Linguistics and Education 24 (2013) 1–3

Contents lists available at SciVerse ScienceDirect

Linguistics and Education

journal homepage: www.elsevier.com/locate/linged

Preface

Cumulative knowledge-building in secondary schooling: Guest editors' preface

This Special Issue of *Linguistics and Education* explores cumulative knowledge-building in secondary schooling. It arises from a major research project into 'Disciplinarity, Knowledge and Schooling', funded by the Australian Research Council (Grant Number DP0988123), that has brought together scholars from systemic functional linguistics, the sociology of education, and ethnomethodology. In the first paper of this issue, 'Knowledge and school talk', Peter Freebody introduces this project with a call to arms. He highlights the relatively undertheorized nature of our understanding of how classroom talk mediates written forms of educational knowledge, and argues that far more attention needs to be paid to literacy if we are to understand school work. In doing so, he introduces many of the key issues that motivated the genesis of this interdisciplinary research endeavour. The project itself involved extensive textual analysis of curriculum materials, teaching texts, 100 hours of video-recorded classroom interaction, and a pedagogic intervention involving teacher training and support. This research is not only shedding light on how knowledge-building is enabled and constrained within classrooms discourse but also, and just as significantly, directly leading to theoretical developments in both systemic functional linguistics and the tradition of code sociology inspired by Basil Bernstein. As we explicate below, each of the papers in this issue begin from and clearly relate their ideas to the question of cumulative knowledge-building; here we briefly contextualize these theoretical developments.

There has been a long and fruitful history of exchanges between systemic functional linguistics (SFL) and code theory, beginning in the 1960s with conversations among Basil Bernstein, Michael Halliday and Ruqaiya Hasan. Space precludes discussing this rich history in any detail, but several general features of these relations are worth briefly highlighting here. First, dialogue between the two approaches has embraced a widening range of preoccupations over time. Analysing the dialogue, Martin (2011) offers a heuristic schema charting a series of principal phases, where each phase highlights new points of contact for discussion in addition to the ongoing conversations of existing phases. Table 1 adapts this schema to highlight four such phases of dialogue and the key concepts each phase has brought into the conversation.

As Table 1 suggests, dialogue between SFL and code theory has concerned an evolving series of issues, as the frameworks have themselves evolved. New ideas developed within each approach have added to and at times re-enlivened these relations, adding new avenues for mutual influence and shedding fresh light on existing ideas. For example, the first three phases involved key ideas from the development of code theory by Bernstein, principally his conceptualizations of: actors' socialized dispositions in terms of 'coding orientation' (1971); the construction of 'pedagogic discourse' (1975, 1990); and intellectual fields of knowledge production as different forms of 'knowledge structure' (2000). The fecund and suggestive framework Bernstein bequeathed has continued to develop in the form of Legitimation Code Theory (LCT). This framework works within the problematic and approach established by Bernstein to extend, integrate and subsume concepts from code theory (Maton, 2013). In doing so, LCT has re-worked existing ideas from across this history and, as the table intimates, re-ignited dialogue with multiple areas of SFL, including field (Martin, 2007; Martin, Maton, & Matruglio, 2010) and identity (Martin, 2012) Dialogue between the two approaches is thus reaching across manifold issues, both substantive and theoretical. The project discussed in this Special Issue forms part of this dialogue by bringing together LCT with SFL.

Table 1
Key foci of dialogue between code theory and systemic functional linguistics.

Period began	Code theory	Systemic functional linguistics
1960s	coding orientation	semantic variation
1980s	pedagogic discourse	genre-based literacy
1990s	knowledge structure	field
2000s	LCT: Specialization and Semantics	individuation/affiliation, field, mode, appraisal, grammatical metaphor, and many others

0898-5898/$ – see front matter
http://dx.doi.org/10.1016/j.linged.2012.11.003

Secondly, as with any sustained inter-disciplinary dialogue, intensity of relations and directions of influence have both ebbed and flowed. As papers in this Special Issue demonstrate, the latest phase comprises not only dialogue and mutual inspiration but also intense and close collaboration in the analysis of shared data. Discussions concerning relations between theories and the possibility and gains of inter-disciplinarity are frequently conducted at distance and in the abstract. All too often such comparisons reduce one approach to another or announce the incompatibility of different frameworks. In contrast, papers here concretely demonstrate the value of close inter-disciplinary collaboration through the explanatory power this offers in engaging with a shared substantive problem, namely cumulative knowledge-building in secondary schooling. They show how different approaches can shed not only complementary but also mutually informing light on an issue. Many of the key ideas elaborated for the first time in these papers – including 'semantic waves', 'power words', 'power grammar', 'power composition', 'temporal shifting', among others – were developed during the course of this project, from encounters not only between each existing framework and the data but also with each other's analyses.

Most of these new concepts are introduced in the papers by Maton and by Martin. In 'Making semantic waves', Maton introduces key theoretical ideas from LCT that underpinned the project, both as research study and as pedagogic intervention. Maton begins from the problem for understanding knowledge-building of 'knowledge-blindness' in educational research: an inability to see knowledge itself as an object of study. He introduces relatively new sociological concepts from LCT – 'semantic gravity' and 'semantic density' – that systematically conceptualize one set of organizing principles underlying knowledge practices. Using these concepts to analyze passages of classroom practice from secondary school lessons in Biology and History, Maton suggests that 'semantic waves', where knowledge is transformed between relatively decontextualized, condensed meanings and context-dependent, simplified meanings, offer a means of enabling cumulative classroom practice. How these concepts are being widely used to explore organizing principles of diverse practices in education and beyond is discussed, revealing the widespread, complex and suggestive nature of 'semantic waves' and their implications for cumulative knowledge-building.

In 'Knowledge as meaning' Martin takes as point of departure the SFL register variable field, and explores its application to the discourse of Biology and History in secondary school classrooms. In particular he considers the ways in which uncommon sense knowledge is organized in these subject specific discourses, and its critical relation to the high stakes reading and writing expected from students. Uncommon sense is explored in terms of specialized composition and classification relations among technical entities, and their participation in processes unfolding through implication sequences. Martin suggests that the organization of knowledge in classroom interaction and reading and writing tasks can be made more accessible to teachers through the practical concepts of 'power words', 'power grammar' and 'power composition'.

Together these papers suggest that cumulative knowledge-building is enabled by making 'semantic waves' in knowledge and involve the mastery of a 'power trio' of linguistic resources. The following two papers build on these concepts and thereby highlight a further characteristic of current relations between SFL and LCT, namely that direct collaboration in empirical research is not only leading to the generation of new ideas but also the emergence of a new generation of scholars who are more bilingual – they are increasingly fluent in *both* SFL and LCT. This issue includes papers first-authored by two educational linguists, Erika Matruglio and Lucy Macnaught that bring together ideas from both approaches. In 'Time travel', Matruglio, Maton, & Martin (2013) further explore cumulative knowledge-building in History teaching to highlight a key feature concerning the manipulation of time. Specifically, they reveal how making semantic waves in History teaching involves 'temporal shifting' and examine the linguistic resources this involves. In 'Jointly constructing semantic waves', Macnaught, Maton, Martin, & Matruglio (2013) discuss the pedagogic intervention stage of the project, exploring the implication of LCT's 'semantic waves' and SFL's 'power trio' for teacher training. Specifically, they focus on the experience of a Year 11 Biology teacher's experience of new metalanguage and explicit pedagogy, in teacher training, and first attempts at classroom Joint Construction, a form of collaborative text creation.

In the final paper of this Special Issue, Peter Freebody looks closely at the nature of the interaction between teachers and students, from an ethnomethodological perspective – representative of this major strand of classroom discourse research (complemented elsewhere, from an SFL perspective, by work inspired by Sinclair & Coulthard, 1975; e.g. Christie, 2002; Dreyfus & Martin, in press). He focuses on the details of the speech exchange systems in classrooms, highlighting the fine coordination of interaction that classrooms display. Freebody also focuses on the procedural definitions of the connection between literacy and knowledge that serve the purposes of initiating and maintaining lessons, compared to definitions that are operable in the production and assessment of students' learning through their written assignments. He suggests that constructs such as 'knowledge' are occasioned, purpose built-through on site through conventionalized systems of exchange that, reflexively, function to bring off the events that constitute the workings of such sites. The challenge for students in many classrooms, he argues, is to provide the 'missing what' that connects the daily heavy duties of classroom talk, which determines their success as classroom participants, to the occasional high-stakes writing performances that will come to characterize their success as learners. It is this 'missing what' that the preceding papers and concepts of 'semantic waves' and 'power trio' of linguistic resources also aim to help explore. In doing so, this research not only focuses on cumulative knowledge-building but also is helping to itself build knowledge about education.

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Available online 12 December 2012

Linguistics and Education 24 (2013) 8–22

Contents lists available at SciVerse ScienceDirect

Linguistics and Education

journal homepage: www.elsevier.com/locate/linged

Making semantic waves: A key to cumulative knowledge-building

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ARTICLE INFO

Available online 17 January 2013

Keywords:
Social realism
Legitimation Code Theory
Knowledge-building
Cumulative teaching
Semantic gravity
Semantic density

ABSTRACT

The paper begins by arguing that knowledge-blindness in educational research represents a serious obstacle to understanding knowledge-building. It then offers sociological concepts from Legitimation Code Theory – 'semantic gravity' and 'semantic density' – that systematically conceptualize one set of organizing principles underlying knowledge practices. Brought together as 'semantic profiles', these allow changes in the context-dependence and condensation of meaning of knowledge practices to be traced over time. These concepts are used to analyze passages of classroom practice from secondary school lessons in Biology and History. The analysis suggests that 'semantic waves', where knowledge is transformed between relatively decontextualized, condensed meanings and context-dependent, simplified meanings, offer a means of enabling cumulative classroom practice. How these concepts are being widely used to explore organizing principles of diverse practices in education and beyond is discussed, revealing the widespread, complex and suggestive nature of 'semantic waves' and their implications for cumulative knowledge-building.

Semantic waves are the pulses of cumulative knowledge-building.

1. Introduction: the cumulative and the segmental

Almost everyone in education shares a desire for cumulative knowledge-building. Researchers typically aim to generate ideas that have utility or appeal beyond the specificities of their originating contexts. Educators urge the need for pedagogic practice to have, as Bransford & Schwartz (1999: 61) put it, 'positive effects that extend beyond the exact conditions of initial learning' by enabling students to build on previous understandings and transfer what they learn into future contexts. Policymakers proclaim that education must prepare students for living and working in fast-changing societies by providing knowledge and skills that can build throughout 'lifelong learning' (Field, 2006). Thus, cumulative knowledge-building in research, teaching and learning are at the heart of education. Conversely, research and policy debates are replete with concern over segmentalism, when knowledge is so strongly tied to its context that it is only meaningful within that context. That this remains a serious problem is acknowledged across disciplinary and institutional maps, from arts to sciences, school to university, education to training (e.g. Christie & Macken-Horarik, 2007; Wheelahan, 2010). How the segmental may be overcome to enable the cumulative, however, is less clear.

