. Antigens are.
11	T1: Foreign molecules that.
12	T3: That trigger. Identified antigens as molecules that trigger the immune response.
13	T4: So Antigens stimulate the production of B and T cells. The body activates B and T cells.
14	T3: Initiates or leads to the production of.
15	T4: Activates essential means just to switch it on *(gesture: click of fingers)*

16	T3: That's right.
17	T4: And then from that point B and T cells are either going to, ahh, produce antibodies or they are going to multiply, or they are going to actually actively go and seek out and destroy the antigen.
18	T1: You could say, 'this involves the activation of both'.

Table 2. Spoken suggestions during Joint Construction

As the semantic profile in Figure 6 illustrates, initial verbalised suggestions are often not at the upper end of the semantic scale. From a functional linguistic perspective, most prominent in turns 3-6 and 15-17 (see Table 2) are congruent representations of processes in verbal groups (*designed to attack, knocks out, comes in, switch it on, produce, multiply, destroy).* Another key feature is the use of expressive analogies *(like your infantry, it's the barrier, like your artillery, like a sniper),* which are accompanied by gesture, to work with the technicalised lexical metaphor *(lines of defence).* In this lexical metaphor, the inferred concept of 'war' symbolises the body's interaction with pathogens. The analogies build on this symbolism to differentiate the three contrasting implication sequences, i.e. the first (*infantry, barrier),* second *(artillery)* and third *(sniper)* lines of defence. These features are unsurprising given that teachers are often highly skilled in providing accessible explanations for students. Here verbal groups foreground individual steps in a larger activity sequence and analogies relate the field of biology to the field of warfare, which, through news and other media, infiltrates our everyday world. In LCT terms, these strategies create stronger semantic gravity than the specialised meanings of Biology as academic discourse. While they serve to make concepts accessible to students, they need 'repacking' through power grammar to create more specialised biological meanings.

As the transcript in Table 2 and the scribed text in Table 3 record, the participating teachers recognized that this type of classroom-like chat needed reworking to move back up the

semantic scale. While the first phase of text (created between turns 1-8) is scribed, the material processes of *gone past, attack* and *comes in* are reworked to foreground function within the definition, i.e. *x targets y.* In the next sentence, the definition is then succinctly packaged as *This process.* Here the use of anaphoric referencing *(This)* and a semiotic entity *(process)* look back to and encapsulate the information which has already been provided. Textually, they form a 'given' in SFL terms, and strengthen semantic density in LCT terms. This repackaging of meaning now provides a point of reference for the 'new' information in the rest of the sentence *(B and T cells).* As highlighted in Table 3, the anaphoric referencing (bold) occurs twice and combines with technicality (italics) and grammatical metaphor (underlined) to craft layers of predictive information flow. The text now opens with a *macro-Theme* to state the overall function of the phenomenon, with a subsequent predictive layer (a hyper-Theme in SFL terms) to start narrowing the focus (Martin, this issue). From an LCT perspective, these predictive layers, which contain relatively strongly condensed and generalised meanings provide a platform for downward shifts on the semantic scale.

Periodicity	**Turns**	**The (incomplete) scribed text**
macro-Theme	1-8	*The third line of defence* is a specific response which targets identified *antigens* which have breached the *first and second lines of defence.* **This process** involves (requires, comprises) different types of *lymphocytes* including *T cells and B cells.*
hyper-Theme	9-18	*Antigens* are foreign *molecules* that trigger the *immune response.* **This** involves the activation of *B and T cells*…….

Table 3. The scribed text created by the teacher group, during Joint Construction

While the Joint Construction workshop with teachers did not allow time for the completion of subsequent phases, or to further revise the scribed text, the collaborative writing experience illuminated a number of portable principles in terms of enactment. These include:

- the necessity of interactive strategies (such as analogies and gesture) that enable shifts down the semantic scale to connect with everyday language and lived experience;
- providing text-creating participants with the opportunity to repackage initial suggestions through power grammar in order to move up the semantic scale;
- and the potential of intertwining linguistic resources (such as anaphoric referencing, technicality and grammatical metaphor) to create power composition.