This problem forms the starting point for the inter-disciplinary research discussed in the papers collected in this Special Issue. Freebody (2013) outlines some key issues serving as the background to this research, which focuses specifically on teaching in secondary schools. The current article offers a means of conceptualizing knowledge-building in terms of features of the knowledge itself. Specifically, I highlight the significance of 'semantic waves' for cumulative teaching. Martin (2013) explores the linguistic resources actors marshal to achieve semantic waves in teaching, identifying a trio of complexes he terms 'power words', 'power grammar' and 'power composition'. Matruglio, Maton, and Martin (2013a) draws on both these

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http://dx.doi.org/10.1016/j.linged.2012.11.005

papers to explore the temporal features of semantic waves in teaching, focusing specifically on History. Finally, Macnaught, Maton, Martin, and Matruglio (2013) discusses how 'semantic waves' and Martin's 'power trio' were enacted in a pedagogic intervention involving teacher training. The current paper is thus primarily concerned with establishing and illustrating some of the key conceptual ideas that shaped and emerged during this research project and which, as I shall discuss, are being used in a growing number of studies into diverse practices.

The paper begins by exploring two obstacles to understanding and enabling knowledge-building: knowledge-blindness, whereby educational research overwhelmingly obscures knowledge as an object; and, among models that do see knowledge, segmental theorizing of its forms. Secondly, I introduce concepts from Legitimation Code Theory, a sociological framework that builds primarily on the approach of Basil Bernstein. These concepts of *semantic gravity* and *semantic density* offer insight into one set of organizing principles of knowledge practices, and enable the analysis of change over time in terms of *semantic profiles*. Thirdly, these concepts are employed to examine knowledge within classroom practice. Drawing on a major study of secondary school History and Biology, I highlight how teaching often involves (to put it simply) a repeated pattern of exemplifying and 'unpacking' educational knowledge into context-dependent and simplified meanings. This raises questions of how this knowledge may be transformed to become the relatively decontextualized and condensed knowledge students must demonstrate in educational assessments to show their mastery of pedagogic subjects. Using brief examples from History and Biology lessons I illustrate how *semantic waves*, involving shifts in meaning in both directions, offer a potential means of traversing this gap in classroom practice. Fourthly, I discuss how the concepts outlined here are being used to explore the organizing principles of diverse practices in education and beyond, and their relations with other concepts and frameworks. Lastly, I return to the issue of cumulative knowledge-building to consider what light these ideas might shed on this widely shared goal for education.

2. Knowledge-blindness and segmental theorizing

2.1. Knowledge-blindness in educational research

Much educational research is characterized by 'knowledge-blindness' (Maton, 2013): knowledge as an object is obscured. The forms taken by this condition result at least partly from how psychology and sociology have influenced educational research over recent decades (Freebody, Maton, & Martin, 2008). On the one hand, psychologically-informed approaches typically focus on generic processes of learning and sideline differences between the forms of knowledge being learned. Research on 'transfer', for example, explores forms of knowing ('knowing with', 'knowing that', 'knowing how', etc.) rather than knowledge (Bransford & Schwartz, 1999). This construction of the object for research has been bolstered by the dominance of constructivisms, which include a view of 'knowledge' as mental processes and states of consciousness that reside within the learner. The notion of knowledge as an object of study emergent from but irreducible to how individuals know is thus obscured. On the other hand, approaches informed by sociology and cultural studies have tended to focus on the effects of power relations for the experiences and beliefs of different social groups (Maton & Moore, 2010). Here the central aim is to unmask the social power underpinning knowledge, to reveal those whose interests it serves or diminishes, where the form taken by that knowledge is considered arbitrary. Here, knowledge is reduced to a reflection of social power.

Educational research has thus typically backgrounded knowledge as an object. Key issues for research are exploring processes of learning and revealing whose knowledge is being learned. What is being learned and how it shapes these processes of learning and power relations among knowers have been largely obscured. Such knowledge-blindness thus proceeds as if the nature of what is taught and learned has little relevance. Accordingly, debates over teaching have oscillated between 'traditional' and 'constructivist' pedagogies that are generalized across the curriculum, and knowledge-building has been typically understood generically, as accumulation of content or ill-defined skills such as 'critical thinking'. How the forms taken by educational knowledge may enable or constrain cumulative teaching and learning remains relatively under-researched.

2.2. Segmental theorizing of knowledge

Highlighting the prevalence of knowledge-blindness is not to say there exist no models of knowledge. A host of thinkers, including Bourdieu, Foucault, Habermas, and Piaget, have distinguished everyday or commonsense knowledge from educational or uncommonsense knowledge (Bernstein, 2000). Similarly, there exist numerous attempts to characterize forms of academic knowledge. For example, Biglan (1973a, 1973b) typologized disciplines into hard/soft, pure/applied, and life/non-life; Kolb (1981) offered categories of abstract/concrete and active/reflective; and Becher (1994; Becher & Trowler, 2001) combined these typologies to describe the cultural and cognitive styles of academics as disciplinary 'tribes'. Such distinctions are legion: effective/ineffective; context-independent/context-dependent; conceptual/contextual; and many more, including the well-known taxonomies of Bloom (1976) and Shulman (1986). The creation of knowledge typologies is a thriving cottage industry.

These models are to be welcomed: they bring knowledge into view as an object of study. Categories such as abstract/concrete or context-dependent/context-independent offer a useful starting point for highlighting knowledge – I drew on such terms in the Introduction to this paper as a simple way into the issues. However, overcoming knowledge-blindness is but a first step. It is not enough to see knowledge, one also needs to theorize knowledge in ways that

enable knowledge-building to be explored in empirical research. This highlights a second obstacle: most models embody a segmental form of theorizing. They may expand or contract, overlap or integrate the types of knowledge they delineate, but they nonetheless offer a series of types into which relatively few empirical practices neatly fit and which struggle to accommodate change within or between them.

This issue is often mentioned when such models are proposed and debated. Proponents temper their advocacy by admitting they cannot do justice to the empirical complexity and variation of all kinds of knowledges. Similarly, critics focus on difficulties placing empirical practices into types, identify missing kinds of knowledge, and argue for further categories or sub-types. Such caveats and criticisms highlight the problem, but where they view the solution as delineating more categories they misunderstand its nature. The principal limit to such models is not simply whether they offer sufficient categories to embrace the variegated and changing nature of knowledge practices but rather that such theorizing cannot *by itself* fully embrace such diversity. It is *not* that typologies are a misstep; rather, it is that they are a valuable *first* step. The *next* step is to conceptualize the organizing principles that generate these diverse kinds of knowledge practices (and others yet to be delineated in these models).

Bernstein's model of 'discourses' and 'knowledge structures' (2000) offers a particularly pertinent example. By foregrounding forms of development, it is the most relevant model; as one of the most suggestive typologies, it also reveals their limits. Bernstein distinguished, first, between 'horizontal discourse' or everyday knowledge and 'vertical discourse' or educational knowledge. Horizontal discourse 'entails a set of strategies which are local, segmentally organized, context specific and dependent, for maximizing encounters with persons and habitats' (2000: 157). Vertical discourse comprises 'specialized symbolic structures of explicit knowledge' (2000: 160) where meaning is related to other meanings. Bernstein further distinguished within vertical discourse between knowledge structures. 'Hierarchical knowledge structures', exemplified by the sciences, are explicit, coherent, systematically principled and hierarchical organizations of knowledge that attempt to create generalizing theories that integrate knowledge across an expanding range of apparently different phenomena. 'Horizontal knowledge structures', exemplified by the humanities, comprise a series of segmented approaches, each with its own distinctive criteria. One issue these types highlight is knowledge-building: hierarchical knowledge structures develop by new theories integrating and subsuming previous ideas; horizontal knowledge structures develop through adding another segmented approach. Bernstein was describing the production of knowledge in intellectual fields, but these types can be homologously extended to distinguish: hierarchical and horizontal *curriculum structures*, where new units either extend and integrate or remain strongly bounded from knowledge articulated in preceding units; and *cumulative* and *segmental learning*, depending on whether students' understandings transfer across contexts and over time or remain locked into their pedagogic contexts (Maton, 2009).

Bernstein's model is insightful and suggestive. It has inspired a renewed focus in sociology and linguistics on knowledge practices (Christie & Martin, 2007; Christie & Maton, 2011; Maton & Moore, 2010). It has also brought knowledge-building into the foreground. Nonetheless, Bernstein's model represents a valuable *first* step on which to build by conceptualizing the principles underlying discourses and knowledge structures. This is to ask: what makes something horizontal or vertical, hierarchical or horizontal? Muller (2006) suggests 'verticality' and 'grammaticality' as key characteristics, usefully highlighting internal and external relations, but the question remains: what underlies these characteristics? It is unclear what they refer to or how they can be enacted in substantive research. Problems arise as soon as one attempts to operationalize the model to analyze empirical data. Few practices fit into the dichotomies, many combine characteristics of knowledge structures, and processes over time, such as research or classroom practice, elude the conceptualization.

Bernstein himself highlighted these kinds of limitations, noting that, at this stage of conceptual development, understanding of the organizing principles underlying such dichotomous forms is 'very weak' in its generative power (2000: 124). Nonetheless, as Bernstein wrote of other ideas, this 'does not mean that we abandon such a conceptual syntax but should recognize it for what it is, something good to think with, or about' (2000: 133). Against the tendency to regard each paper as the final word, he also emphasized that 'a paper is part of a development leading to a new development' (2000: 125). The model was made to be developed further. It is thus a valuable *first* step; as Muller (2006: 14) states, 'for all its richness, this analysis merely starts the ball rolling'. Usefully, Bernstein's framework also offers blueprints for how to keep it rolling. Code theory emphasizes the analysis of organizing principles underlying practices to enable research to determine difference, variation and similarity, and to explore change over time. Bernstein's model of change in knowledge structures also foregrounds the necessity for such concepts to be capable of enactment in research into all kinds of practices, to embrace the greatest range of phenomena within the most economical conceptual framework. Using Bernstein's blueprints for cumulative knowledge-building to cumulatively build on Bernstein's knowledge is an ongoing concern of Legitimation Code Theory, to which I now turn.

3. Legitimation Code Theory: Semantics

Legitimation Code Theory (LCT) is a sociological toolkit for the study of practice. It forms a core part of social realism, a broad 'coalition' of approaches (Maton & Moore, 2010) which axiomatically reveal knowledge as both socially produced and real, in the sense of having effects, and which explore those effects (Maton, 2013; Moore, 2009; Muller, 2000; Wheelahan, 2010; Young, 2008). Though LCT integrates insights from a range of approaches, its principal foundational framework is Bernstein's code theory (1971, 1975, 1990, 2000; see Moore, 2013). LCT cumulatively works within the problematic and

approach of code theory to offer concepts that extend existing conceptual tools (Maton, 2013). This development is in close relation with research. LCT is a practical framework that is being used to explore a host of issues, practices and contexts in education and beyond (e.g. Maton, Hood, & Shay, 2013), both on its own and alongside complementary frameworks, especially systemic functional linguistics (e.g. Hood, 2010, 2013; Matruglio, Maton, & Martin, 2013b).[1] As Maton (2013) emphasizes, LCT is a work-in-progress, an ongoing and open-ended endeavour that foresees its own repeated refinement, deepening and extension through dialectical relations with empirical studies, foundational frameworks, and complementary approaches. LCT is also a multi-dimensional conceptual toolkit; each dimension offers concepts for analysing a particular set of organizing principles (or *legitimation codes*) underlying practices. Here I focus on the most recently developed dimension of Semantics.

3.1. Semantics

The LCT dimension of Semantics constructs social fields of practice as *semantic structures* whose organizing principles are conceptualized as *semantic codes*, comprising strengths of *semantic gravity* and *semantic density*. These concepts have their genesis in all three dialectical relations mentioned above (Maton, 2009, 2011, 2013). First, substantive studies using concepts from the longer-established LCT dimension of Specialization, including the project discussed in this paper, 'spoke back' to the theory, highlighting issues of context-dependence and condensation of meaning that this dimension was not fully grasping – the framework needed extending. Secondly, these two issues are also highlighted by Bernstein's code theory, principally in his models of elaborated and restricted codes (1971) and discourses and knowledge structures (2000). However, they remained conflated within dichotomous types and their organizing principles had yet to be conceptualized – this foundational framework needed development. Thirdly, a series of collaborative studies with systemic functional linguists raised questions of how linguistic features such as 'grammatical metaphor' were expressed in knowledge practices – a complementary framework highlighted new facets of phenomena.[2]

Semantic gravity (SG) refers to the degree to which meaning relates to its context. Semantic gravity may be relatively stronger (+) or weaker (−) along a continuum of strengths. The stronger the semantic gravity (SG+), the more meaning is dependent on its context; the weaker the semantic gravity (SG−), the less dependent meaning is on its context. All meanings relate to a context of some kind; semantic gravity conceptualizes how much they depend on that context to make sense. (The nature of the context is analyzed using other concepts; see Section 5.3). How strengths of semantic gravity are realized empirically depends on the specific object of study (Maton, 2013). Nonetheless, to give a simple example: the meaning of the name for a specific plant in Biology or a specific event in History embodies stronger semantic gravity than that for a species of plant or a kind of historical event, which in turn embodies stronger semantic gravity than processes such as photosynthesis or theories of historical causation. Semantic gravity thus traces a continuum of strengths with infinite capacity for gradation. Moreover, by dynamizing this continuum to analyze change over time, one can also describe processes of: *weakening* semantic gravity (SG↓), such as moving from the concrete particulars of a specific case towards generalizations and abstractions whose meanings are less dependent on that context; and *strengthening* semantic gravity (SG↑), such as moving from abstract or generalized ideas towards concrete and delimited cases.[3]

Semantic density (SD) refers to the degree of condensation of meaning within socio-cultural practices, whether these comprise symbols, terms, concepts, phrases, expressions, gestures, clothing, etc. Semantic density may be relatively stronger (+) or weaker (−) along a continuum of strengths. The stronger the semantic density (SD+), the more meanings are condensed within practices; the weaker the semantic density (SD−), the less meanings are condensed. (The nature of these meanings, which may comprise formal definitions, empirical descriptions, feelings, political sensibilities, taste, values, morals, affiliations, etc., is analyzed using other concepts; see Section 5.3).

The degree of condensation within a symbol or practice relates to the *semantic structure* in which it is located. For example, Martin (2013) shows how the term 'cilia' is situated by the academic discourse of Biology within: compositional structures that describe the physical constituents of cilia and what cilia are constituents of; taxonomic structures that involve different ways of classifying parts of the body; and a range of biological processes and causal explanations in which cilia play a role. In short, by virtue of its positions within the constellations (relational systems of meanings) comprising the semantic structure of the intellectual field of Biology, 'cilia' possesses a semantic density of considerable strength. This strength is, though, not essential or intrinsic to the term itself. Within Biology, the semantic density characterizing 'cilia' in research publications is likely to be stronger than that characterizing the term's use within school textbooks, which in turn may be stronger than its use in classroom discourse or student work products. Furthermore, for terms that are also in everyday use

[1] To keep abreast with LCT research, publications, and events, see: http://www.legitimationcodetheory.com.

[2] Discomfort with inter-disciplinary dialogue, conceptual development, the term 'semantics', and close analyses of textual data could lead some sociologists to profanize this dimension as overly inspired by or resembling linguistics. This would ignore relations to substantive studies in code theory and to Bernstein's framework (which was itself influenced throughout by SFL), and decontextualize the concepts from their wider sociological framework (weakening their semantic density).

[3] In LCT, the meanings of '↑' (strengthening) and '↓' (weakening) remain the same across all code concepts. Thus, 'weakening semantic gravity' is denoted by 'SG↓', though weaker semantic gravity (SG−) is typically placed at the top of semantic scales.

(unlike 'cilia'), these pedagogic realizations are, in turn, likely to exhibit stronger semantic density than uses in horizontal discourse.[4] For example, 'gold' may be commonly understood as, for example, a bright yellow, shiny and malleable metal that has been used in coinage, jewellery, dentistry and electronics, whereas within the discipline of Chemistry the term may additionally signify such meanings as an atomic number, atomic weight, electron configuration, lattice structure, a capacity for reflecting infrared radiation and for conducting electricity and heat, and much more. Many of these meanings involve compositional structures, taxonomic structures or explanatory processes; for example, its atomic number represents the number of protons found in the nucleus of an atom, identifies it as a chemical element, and is situated, inter alia, within the periodic table, among many other relations. Thus, in Chemistry 'gold' is relationally situated within structured, complex, and evolving webs of meanings – the 'constellations' comprising its academic discourse (Maton, 2013) – imbuing the term with a far greater range of meanings. Semantic density thereby traces a continuum of strengths, with infinite capacity for gradation.

This continuum can also be dynamized to describe *strengthening* semantic density (SD↑), such as moving from a symbol or term that denotes a small number of meanings towards one that implicates a greater range of meanings. For example, bringing together a series of places, time periods, customs, ideas, beliefs, etc. within the term 'Mycenaean Greece' in History; or relating the structures of cells, proteins, pigments, etc. within a leaf to describe the process of 'photosynthesis' in Biology. Strengthening semantic density is thus creating (or revealing) constellations of meanings. Conversely, one can describe *weakening* semantic density (SD↓), such as moving from a highly condensed symbol to one that involves fewer meanings. For example, explaining a technical term from a written academic source in simpler terms typically enacts only a limited number of the meanings it possesses within that source: it reduces its range of meanings to those given in that explanation, weakening semantic density by delocating the term from its constellational relations with other terms in its semantic structure. (Thus, though commonly called 'unpacking', this practice might be more accurately described as 'partial unpacking').

3.2. Semantic profiles

Revisiting obstacles to exploring knowledge-building, the concepts of semantic gravity and semantic density overcome knowledge-blindness and segmental theorizing. Rather than gathering empirical characteristics, they bring the principles underlying those characteristics into the light. The relative strengths of semantic gravity and semantic density may be varied independently to generate *semantic codes* (SG+/−, SD+/−) that conceptualize one set of organizing principles of practices. Put another way, 'semantic gravity' and 'semantic density' are not categories into which complex and changing empirical practices are to be placed. All practices are characterized by both semantic gravity and semantic density; the question for empirical research concerns their strengths. However, they do not dispense with notions of boundaries, such as between types. Semantic codes combine typology and topology, notions of boundaries between categories and continua of difference: they offer a 'both/and' rather than an 'either/or'. Semantic codes embrace *both* four principal modalities (given by varying '+/−' within SG+/−, SD+/−), which provide a basis for typologizing practices (e.g. Shay, in press, on curriculum in professional education), *and* continua of strengths along which practices can be situated to generate their positions within a relational topology (see Maton, 2011: 66). The concepts thereby move beyond segmented and homogenizing categories such as abstract/concrete, to additionally embrace differences between and within different forms, as well as change over time.[5]

Dynamizing static accounts of structures is crucial for capturing knowledge-building, a practice enacted through time. Conceptualizing processes of strengthening and weakening semantic gravity and semantic density (SG↑↓, SD↑↓) enables research to trace the *semantic profile* of practices over time, and the associated *semantic range* between their highest and lowest strengths. For example, Fig. 1 describes a *semantic scale* of strengths of semantic gravity and semantic density on its *y*-axis, and time on its *x*-axis (such as the unfolding of classroom practice, curriculum or text). Fig. 1 traces several illustrative profiles and their respective *semantic ranges*: a high *semantic flatline* (A1), a low *semantic flatline* (A2) and a *semantic wave* (B). Semantic profiles take the pulse of knowledge-building; semantic ranges reveal, for example, how faint the pulses of flatlines are compared to those of waves. Again, this conceptualization combines categories with continua; as illustrated by the dotted line in Fig. 1, typologies of knowledge, such as horizontal discourse/vertical discourse, may also be distinguished. Semantic waves may thus involve the *semantic weaving* together within practices of different types of knowledge or semantic codes.

[4] I am here describing *epistemic semantic density* based on *epistemological condensation*; commonsense understandings may exhibit far stronger *social semantic density* based on *axiological condensation* (see Section 5.3, below; Maton, 2013). The point here is that 'semantic density' does not project a deficit model of horizontal discourse: it may exhibit relatively strong semantic density of a different kind.

[5] It is possible to redescribe categories such as abstract / concrete as the end-points of a continuum. However, their definitions are vague, hotly-contested, embedded in dichotomizing discourses, elide instances with principles, and possess considerable axiological loading within debates. They also often conflate *semantic gravity* and *semantic density*. In short, they are characterized by weaker epistemological condensation, stronger axiological condensation (see Section 5.3), and a limited range of semantic gravity. Notably, using existing categories such as abstract/concrete to analyze categories such as abstract/concrete would offer less insight into their value and limits.

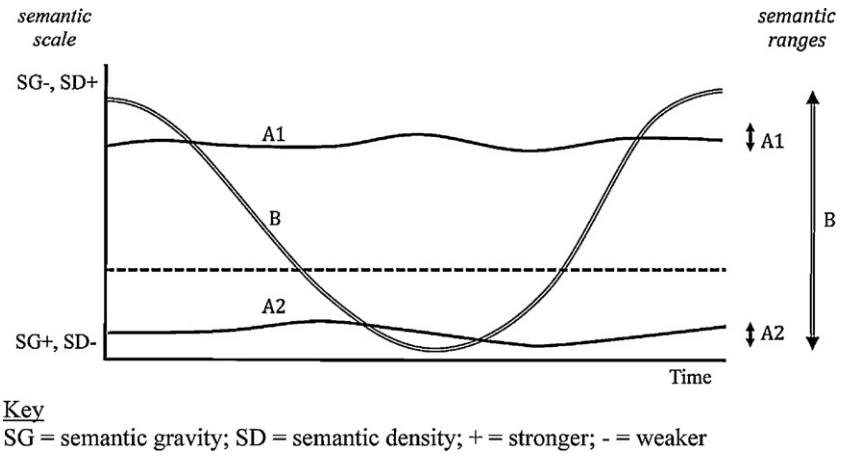

Fig. 1. Illustrative semantic profiles and semantic ranges.

3.3. Simplicity

I should emphasize that the discussion of concepts thus far is but a basic introduction – the definitions are anything but definitive. As discussed in Section 5 (below), studies using these concepts are rapidly revealing both their fecundity and complexity. There is, for instance, more than the one form of semantic density I shall explore in this paper. Similarly, semantic profiles are more complex than presented here. Those I depict as figures trace together the strengths of semantic gravity and semantic density as a single line, with the two strengths moving together inversely. However, the two strengths may change independently and not always in this manner. Thus, different profiles could be drawn for SG and SD, there is more than one possible 'semantic scale', and the one used in this paper does not embrace two semantic codes (SG+, SD+ and SG−, SD−). Moreover, these figures are heuristic; other studies are developing means for calibrating semantic scales and plotting profiles with greater precision. Research is also revealing semantic waves of different amplitudes, frequencies, lengths and shapes – they are not homogeneous. Nonetheless, as I discuss below, 'unpacking' must begin somewhere, and the simple semantic profiles above were central to the collaborative research into cumulative teaching in secondary schooling discussed in the papers comprising this special issue.