As students tackle a wide range of texts in their disciplines, extracting these kinds of transferable principles is key to the success of Joint Construction in preparing them to recognise and manage semantic waves in their reading and writing. The remainder of this paper will discuss the enactment of Joint Construction in one year 11 Biology classroom. It documents the teacher's first attempts at introducing students to the concepts of power words, power grammar and power composition to start making knowledge-building resources visible to students.

4. Teaching the language of Year 11 Biology

4.1 Power Words

In Australian secondary schools, by the time students reach Year 11 Biology, they have usually had four years of reporting on experiments and learning technical and specialized labels for equipment, entities and concepts. This means that they have already encountered an abundance of power words and are familiar with the logogenetic unfolding of certain kinds of

scientific texts, i.e. the idea that texts are socially-oriented, goal-centred and carefully staged to meet those specific goals (Martin & Rose 2008). However, findings from earlier stages of the DISKS project suggest that they have rarely been supported to consider how power words and power grammar work together to create power composition.

In the lessons we observed, the teacher focused on the appropriate pairing of power words and specific exam prompts. The focus here can be described as logocentric. Teachers 'brainstormed' list of relevant words with students and made sure that students had a sufficient list for the exam question at hand. For example, for the question, *Explain the conditions that support both theories that life was seeded from outer space AND life commenced on Earth*, the following list was created:

meteorites

comet

Abiogenesis

Panspermia

primordial (prebiotic) soup

Urey and Miller

Haldane and Oparin

apparatus

reaction chamber

electrical discharge

amino acids

recreated conditions

primitive earth

synthesise

microorganisms

When generating such lists, teachers appear to draw mainly on collocational relations between entities, i.e. the suggestion of *meteorites* triggered the suggestion of *comets; apparatus* was followed by *reaction chamber;* and the name of one theory or theorist was followed by the name of another theory/theorists, etc. These power words were also highlighted in the completed text, at which point students could ask further questions about the meaning of individual technical terms. Following the teacher's lead, students also created checklists (see Figure 7) of power words in their independent writing.

[INSERT FIGURE 7 HERE]

While these types of lists (sometimes organised as mindmaps) are useful to kick-start a pre-writing phase, they do not illustrate explicit 'constellations' (relational systems of meaning). As Maton (this issue) describes, the strength of semantic density in any given technical term is not 'intrinsic to the term itself'. It is the broader 'semantic structure', in which biological terms can be positioned, and their placement in various sites of production, recontextualisation or reproduction that contribute to and create relative strengths of semantic density. Reorganizing such lists to foreground relationships serves to 'relocate' terms within 'evolving webs of meaning'. For example, from the perspective of ideational meaning in SFL, biological entities can be organised into chains of causal relations, or implication sequences. As illustrated in Figure 8, the potential meaning condensed in the technical term for one of the theories, *Abiogenesis,* is established by relating it to environmental conditions, subsequent changes in molecular structure and the development of first life. On the left hand-side, Abiogenesis is also linked to the theorists who proposed and tested this particular theory.

Other representations, in other contexts, may bring a wider or more limited range of meanings to the same technical term.

[INSERT FIGURE 8 HERE]

In terms of on-going teaching, one advantage of such relational representations is that they pave the way for more extended explanations (for example, more detailed unpacking of changes in molecular composition) and the introduction of power grammar to precisely nuance the chain of cause and effect relationships that the diagram is illustrating. The general point here, in relation to preparing for Joint Construction, is that drawing links between terms in a constellation of terms enables more meanings to be condensed within each by virtue of their relations. Thus, texts can be organised to show how technical terms 'mean' in relation to each other, where meanings at the lower end of the semantic scale are in service of those higher up the semantic scale and vice-versa.