4. Modelling semantic waves in teaching

The 'Disciplinarity, Knowledge and Schooling' project (DISKS) utilized LCT and systemic functional linguistics (SFL) as complementary frameworks for exploring cumulative teaching in secondary schooling. The study was structured into three main stages. First, data collection principally comprised video-recordings of 100 lessons in Years 8 and 11 of both urban and rural secondary schools in New South Wales, Australia. To explore contrasting areas of the disciplinary map, the lessons were in Science (Year 8) or Biology (Year 11) and Ancient History or Modern History (depending on school). Secondly, LCT and SFL were drawn on to analyze teaching texts, student assessments and classroom practice, focusing on phases of classroom interaction in which knowledge was actively transformed in some way, such as unpacked, repacked, recalled from the past, built on, elaborated, reworked, projected into the future, etc. Thirdly, these analyses formed the basis for a pedagogic intervention in which teachers were trained to engage in 'joint construction' with their students, in order to model semantic waves and teach the linguistic resources they involve (Macnaught et al., 2013). Three dimensions from LCT were drawn on in the project: Specialization, Semantics and Temporality. It is beyond the limits of this paper to explicate the substantive and theoretical outcomes of this research. Here I shall focus on Semantics and specifically on one issue for cumulative knowledge-building that became central to the project's pedagogic intervention.

4.1. High stakes and down escalators

The issue I focus on concerns what can be described as the 'high stakes' of teaching and learning. As heuristically portrayed in Fig. 2, classroom practice must traverse a potential semantic gap between what are often called 'high-stakes reading' and 'high-stakes writing'. On one side is the educational knowledge to be learned, typically embodied in written forms such as textbooks or source documents and accessed through reading; on the other side is the knowledge students must display in their assessments, mostly though not exclusively in writing tasks, to reveal successful mastery of the pedagogic subject. Though the position on the semantic scale of the latter relative to the former varies (such as being typically lower but rising from earlier to later years of study), our analyses of teaching texts and students' assessments suggest both sides exhibit weaker semantic gravity and stronger semantic density than the knowledge expressed in classroom discourse. One

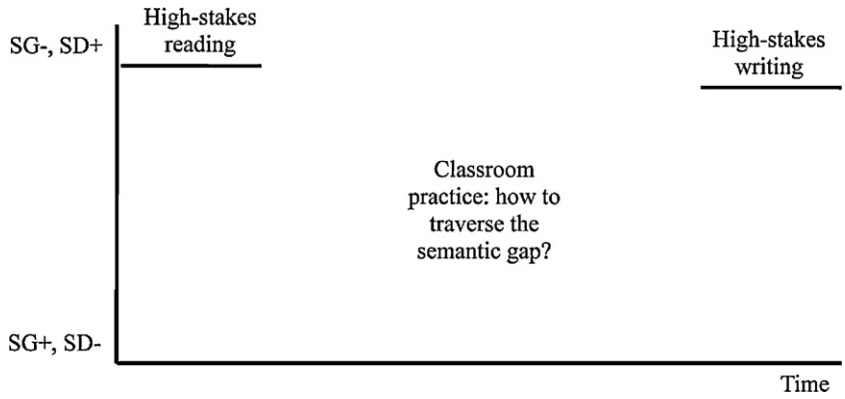

Fig. 2. The high stakes of teaching and learning.

question this raises concerns how this potential gap is traversed; how do classroom activities mediate between knowledges that are higher up a semantic scale?

Analyses of phases of interaction highlighted several semantic profiles of classroom practice. As depicted in Fig. 3, one that featured frequently comprises a series of *downward semantic shifts*: from highly condensed and decontextualized ideas (SG−, SD+) towards simpler, more concrete understandings, often including examples from everyday life (SG+, SD−). The pedagogic practices associated with this 'down escalator' profile typically involved teachers repeatedly 'unpacking' and exemplifying meanings from written sources. As I illustrate below, such 'unpacking' may form part of other profiles; however, the signature of the 'down escalator' profile is the exclusive focus on and repeated nature of this 'unpacking'. For example, when reading together through a text or source, teachers often explained particular ideas and words to students using less technical, more 'everyday' language and examples, and then returned to the text, repeatedly finding points to 'unpack' and discuss, but rarely if ever moving back into the pedagogic discourse of the subject through 'repacking' explicated meanings and examples into terms or ideas. Thus, the profile models movements downwards but not back upwards from knowledge that is non-technicalized, concretized and often segmented (such as into disparate examples) towards more condensed, technicalized knowledge that is 'plugged into' the constellations of meanings constituting academic subjects. This represents a potential problem for cumulative knowledge-building: knowledge characterized solely by relatively strong semantic gravity and relatively weak semantic density may be too related to specific contexts and too disconnected to either build upon previous knowledge or be built upon in the future.

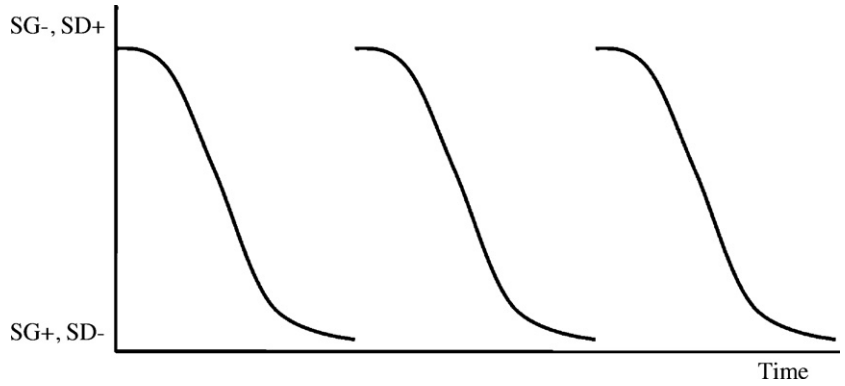

Fig. 3. A 'down escalator' profile.

4.2. Semantic waves

A contrasting semantic profile characterizing classroom practice in the study involved not only *downward semantic shifts* but also *upward semantic shifts*. These *semantic waves* thereby offer the possibility of additionally modelling transitions of knowledge from contextualized and simpler understandings towards more integrated, manifold and deeper meanings. Moreover, they model how meanings may be transformed through semantically weaving together different forms of knowledge within practice. To illustrate these shifts I shall explicate a single wave in two brief examples from Biology and History.

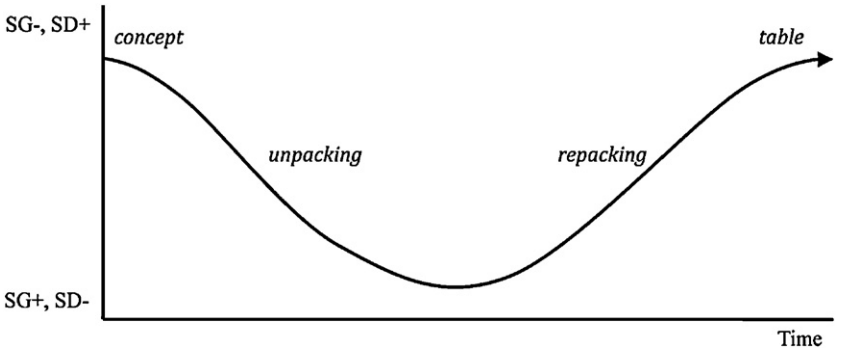

Fig. 4. Example of a semantic wave in Biology teaching.

4.2.1. A semantic wave in a Biology classroom

In this example from a Year 11 Biology classroom, the topic of discussion is biological lines of defence, focusing here on the 'cilia':

Teacher	Okay [student's name] what are the 'cilia'. What was it? No? [Student's name] do you know what cilia is? No? Someone must know what they are. . .
Student	Hairs
Student	The little hairs?
Teacher	The little hairs. And basically, they beat in an upward motion from inside your body out through to your nose. [Teacher is waving arms upwards]. So, they beat up and they take the pathogens away with them. And, guys, I don't know if I've ever told you this, but when you smoke cigarettes, the tar actually causes your cilia to, because it's so heavy, to drop, and so your cilia don't work properly after that because they're too heavy, they've dropped, so they can't beat the pathogens out of your body! So that's one reason that smoking's bad as well. Okay! Alright, write this down under description!

Fig. 4 portrays the semantic profile of this classroom interaction. The example begins with the teacher introducing 'cilia', an abstract scientific term that condenses a wide range of meanings within Biology (Martin, 2013). The context of the science classroom, the explicitly stated focus of this particular lesson, the teacher's solicitation of a definition, and the unfamiliarity of the word, together announce its high position on a semantic scale ('concept' in Fig. 4). With contributions from students, the teacher then explicates some meanings of the term using a combination of previously learned concepts, such as 'pathogens', and everyday language, such as 'the little hairs', as well as body language (waving her arms). She also provides a concrete example from everyday life, that smoking stops the cilia from performing a function integral to their definition. Locating the 'cilia' in the body and setting limits to its functions strengthens semantic gravity; 'unpacking' the term by delineating a limited number of its meanings weakens semantic density. This moves down the semantic scale towards more grounded and less condensed meanings.

I should emphasize that to conceptualize the partial 'unpacking' of educational knowledge as weakening its semantic density is *not* to negatively evaluate such activity. 'Translating' a technical term into commonsense understandings reduces its range of meanings, but that is the purpose: to provide a point of entry for noviciates into those meanings. This also represents a potential starting point for progressively strengthening its semantic density through elaborating, extending and refining additional meanings, such as by locating the term within systems of composition, taxonomies, and processes. The 'down escalator' profile eschews this possibility by returning to the start of the sequence to commence a new 'unpacking'. However, in the current example the teacher engages in 'repacking' knowledge into the term.

cilia	Hair-like projections from cells lining the air passages	Move with a wavelike motion to move pathogens from the lungs until it can be swallowed into the acid of the stomach

Fig. 5. Biology teacher's table entry for 'cilia'.

After telling the students, as quoted above, to 'write this down under description', the teacher writes on the board: 'cilia', a brief definition, and a description of a function they serve in the body (see Fig. 5). This is more than a summary of the preceding passage of 'unpacking'; it begins to 'repack' the term 'cilia' by bringing together elaborated meanings without specific contexts such as smoking. In other words, it begins moving expressed knowledge up the semantic scale ('repacking' in Fig. 5). This upward semantic shift is then continued further: the definition forms part of a table (reproduced as Fig. 6) that the class works through together in learning about biological lines of defence. This table reveals a greater range of relations within which the term 'cilia' is embedded, including biological processes and causal explanations (for example, 'cilia' form part of the workings of 'chemical barriers'), tracing a semantic wave. As the table highlights, this wave forms part of a longer sequence in which the current teaching and learning builds on previously discussed ideas and is then taken forward into future practice.

Line of defence	Description	What it does
skin	Skin continuously grows by new cells being produced from below. Cells fit tightly together to form a protective layer covered by dead cells.	When unbroken skin prevents the entry of pathogens. Pores in the skin secrete substances that kill microbes. Skin constantly flakes off carrying microbes away. It is a difficult environment for a pathogen to grow (no water).
mucous membrane	Cells lining the respiratory tract and openings of the urinary and reproductive systems that secrete a protective layer of mucous.	
cilia	Hair-like projections from cells lining the air passages	Move with a wavelike motion to move pathogens from the lungs until it can be swallowed into the acid of the stomach
chemical barriers	Acid in the stomach, alkali in the small intestine, the enzyme lysozyme in the tears.	Stomach acid destroys pathogens including those that are carried to the throat by cilia and then swallowed. Alkali destroys acid resistant pathogens. Lysozyme dissolves the cell membranes of bacteria.
other body secretions	Secretions from sweat glads and oily secretions from glands in hair follicles.	Contain chemicals that destroy bacteria and fungi.

Fig. 6. Table used for teaching lines of defence in a Biology classroom.

4.2.2. A semantic wave in a History classroom

My second example is from a Year 11 History classroom discussion of a take-home assignment on 'the influence of Greek and Egyptian cultures in the Roman Empire'. The question includes terms from the pedagogic discourse of History with relatively weak semantic gravity and relatively strong semantic density: 'Greek culture', 'Egyptian culture' and 'Roman Empire' embrace a range of meanings concerning time periods, geographical locations, practices, beliefs, etc. Moreover, the question condenses more than the sum of its terms: 'influence' elicits understanding of historical processes. Though here interleaved with analysis, the following quotes represent continuous interaction, which begins:

Teacher This is a little bit hard, "H. THE INFLUENCE OF GREEK AND EGYPTIAN CULTURES." What does that mean. What would the influence of Greek and Egyptian cultures mean, okay? No idea, right.

The teacher begins by indicating the knowledge being discussed is relatively high on the semantic scale ('a little bit hard . . . No idea, right'). Notably, an indicator was unnecessary in the Biology example: the term's technical nature announces itself, as it were, while terms in History may be less self-evidently specialized (cf. Martin, 2013 on 'flexi-tech'). Fig. 7 thus depicts the semantic profile as beginning relatively high. The teacher then moves the knowledge down the semantic scale in stages ('unpacking' in Fig. 7) by providing a series of examples of 'influence':

Teacher What it means is, if we started to look at all the things in Pompeii and Herculaneum, what objects may be showing Greek design? Or Egyptian design? Or Greek mythology? Or Egyptian mythology? Or what building techniques, like columns? Are there Greek columns? Do, you know, are the themes of their artwork reflecting it?

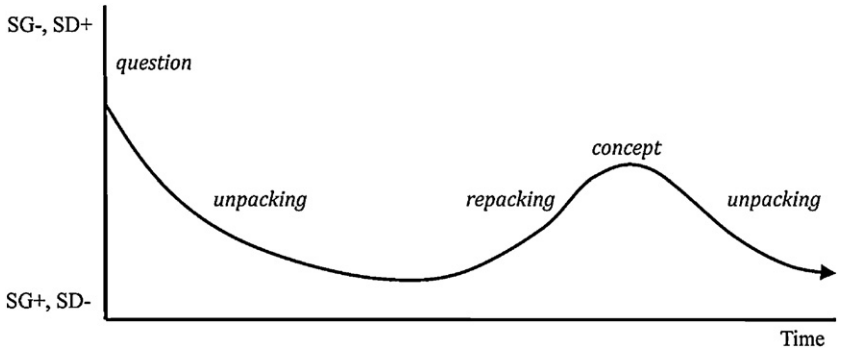

Fig. 7. Example of a semantic wave in History teaching.

With the examples of 'objects' that 'may be showing Greek design', 'Egyptian design', 'Greek mythology' or 'Egyptian mythology', the knowledge expressed by the teacher begins to descend the semantic scale by specifying and unpacking meanings from the wide-ranging, abstract terms, a move continued by the more specific and concrete examples of 'building techniques', which is in turn exemplified by 'columns'. Moreover, the teacher provides a second avenue of descent by grounding the question in the historical period through examples of prior events in history (see Matruglio et al., 2013a) and the current discussion of the question in the context of what has been learned in previous lessons:

Teacher So, it's saying . . .remember when we started, we said that Pompeii had originally been settled by Greeks? Okay? And if we look at where Italy is, it's not that far from Egypt at this time, umm, we've, we've had, umm . . . Cleopatra has been killed by the time the volcano erupts, she and Mark Antony are dead and Egypt is part of the Roman empire.

As discussed above, our research often encountered such downward semantic shifts in secondary classrooms. However, in this case, the teacher begins to move knowledge in the opposite direction:

Teacher So, there would be massive amounts of trade going on, and umm, you know people visiting their diplomats you know or their, their, ambassadors. . . like their envoys and things like that all going back and forth across the countries. So, ideas. When you get trade in ideas – you wouldn't have heard this word before – we call it 'aesthetic trade'. Have you heard of it? Yeah.
Student You told us before.
Teacher Ohh! Told you before great, *excellent*! You remember aesthetic trade! 'Trade in ideas'. So, of course, when you've got contact with the country you're gonna get the trade in ideas coming as well.

This discussion weakens semantic gravity by addressing recurrent events (trade and diplomatic visits) rather than specific events, and progressively strengthens semantic density by 'packing up' the various activities being recurrently conducted between countries as 'trade in ideas', and thence into the technical term, 'aesthetic trade', which also exhibits weaker semantic gravity (see 'repacking' to 'concept' in Fig. 7). Though this does not return to the heights embodied by the question, this upwards shift almost completes a semantic wave in explaining one key aspect of 'influence'.

As with the Biology example, a semantic profile is typically part of a bigger picture, set within proceeding and subsequent practice. In this example, the knowledge discussed descends the scale again through the teacher providing examples of the concept 'aesthetic trade' and emphasizing how seemingly 'hard' questions can be 'unpacked' in this way:

Teacher So that's what that one is. It looks hard, but all you've gotta do is have a look and think what things are there. Let me give you a big clue some of them are massive. Laah-la-lah-la- la-la-la-la-lahh, la-lah
Student Theatres
Student La-lahh
Teacher Theatres. Okay, theatres are a Greek design. The Greeks invented the theatre, and then the Romans take the idea because they like it too. So, some of them are very obvious.

4.3. Semantic waves and high stakes

Though specifying and 'unpacking', generalizing and 'repacking' may be valuable pedagogic strategies, the principal point of the examples is less to identify exemplary practices than to illustrate semantic waves in the knowledge being discussed. The DISKS project also explored other dimensions of knowledge (Section 5, below), as well as the complex linguistic resources they enact (Martin, 2013) and the role of time in their creation (Matruglio et al., 2013a). From this research, we tentatively conjecture, inter alia, that one means for traversing the potential semantic gap between high-stakes reading and high-stakes writing may reside in a series of waves progressively reaching further up the semantic scale, as depicted by Fig. 8. This tentative conjecture underpinned a small-scale pedagogic intervention that comprised the third stage of the research. As Macnaught et al. (2013) discusses, in the light of the pervasive nature of the 'down escalator' profile, we focused on training teachers to engage in 'joint construction' with students as a means of moving up the semantic wave and master the linguistic resources required for high-stakes writing.

Our research project focused on one specific issue, but the notion of semantic waves may ripple out further. The examples given here each trace a single semantic wave through a brief passage of classroom practice, in order to demonstrate that this phenomenon need not be lengthy. However, the endpoints – a table of 'biological lines of defence' and further historical examples of 'aesthetic trade' – highlight their location within more extended sequences of activity. Semantic profiles can be traced at any level – exchange, phase, lesson, unit, course, curriculum, educational career, etc. As one moves from micro through meso to macro levels, analysing profiles may fractally reveal waves within waves that aim to progressively move higher as they build upon previously waved knowledge (see 'detail' in Fig. 8). This may also involve, as in a 'spiral curriculum', revisiting knowledge to heighten or deepen past waves. Although, for example, Liu (2012) details how successful pedagogies such as the Reading to Learn programme (Rose & Martin, 2012) trace semantic waves, further studies are required to explore the veracity of these tentative conjectures. On these issues the DISKS project suggests more than it can show. Nonetheless, as I now discuss, other studies are revealing the widespread and manifold nature of semantic waves and the fertility of semantic profile analysis.

5. The depth of semantic waves

Having introduced somewhat abstract and condensed concepts from LCT in Section 3, the examples of semantic waves in classroom discourse in Section 4 were relatively simple, concrete, and drawn from the specific focus of one research project. I concluded by suggesting semantic profiles may be analyzed for contexts and practices beyond single passages of classroom discourse. Here I continue this last direction by discussing how studies are showing semantic waves to be more pervasive and complex, and the concepts for analysing them more fecund, than hitherto suggested. Substantively, studies are revealing that semantic waves: appear far beyond classrooms; take many forms; interact with other principles underlying practices; and relate to the dispositions of actors. Theoretically, they are showing that semantic profile analysis can: explore a wide range of practices; embrace manifold diversity; form part of multi-dimensional analyses of practices; and embody a social justice agenda. I address each of these four couplets in turn.

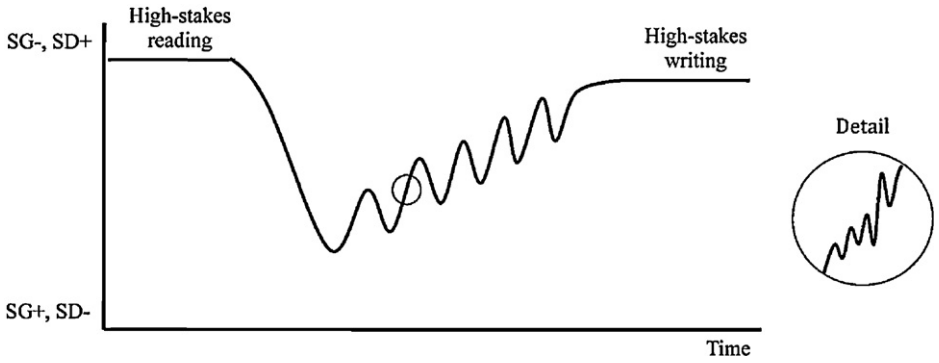

Fig. 8. Semantic waves and the high stakes of teaching and learning.

5.1. Reaching beyond classrooms: pervasive profiles

Substantive studies are revealing the forms, attributes and roles of semantic codes and profiles across a growing range of practices and contexts. Research is exploring research, curriculum, pedagogy and assessment in, for example, subjects from across the disciplinary map, including cultural studies (Hood, 2013), design studies (Shay & Steyn, 2013), English (Christie, 2013), engineering (Wolff & Luckett, in press), environmental education (Tan, 2013), jazz education (Martin, 2012), journalism (Kilpert & Shay, 2012), marketing (Arbee, 2012), nursing (O'Connor, McNamara, Ahern, MacRuairc, & O'Donnell, 2011), physics (Lindstrøm, 2010; Zhao, 2012), sociology (Stavrou, 2012), and teacher education (Shalem & Slonimsky, 2010). Other studies are also exploring practices beyond education, such as parliamentary procedures (Siebörger & Adendorff, 2011) and freemasonry apprenticeship (Poulet, 2011).

These studies are showing that, while its use in the DISKS project gave rise to some tentative conjectures regarding the nature of cumulative pedagogic practice in secondary school classrooms, the value of the approach does not rest upon the fertility or otherwise of those specific and localized suggestions. Published and ongoing studies are showing the wider applicability of semantic profile analysis and the significance of those profiles for understanding powerful and cumulative knowledge practices within otherwise disparate terrains. They are suggesting that, whatever the field, the recontextualization of knowledge – an essential attribute of building knowledge over time – requires *both* upwards shifts from specific contexts and meanings, *and* downward shifts from generalized and highly condensed meanings. Simply put, semantic waves represent the pulses of knowledge-building. In educational research, for example, approaches often trace either high flatlines reflecting abstract discussion of condensed concepts that engage little with empirical data or low flatlines comprising empirical descriptions that remain bounded from studies of other contexts. In contrast, cumulative theories with explanatory power can be enacted within specific contexts in substantive studies (concretizing and engaging only some of their meanings), and enable empirical descriptions to be translated back into and transform the constellations of the theory – i.e., they trace semantic waves (Maton, 2011, 2013). Similarly, studies of student work products are suggesting semantic waves play a role in achievement. Fig. 9 draws upon Maton (2009, 2013) to portray the semantic profiles of high- and low-achieving student essays from secondary school English that discuss three texts in relation to the abstract idea of 'the journey'. The high-achieving essay traces a series of semantic waves between wide-ranging and literary ideas and the concrete particularities of each text; the low-achieving essay traces a semantic flatline with strongly bounded discussion of highly contextualized and simple meanings from each text.