4.2. Linking power words with power grammar

While the teacher in this case study was comfortable with explaining technical power words and discerning those that are essential to specific exam questions, the notion of power grammar was out of his "comfort zone". During the training day, the two aspects of power grammar, which were introduced, were *nominalisation* and *cause in the clause*. Nominalisation was introduced as a way to package complex processes into things, e.g. *dividing cells* as *cell division*. The focus on derivation was seen as first step towards building understanding of the affordances of grammatical metaphor. In particular, the training day focused on the role of nominalisation and power words in causal relationships, i.e. the potential to relate one complex packaged process to another. The label chosen for logical

metaphors, where an element within the clause, such as verbal group, does the work of a series of causal conjunctions, was 'cause in the clause', e.g. *The change from inorganic compounds to organic compounds lead to the evolution of first life.* In this case study, the participating teacher saw the potential of power grammar to precisely "link things to things" and repackage spoken-like "waffle" in writing. In other words, he recognized that power grammar can be used to create meanings higher up on the semantic scale and build explicit relationships between power words.

To teach power grammar to his students, two preparatory activities were undertaken in preparation for Joint Construction. In the first activity, the teacher and students created a pool of logical metaphors or "linking words" to use during Joint Construction. e.g. *allowed, lead to, enabled.* The benefit of making visible a variety of language choices is that it allowed the teacher to direct students to a number of options, rather than the teacher taking over and providing the wording. As students became increasingly aware of their language choices, they also directed the teacher to find alternatives. For example, one student directed the teacher to use the right click mouse function in Microsoft Word and asked, "Can we thesaurus *allowed*? Cos we keep saying, 'allowed'!"

The second pre-writing activity focused on nominalisation. Students were asked to re-write three sentences which were extracted from anonymous writing samples from cycle 1. The task involved underlining verbal groups and changing them into nominal groups. (In functional grammar terms, this involves Processes becoming Participants.) The first sentence was completed with the whole class and then students worked individually or in pairs. For example:

Original: *Urey and Miller's experiment is about how life was able to start.*

Reworked 1: *Urey and Miller's experiment is about* ***the formation*** *of life on earth.*

Reworked 2: *The theory of Abiogenesis is about **the formation** of life on earth.*

As students re-worked the sentence and tried various alternatives, one student pointed out that the answer should foreground the theory rather than the people (see reworked example 2). This change makes the technical term, *Abiogenesis,* part of the Carrier in a relational clause. The other participant, in this clause (*the formation of life),* has the functional role of Attribute. This Attribute contains condensed meaning which is created by the grammatical metaphor. (As previously illustrated in Figure 8, *the formation* of first life involves a complex series of cause and effect relationships, which the grammatical metaphor encapsulates.) This kind of reworking of congruent grammatical choices highlights the role of grammatical metaphor in creating precise condensed characterisations of power words. From an SFL perspective, this is particularly important for the predictive layering of texts in explanation genres where the definition/classification in the initial phase is unpacked in subsequent phases. Similarly, in LCT terms, reworking suggestions to weaken semantic gravity and strengthen semantic density is essential to managing movements along the semantic scale.

These two short activities document initial attempts at teaching power grammar to students in the classroom. While participating in this activity, one student – who is the creator of the low scoring response, in table 1 – exclaimed, "That's the first thing I've got right all year!" While analysis of her (and other students') individual writing samples is still underway at the time of writing this paper, her comment points to the importance of longitudinal studies to track the impact that explicitly teaching power grammar has over time. In this study, we were able to capture the way power words and power grammar were starting to work towards power composition, in the third and final Joint Construction.

4.3 Towards power composition

As previously mentioned, Joint Construction, as the middle step in the Teaching and Learning Cycle is a genre consisting of several stages. As Humphrey & Macnaught (2011) report, teachers frequently create a pre-writing, or *Bridging* stage, followed by a *Text Negotiation* stage where the text itself is crafted. These stages are usually followed by a final *Review* stage where editing and reflecting on the text is completed. The teacher in our case study organised his Joint Constructions in this way to craft the text (see Table 4) with his students. In this text, logical metaphor is in bold font, experiential grammatical metaphor is underlined and indentation shows periodicity (predictive thematic layering).

Exam Question: Describe technologies which have increased our understanding of prokaryotic organisms.
A prokaryotic organism has no membrane enclosed organelles and therefore has free floating DNA. Prior to <u>the development</u> of certain technologies, our knowledge of these organisms was limited. Technologies such as the light microscope ***enabled*** us to observe prokaryotic cells. This ***allowed for*** prokaryotes to be distinguished from eukaryotes. Subsequently, the electron microscope has ***increased*** <u>magnification</u> and <u>resolution.</u> This ***enabled*** <u>the observation</u> of internal structures (micro-anatomy). This ***led to*** the <u>classification</u> of prokaryotic domains, Archae and Eubacteria.

Radiometric dating

led to the ability to determine the age of decreased organisms advancing our knowledge to determine how long ago these groups of organisms diverged from one another.

DNA fingerprinting

allows for accuracy in determining how closely related these groups of organisms are. This technology ***re-affirmed*** the validity of the separation of the domains Archae and Eubacteria.

Table 4. The third jointly constructed text

This jointly constructed text is starting to show a number of features of power composition. Firstly, the descriptive report opens with a classification phase, which defines the central power words (*prokaryotic organism*) for the reader. In terms of periodicity, this phase functions as a macro-Theme to predict subsequent information flow. Secondly, as shown with the indentation in Table 4, the opening phase is followed by four explanation phases –one for each of the new technologies. These phases link power words (the specialized equipment and their nominalized effects[1]) with new knowledge, through the use of external logical metaphor, e.g. *DNA fingerprinting* ***allows for*** *accuracy.* And thirdly, hyper-News appear for the first time. In SFL terms (see Martin, this issue), a hyper-New gathers the previously presented material to a cumulative point. The most striking hyper-New appears in the final paragraph, which was suggested by an advanced student, during the Review stage: *This technology re-affirmed the validity of the separation of the domains Archae and Eubacteria.* Here, the student is using internal logical metaphor (***re-affirm*** *= causes us to think)* and experiential

[1] As power grammar is developing, there is some variation as to whether effects are nominalized or whether the beneficiary is foregrounded. See the use of both *enabled us to observe* and *the observation.*

grammatical metaphor, which is packaged in a complex nominal group (*validity of the separation of…)*, to target significance (for internal and external logical metaphor, aka 'cause in the clause', see Halliday 2004). In terms of the structuring of knowledge in biology, this 'so what factor' relates to the expansion, or increase in delicacy of a particular classifying taxonomy. Already, after minimal training and only three TLC cycles, in LCT terms, we are starting to see jointly constructed texts where there is deliberate movement up and down the semantic scale.

Power composition and semantic waving of this kind are the ultimate goal of gradually introducing students to the importance of, and connections between, power words and power grammar. While it is understandable that teachers and students initially dealt with these language concepts individually, their true potential is as an intertwining trio: power composition is not possible without using grammar to represent complex processes and causal relationships metaphorically; and power words are only powerful when connected through power grammar, and not listed as isolated entities. Further teacher training and increased support with enacting new pedagogy has the potential to make both the unpacking and repacking of knowledge, through deliberate selection and control of linguistic resources, a central part of classroom interaction.

5. Conclusion

This paper began by contrasting two student exam responses to show the challenge teachers face in supporting students with moving up and down the semantic scale in order to create and manage specialised biological meanings. The central question that was asked was how the concept of semantic waves (Maton, this issue) and the notion of the power trio (Martin, this issue) can inform teacher training for the benefit of students. The underlying argument, which

shaped the teacher training day and subsequent pedagogic intervention, is that communities of teachers need a way to make the organising principles of knowledge visible to students through explicitly teaching discipline-specific language resources that create and shape the knowledge of their disciplines. Without such explicit instruction, many students (such as student A, in Table 1) are limited to a range of meanings lower on the semantic scale, i.e. relatively strong semantic gravity and weaker semantic density.