5.2. Embracing complexity: diverse profiles

Profiles involving both upward and downward semantic shifts may be pervasive but they are not uniform; the examples analyzed in this paper are not the only form semantic waves take. The aforementioned studies are demonstrating the

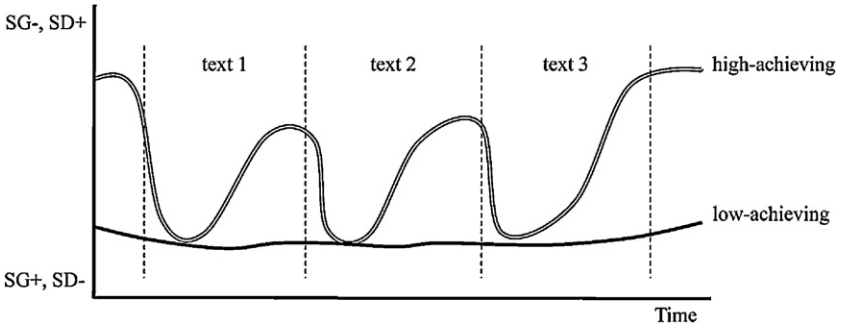

Fig. 9. Semantic profiles of two student essays in school English.

diversity of profiles and the ability of Semantics concepts to embrace that complexity by exploring an expanding range of characteristics, including range, directional shifts, entry and exit points, flow, and threshold.

First, in terms of *semantic range*, though the limited nature of flatlines may be problematic, as the low-achieving essay of Fig. 9 highlights, it is not a simple case of "the higher the better". Research into undergraduate physics education, for example, reveals that students may reach too high up the semantic scale in their assessed work, to grasp for concepts, principles, equations or laws that are overly abstract and generalizing or which condense more meanings than appropriate to their assignment (Georgiou, 2012). This 'Icarus effect' suggests one facet of being inducted into a subject area is learning the semantic range appropriate to addressing different kinds of problem-situations.

Secondly, though both upward and downward shifts are required for cumulative knowledge-building, the directions of *semantic shifts* may play different roles across fields. In discussing classroom examples (Section 4) the importance of ascending a semantic scale was emphasized in response to the frequency of 'down escalators' in lessons analyzed for the DISKS project. In contrast, studies of professional education (e.g. Kilpert & Shay, 2012) are highlighting that *downward* semantic shifts are not confined to 'unpacking' and are crucial in teaching and learning appropriate ways to select, recontextualize and enact abstract and condensed principles of knowledge within concrete and specific cases of professional practice.

Thirdly, semantic waves do not necessarily begin and end on relative highs in the manner of the examples. Beginning from concrete, simpler meanings may offer a more engaging way into and out of the central focus of an activity or topic. Ongoing research is thus exploring the role of different *entry* and *exit points* on semantic scales in research publications, lessons, student assignments, etc. Fourthly, while the classroom examples exhibited relatively strong *semantic flow* or degree of connectedness between consecutive points, this cannot be assumed. Knowledge expressed in practices may realize disconnected shifts up and down, such as unexplained jumps between theories and data or concepts and examples, or minimally linked moves that create vertiginous shifts in the context-dependence and condensation of meanings. Lastly, the *semantic threshold*, or extent to which accuracy matters, may vary among practices and contexts. Ongoing research is suggesting that the degree of this threshold as well as its nature, such as relative emphases on epistemological and axiological issues, differs across subject areas and through stages of education. For example, the definition of the function of 'cilia' offered by the teacher in Section 4.2 is not entirely correct biologically in too closely relating the respiratory system to the gastrointestinal system.[6] Further research may show, however, that such simplified definitions go on to be elaborated and clarified as students progress through the curriculum, raising the semantic threshold. The concepts for semantic analysis thereby embrace prolific diversity, of not only practices but also profiles.[7] This diversity highlights that semantic waves are not homogeneous and no one kind is a universal panacea. It suggests a key question for research is: what profiles serves what purposes, for whom, and in which contexts?

5.3. Plugging into multi-dimensionality: Semantics and other principles

That studies suggest semantic waves appear in a range of institutional and disciplinary contexts does not negate differences between practices. For example, as Bernstein (1990) highlights, practices within fields of production, recontextualization, and reproduction cannot be reduced to each other – they have different logics. Thus, homologous semantic profiles across the research, curriculum, and pedagogy of a subject area would not suggest these practices are unproblematically the same. One would also need to explore the organizing principles whereby knowledge is recontextualized between these fields and their effects on that knowledge. Moreover, strengths of semantic gravity and semantic density are likely to differ for the same sets of ideas across these three fields. For example, as noted in Section 3.1, recontextualizations of ideas

[6] I am grateful to Gabi De Bie for bringing this to my attention.

[7] These attributes offer a simple list for profile analysis of exploring 7-Gs: going in (semantic entry), going up and going down (semantic shifts), gamut (semantic range), going along (semantic flow), going out (semantic exit), and getting it right (semantic threshold)

from research to curriculum to pedagogy are likely to involve, inter alia, weakening semantic density. So, though profiles may be similar, their location on a semantic scale may differ.

In addition, semantic codes are not the only principles underlying practices. For example, similar semantic profiles may recur across subject areas that differ along other dimensions. In the DISKS project the knowledge expressed in lessons in both Biology and History offered similar semantic profiles but fundamentally differed in other ways. Drawing upon concepts from Specialization, a second dimension of LCT (Maton, 2013), revealed that Biology lessons embodied a *knowledge code* (where legitimacy emphasizes epistemic relations to objects of study) and History lessons embodied a *knower code* (where legitimacy emphasizes social relations to actors). As a wide array of research is showing, these specialization codes have different effects for educational practice (Maton et al., 2013).

The concepts of Semantics thus form part of a multi-dimensional toolkit for exploring complexity. Moreover, these dimensions can be integrated. In Section 3 I highlighted that the nature of the context (for semantic gravity) and the meanings being condensed (for semantic density) may take a range of forms that can be analyzed using other concepts. For example, using Specialization reveals different forms of semantic density (Maton, 2013). A technical term may involve the *epistemological condensation* of meanings of other concepts or empirical referents, as illustrated in the classroom examples of 'cilia' and 'aesthetic trade'. This is the form I have focused on throughout this paper. However, studies also highlight semantic density involving *axiological condensation* of emotional, ethical, political and moral stances. For example, in educational research stances associated with 'student-centred learning' are typically condensed with political connotations (Maton, 2013); and analyses of History lessons reveal the moral stances condensed within such '-isms' as colonialism, nationalism and imperialism (Martin, Maton, & Matruglio, 2010).

5.4. Integrating with knowers: Semantics and social justice

While semantic profiles offer insight into the organizing principles of knowledge, not everyone is equally capable of enacting the semantic shifts required for achievement. As the essays depicted in Fig. 9 highlight, not all students recognize that semantic waves are a crucial aspect of this assignment and/or realize such a profile in their written assessment. Moreover, as actors are apprenticed into the semantic structures of specialized discourses such as academic subjects, one would expect their appreciation of the diverse applicability and manifold meanings condensed within ideas to deepen. This highlights a key issue for further research: the diverse and potentially evolving semantic ranges of actors.

Practice, as Bourdieu (1993) emphasized, is the meeting of two evolving histories, embodied in the logics of the context and of actors' dispositions, or (in Bernstein's terms) codes and coding orientations. Social realist calls to recover knowledge for educational research emphasize, and studies using the multidimensional toolkit of LCT typically explore, the attributes of knowledge expressed in practices. Codes have been the primary focus. However, overcoming knowledge-blindness does not require succumbing to knower-blindness. Accordingly, LCT can also be used to analyze the dispositions actors bring to educational contexts by virtue of their previous experience. There is a pre-existing tradition of research drawing on code sociology (e.g. Holland, 1981) and systemic functional linguistics (Hasan, 2009) that explores the coding orientations of actors and their social distribution. In LCT terms these highlight that a greater semantic range, the capacity to reach higher up the semantic scale, from concrete, simple meanings to highly abstract, condensed meanings, is not equally distributed across actors from different social backgrounds. More detailed attention to this existing work and further research are required to explore both the coding orientations of different knowers and their relations to the codes dominating educational contexts. For example, while the DISKS project tentatively conjectures that cumulative teaching involves semantic waves, modelling such waves in pedagogic practice does not guarantee enabling all students to experience cumulative learning. Nonetheless, the concepts provide the means for bringing analyses of knowledge and knowers together to reveal ways in which more learners can acquire the keys to the legitimate codes.

6. Conclusion

Almost everyone in education shares a desire for cumulative knowledge-building, but commitment is not consequence. Knowledge-blindness and segmental theorizing represent two obstacles to grasping the complex nature of knowledge-building, revealing its organizing principles, and enabling greater social equality of access to those principles across diverse institutional and disciplinary fields. This paper has offered concepts to further these aims: semantic gravity, semantic density, and their arrangements within semantic codes and profiles. Building on issues highlighted by Bernstein's framework and in substantive studies, these concepts bring one dimension of knowledge practices into view. They also represent a step forward by supplementing typologies with a means for exploring the organizing principles of knowledge practices and change over time.

One tentative conjecture proposed in this paper has been that semantic waves represent a key to cumulative development by enabling the recontextualization of knowledge through time and space. I emphasized, though, that semantic waves may take many forms and are not, by themselves, the answer to everything. Moreover, the concept of *semantic threshold* offers the salutary lesson that semantic waves may be necessary but not sufficient, that 'getting it right' may remain crucial. This also highlights the significance of working with subject specialists, and that building knowledge requires mastering both its form and its content. It is why, for example, the pedagogic intervention concluding the DISKS project was a collaborative engagement with teachers of Biology and History (Macnaught et al., 2013). Our understanding of semantic profiles, let alone

cumulative knowledge-building, is thus at an early stage. However, to reiterate Bernstein, this is not the only or terminating paper: it develops ideas for further development; as I discussed, it contributes to a wider work-in-progress by a diverse range of scholars. Moreover, as this growing body of work is showing, the ideas outlined here provide a basis for exploring these issues further.

Turning the tools of Semantics upon themselves helps explain this productivity: the concepts embrace an extensive semantic range, from abstract, generalizing, highly condensed and complex meanings as part of the wider sociological framework of LCT and code theory, to concrete, specific and simpler meanings in practical application. As a growing number of studies illustrate, they can be enacted within research into a wide array of problem-situations. The concepts thereby enable analyses of an expanding range of apparently different phenomena to be brought together, highlighting their underlying uniformities and differences. To traverse the semantic gap between the concepts and such diverse data and practice, many studies are developing 'external languages of description' (Bernstein, 2000) for translating between the concepts and their differing realizations within specific objects of study. In doing so, studies often incorporate existing typologies, enabling their findings to build on and extend past work, and thereby revealing how waves may also weave by bringing together knowledges of different types. As a whole, this research practice is thus embodying what it studies – semantic waves as the pulses of building knowledge about knowledge-building.