While the limited nature of the intervention (several hours distributed over ten weeks and following only one day of teacher training) constrained our ability to fully test our tentative conjectures, we saw signs to suggest that the power trio and semantic waves have potential when operationalized in explicit pedagogy. In particular, the intuitive awareness that teachers have about the language of their discipline can combine with more precise theoretical understandings to build a shared metalanguage with students. At the beginning of this project, the participating teachers, many of whom serve as Year 12 examiners, remarked that after only reading two or three lines of an exam response, they already know what grade the student will be awarded. In other words, they could tell a student's depth or degree of understanding *through* the language patterns that were selected. A shared metalanguage for 'seeing' knowledge-building resources and supporting this understanding through Joint Construction afforded several changes to the classroom practice that we observed in earlier stages of this research project, including:

(1) teachers deploying not only strategies that move down the semantic scale (such as the use of lexical metaphors and analogies) to connect with students' everyday language and lived experience, but also explicitly teaching linguistic resources (such as experiential and logical metaphor) that enable the inverse upward shift;

(2) the use of power words, power grammar and power composition to explain contrasting exam outcomes to students and connect language choices with different kinds of meanings;
(3) providing students with the opportunity to practise these new understandings – with explicit guidance – as they gradually learn to capture more of the meaning potential in the power words that are found in textbooks and circulating in their classrooms; and
(4) collaborative construction of texts which reach higher up the semantic scale and explore the deliberate pairing of power words with power grammar to create power composition.

At the time of writing this article, closer analysis of the recorded Joint Constructions and samples of students' independent writing is still ongoing, for both Biology and Ancient History. Thus far, this pilot study has raised a number of important issues for future research. First, gradually building awareness about discipline-specific language resources is clearly suited to longitudinal collaborations between teachers and educational linguists. Ideally, training and support would flow across units of work. This would afford the development of a genre spiral, with a planned sequence of agnate genres. The potential benefits of such a design include: the planned gradual accumulation of a shared metalanguage about texts; building critical awareness about the differences and similarities between texts; and discerning the type of texts students find most challenging. A longitudinal study would also allow teachers and researchers to tackle curriculum outcomes that may not be explicitly connected to different kinds of written exam responses, nor visible to students in generic exam prompts. Longer collaborations would also afford careful consideration of teachers' existing knowledge about language. In particular, this could include incorporating and mapping familiar terminology onto new metalanguage and developing terminology that is consistent with national curriculum documents. More importantly, from a training perspective, there would be time and resources to support teachers in the way we are asking them to support students, i.e.

providing carefully sequenced interactive support which draws on the principle of ‘guidance through interaction in context of shared experience’ (Martin 1999).

The second issue for further studies concerns a school-wide approach to building understanding of how knowledge is structured across the disciplines. Our project relied on a few courageous volunteers. After minimal training, they provided classroom instruction without the benefit of sharing ideas, queries, concerns, innovations and resources with other colleagues. Alternately, school-wide literacy projects can involve communities of teachers and supportive leadership (Humphrey & Robinson 2012; Timperley et al 2007). This is particularly important in relation to the third issue, the enactment of Joint Construction. While teachers benefited from experiencing collaborative-writing, during training, this methodology involves complex and intricate interactions with students. Its success is strongly dependent on shared metalanguage, supportive rapport between the teacher and students (and between students themselves), and careful mediation of students’ suggestions (Macnaught forthcoming). Deeper understanding and training in this method is needed so that, as educators have long advised (Cazden 2001; Rose 2005; Gray 2007; Alexander 2008), teacher-student talk patterns can be carefully paired with specific pedagogic goals. This study has pointed to the potential of building and fine-tuning shared metalanguage – deployed during Joint Construction – to demystify the structuring of knowledge in secondary school disciplines. This remains at an early stage of exploration; our conjectures remain tentative and our findings more promising than decisive. However, using the power trio to make semantic waves appears to offer not only ways of understanding, but, just as importantly, changing classroom pedagogies in ways that may enable more students to succeed.

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