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Contents lists available at SciVerse ScienceDirect

Linguistics and Education

journal homepage: www.elsevier.com/locate/linged

Embedded literacy: Knowledge as meaning

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ARTICLE INFO

Available online 29 January 2013

Keywords:
Field
Discourse
SFL
Pedagogy
Power

ABSTRACT

This paper takes as point of departure the register variable field, and explores its application to the discourse of History and Biology in secondary school classrooms from the perspective of systemic functional linguistics. In particular it considers the functions of technicality and abstraction in these subject specific discourses, and their relation to the high stakes reading and writing expected from students. The paper shows how the practical concepts of power words, power grammar and power composition can be developed from this work as tools for teachers to use for purposes of knowledge building. Specific attention is paid to the role of specialised composition and classification taxonomies and activity sequences in specialised fields, and the relation of this valeur to the concept of semantic density in Legitimation Code Theory.

1. Transition

Across cultures, the development from childhood to adolescence is regularly accompanied by the movement from primary to secondary school education. And this movement is accompanied in curricula by a shift from a concern with basic literacy and numeracy, often taught in general terms, to subject-based teaching and learning involving highly specialised discourse of various kinds. From functional linguistic perspective, what changes gears for successful students in this transition is the relationship between wording and meaning – between grammar that transparently encodes semantics to grammar which often symbolises indirectly what it means – between congruent and grammatically metaphorical modes of expression in Halliday's terms (Christie & Derewianka, 2008; Colombi & Schleppegrell, 2002; Halliday & Martin, 1993; Halliday & Matthiessen, 2004; Halliday, 1998, 2004; Simon-Vandenbergen, Taverniers, & Ravelli, 2003).

Historically speaking, the various ramifications of this transition have strongly influenced the nature of the genre-based literacy programs associated with the so-called 'Sydney School' (Martin, 2012c; Rose & Martin, 2012). Infants and primary school interventions in the 80s focused strongly on genre – the mastery of writing for different purposes in a range of genres (e.g. recount, narrative, report, procedure, explanation, exposition and so on). In the 90s, when secondary school and workplace literacy was addressed (Christie & Martin, 1997; Rose, McInnes, & Korner, 1992), more attention had to be given to the disciplines in which reading and writing took place (Science, History, Mathematics, Geography, Economics, Creative Arts, English and so on). The nature of knowledge in particular became a key concern, varying as it does from one subject to another, including its technicality and abstraction, and the role of grammatical metaphor in construing this knowledge. Students continue to read and write genres, of course; but these literacy practices are devoted to developing uncommon sense understandings of the world – understandings upon which their success in education, and thus their prospects in the wider world, critically depends.

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0898-5898/$ – see front matter © 2013 Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.linged.2012.11.006

Accordingly in this paper my main focus will be on what in systemic functional linguistic (hereafter SFL) models of context is referred to as field. I am concerned in particular with what knowledge looks like from this linguistic point of view. The point of this discussion is to better articulate what it means to have an embedded literacy program (as opposed to a generic one), where students read and write to learn, and where **what** they are learning is the key factor that needs to be addressed whenever shaping curriculum and designing the pedagogy through which they are taught. I write this in the context of ongoing dialogue with sociologists concerned with reclaiming knowledge, both in their own discipline and in education, negotiations documented in Christie (1998), Christie and Martin (2007), Christie and Maton (2011), Martin (2011), and Maton, Hood, and Shay (in press).

2. Field

SFL has evolved as a multiperspectival model of language (Halliday & Matthiessen, 2009), involving a series of strata of increasing levels of abstraction (phonology/graphology, lexicogrammar, discourse semantics) and a trinocular perspective on meaning (the ideational, interpersonal and textual metafunctions). Context is generally privileged as one or more additional strata of meaning, with the intrinsic functionality of metafunctions used to map one layer as field (construed ideationally), tenor (enacted interpersonally) and mode (composed textually); Martin and his colleagues (e.g. Martin, 1992, 2012a, 2012b; Martin & Rose, 2008) include an additional level of context called genre, which accounts holistically for relations among the field, tenor and mode combinations that a culture recurrently stages as phases of unfolding discourse. A schematic outlined of these dimensions is provided in Fig. 1.

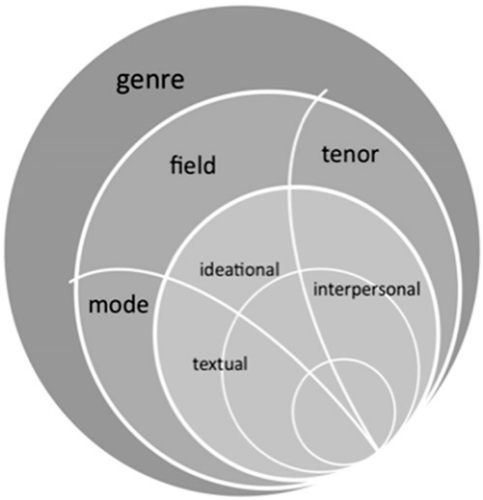

Fig. 1. The dimensions of strata and metafunction in SFL.

Martin (e.g. Martin, 1992) characterises a field is a set of activity sequences oriented to some global institutional purpose, alongside the taxonomies of entities involved in these sequences (organised by both composition and classification). In the penultimate chapter of Martin and Rose (2008) a multimodal text concerning mulga trees from a secondary school geography textbook is analysed (Scott & Robinson, 1993); throughout the textbook verbiage and image cooperate to build knowledge of Australian desert environments and their fauna and flora (cf. Martin, in press). Mulga trees for example are construed compositionally; they have roots and branches, and the branches are in turn composed of stems, flowers, seeds and leaves (Fig. 2). The desert environments they inhabit, the mulga plains, are construed through classification as desert ranges & rocky outcrops, plains or rivers, and if plains, then as mulga plains, spinifex plains or saltbush & blue bush plains (Fig. 3). The crucial point here from the perspective of geography is that recognising a mulga tree, as a visitor to central Australia

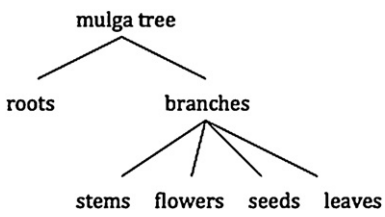

Fig. 2. Composition of the mulga tree.

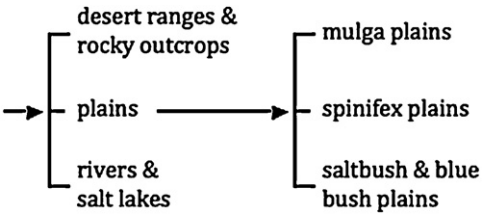

Fig. 3. Classification of desert environments.

or in photographs, is not enough; its uncommon sense composition and uncommon sense classification are central to its meaning in the field.

Beyond this the mulga tree is involved in a number of activity sequences which are fundamental to its survival in its desert environment (Unsworth, 1997). For example, as the text explains and an image illustrates, its branching leaves and stems catch more rain than if the tree grew straight up, and they help it trickle down to the soil; the water is then stored in the soil to be used by the tree during the next drought. The semantics of this implication sequence is outlined more formally below (based on Martin, 1992; Martin & Rose, 2003/2007[1]); the part of the image used reinforce its construal is presented in Fig. 4. From the perspective of Legitimation Code Theory (hereafter LCT) the strength of the semantic density of the entity mulga tree, as understood in physical geography, includes its 'valeur' in the composition and classification taxonomies exemplified above, alongside the role it plays in any implication sequences in which it is involved (see Maton, this issue). There is thus much more to the meaning of the term than a simple definition affords (Halliday & Martin, 1993; Martin, 1989; Wignell, Martin, & Eggins, 1990) – relatively stronger semantic density is involved as well. In our work with secondary school teachers we highlight potential for greater strength of semantic density afforded by these technical terms by referring to them as **power words**.

[branching + leave & stems] + x catch + rain
^
rain + trickles x soil
^
water + stored x soil
^
tree + x use + water x drought

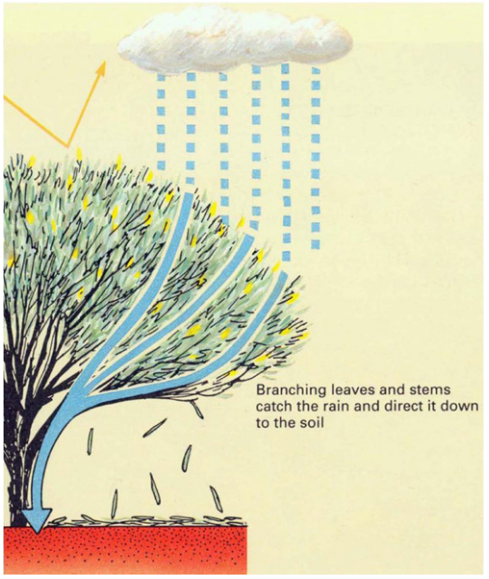

Fig. 4. Imagic construal of water catching implication sequence (Scott & Robinson, 1993: 23).

3. Knowledge structure in Biology

Maton (this issue) introduces the notion of semantic wave in relation to a lesson on cilia in secondary school Biology, as part of a unit of work on the body's defences against infection. As he notes, knowledge about the nature and function of cilia

[1] For this display ^stands for sequence, and x, x+ and + relate participants, processes, circumstances inside each step in the sequence.

were reviewed and then consolidated in a table classifying them alongside other lines of defence (see his Fig. 6). As far as composition is concerned hairs, body, nose, cells, air passages, lungs, stomach and acid are all mentioned, but the precise relations among these parts is not made explicit, verbally or in a diagram. Nor, as far as we know, were cilia examined under a microscope, to see what they look like to the naked eye, augmented by technology; nor, as far as we know, was the internal structure of a single cilium considered, as it has been construed on the basis of decades of research. Fig. 5 outlines some of the various degrees of composition and decomposition that might have been considered had this potential strength of the semantic density of cilia been developed further in the classroom.

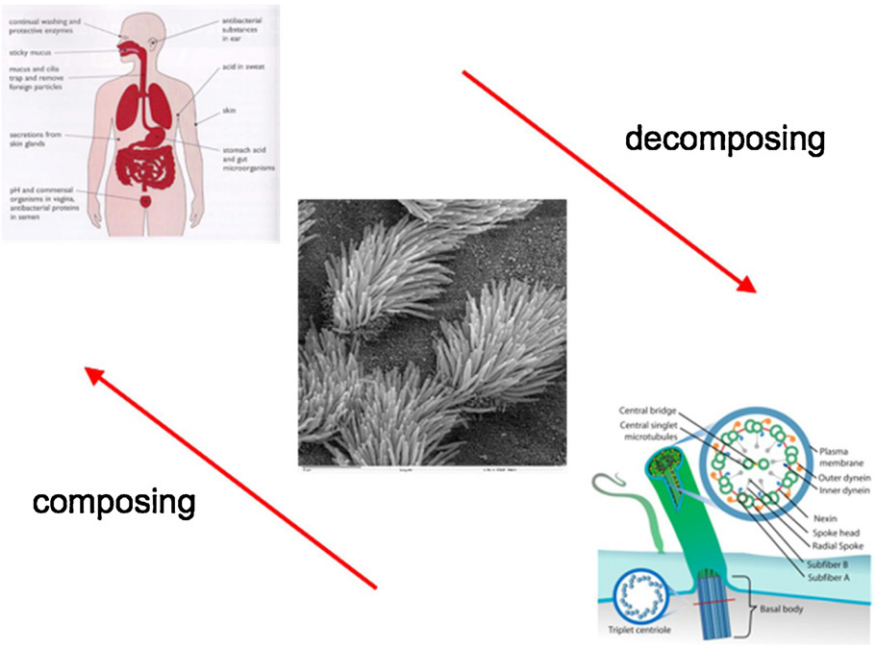

Fig. 5. Degrees of de/composition for cilia (from Evans, Ladiges, McKenzie, Batterham, & Sanderrs, 2011: 178, http://en.wikipedia.org/wiki/Cilium, http://en.wikipedia.org/wiki/File:Eukaryotic_cilium_diagram_en.svg).

Turning to classification, cilia were grouped in the table alongside skin, mucous membranes, chemical barriers and other body secretions as lines of defence. Further study of the body's defences against pathogens (cf. Fig. 6) might position this column of the table as defence barriers (as opposed to defence adaptations and immune responses); or as the first line of defence (as opposed to the second and third); or as one type of non-specific defence, attacking any pathogen (alongside

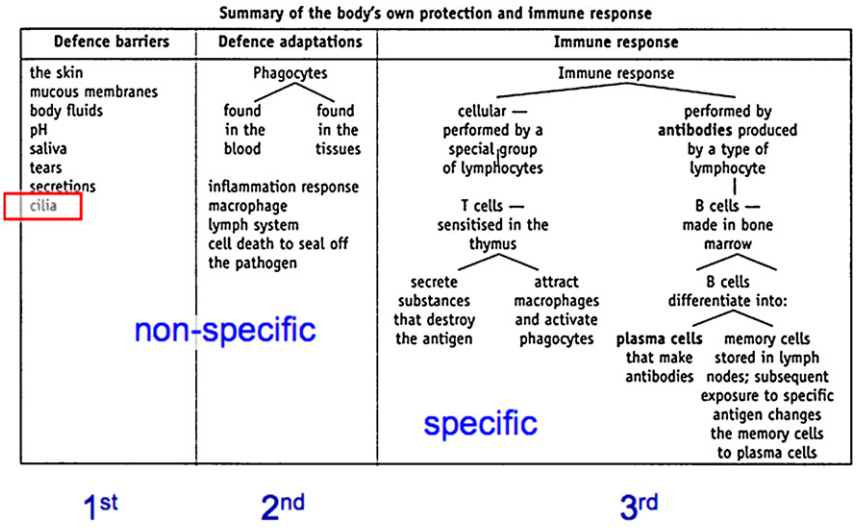

Fig. 6. Alternative terms for the classification of lines of defence (Alford & Hill, 2003).

defence adaptations), as opposed to a specific response involving white blood cells. Each such elaboration of the classification elaborates the structure of the knowledge in which cilia have biological meaning, thereby strengthening the semantic density of the term.

Additional work on the kind of organ cilia are would strengthen semantic density still further. Basically cilia are a kind of organelle found in eukaryotic cells. The lung cilia in question here are motile (undulipodia) as opposed to non-motile (or primary cilia; e.g. cilia functioning as 'sensory antennae'); and they undulate in a wave motion, as opposed to flagella (e.g. sperm cilia) which deploy whip action for propulsion. This kind of classification ultimately depends on the genetically inherited form of cilia, as opposed to their pathogen response function, and illustrates the critical role that classification criteria play in knowledge structure.

As Fig. 6 indicates, there is more to the body's defence systems than the biological entities involved, since the entities participate in processes that discourage and destroy pathogens. One such process is inflammation, which in the Biology class dealing with cilia above was consolidated in board notes as follows:

Inflammatory Response
Fever helps reduce the reproduction of pathogen cells in localised areas. There is increased blood flow to the infected area due to VASO-DILATION (widening of capillaries). This means more phagocytes and macrophages can quickly travel to the infection site.

Vasodilation is positioned as the first stage of inflammation in Fig. 7 below, and involves blood vessels increasing their diameter and permeability; this allows phagocytes (both neutrophils and macrophages[2]) to squeeze through blood vessel walls to engulf and destroy pathogens. What is important here is the nature of the technical terms arising from these implication sequences, which refer not to entities but to processes (e.g. *inflammatory response, reproduction of pathogen cells, blood flow, vasodilation, inflammation, phagocyte migration, tissue repair* in the board notes and Fig. 7). This brings us to the essential role played by grammatical metaphor in construing the uncommon sense knowledge structure of all academic disciplines, and the critical role played by the recontextualisation of these disciplines in secondary school as resources for students to begin their apprenticeship into the language that enables these specialised fields of inquiry (Martin, 1993a, 1993b, 2007).

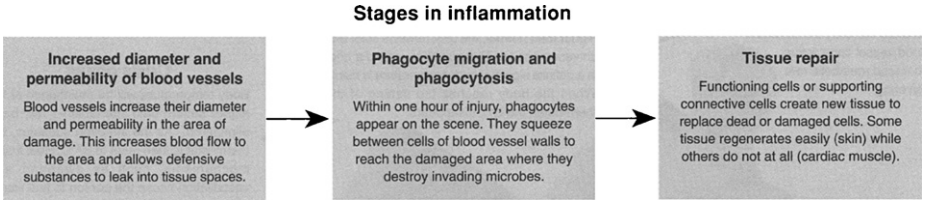

Fig. 7. Stages of inflammation (Allen, 2003: 119).

As noted above, grammatical metaphor affects the coding relation between semantics and grammar; nominals like *inflammation* for example don't encode entities – the people, places and things they regularly encode before a language invents or borrows a writing system (or before puberty and in casual conversation). Rather they symbolise semantic figures involving both entities and the actions engaging them. *Vasodilation* for example encodes the semantic figure '(blood) vessels dilate' as a nominal group rather than a clause; similarly *phagocyte migration* grammatically encodes the semantic figure 'phagocytes migrate' as if it was an entity. In secondary school we are expected to learn to understand that *phagocyte migration* is a grammatical 'thing' encoding a semantic figure. In a sense we are expected to learn to unpack the nominal as involving two layers of meaning, one symbolising the other – as exemplified below using unpackings found in the Biology lessons and textbooks we considered.

nominal grammar	**semantic figure (entity + action)**
vasodilation	*blood vessels increase their diameter*
phagocyte migration	*phagocytes appear on the scene*
tissue repair	*functioning cells create new tissue*
increased blood flow	*blood flows more voluminously*

It may be helpful to represent the difference between congruent encodings of figures as clauses involving a process, participant and circumstance with metaphorical encodings of figures as a participant or circumstance in a diagram such as Fig. 8. In technical terms grammatical metaphors involve stratal tension (i.e. a coding mismatch between levels of language), since figures do not map congruently onto clauses.

[2] The board notes are misleading in this respect, since neutrophils and macrophages are in fact sub-types of phagocyte (a classification diagram of some kind might have discouraged this confusion); the graphology (upper case letter and inserted hyphen) focuses attention on the term *vasodilation* and its etymology (literally 'vessel widening').

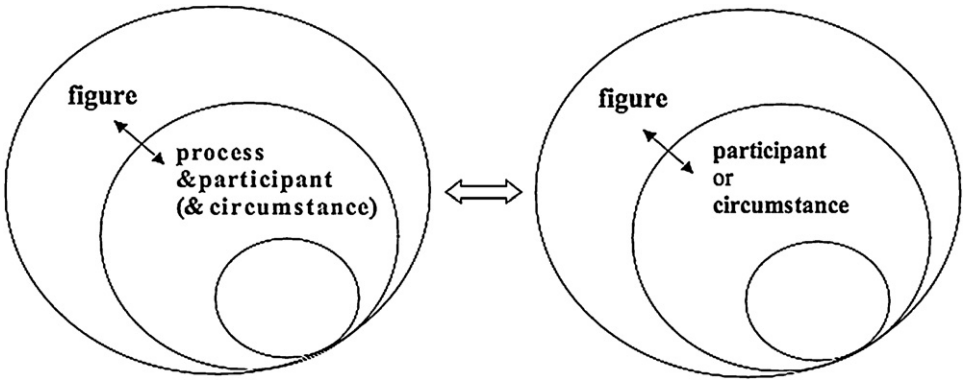

Fig. 8. Congruent and grammatically metaphorical relations between figures and grammar.

Reconfigurations of figures as participants or circumstances allow for a further degree of stratal tension where semantic sequences are realised within rather than between clauses. The board notes introduced above provide a clear example of this when they sum up the effect of vasodilation on blood flow: *There is increased blood flow to the infected area due to VASODILATION (widening of capillaries)*. Here, there are two semantic figures: 'blood flows more voluminously' and 'capillaries widen', both realised nominally as participants. But they are realised as a single clause involving a participant (*increased blood flow*) and a circumstance (*due to vasodilation*). Note that causal relation between the semantic figures is coded as a preposition (*due to*), not as a causal conjunction between clauses. The relation between figures can also be realised grammatically as a process (*increased blood flow* ***leads to*** *vasodilation*) or a participant (*increased blood flow is the* ***cause*** *of vasodilation*); this kind of stratal tension is outlined in Fig. 9.

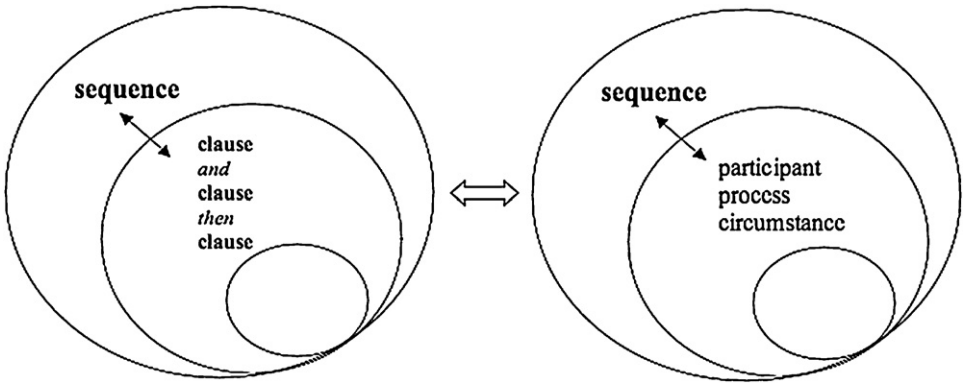

Fig. 9. Congruent and grammatically metaphorical relations between sequences and grammar.

In SFL the coding of a figure as a participant (or as the nominal group in a circumstance) is referred to as experiential metaphor; the coding of sequences as clauses (with the conjunctive relation connecting figures realised as a participant, process or circumstance) is referred to as logical metaphor. Taken together the two sub-types are referred to as ideational metaphor (Halliday, 1998; Halliday & Martin, 1993; Simon-Vandenbergen et al., 2003).

As we can see, grammatical metaphor is essential for both defining technical processes (*vasodilation is the process whereby blood vessel increase their diameter and permeability*) and explaining them (*vasodilation causes increased blood flow*), and thereby strengthens the semantic density of any terms involved. It would be impossible to produce scientific knowledge without grammatical metaphor. And it is thus impossible to learn science without being able process the stratal tension when reading and hearing, and impossible to be successful in assessment processes without being able to write it. The semantic density of science depends on grammatical metaphor, and apprentices depend on secondary schooling to access the code. In our work with secondary school teachers we highlight knowledge construing power of grammatical metaphor by referring to it as **power grammar**.

4. History

History, like Biology (and all academic discourse) deploys both power words and power grammar to construe knowledge. As far as composition is concerned, History is comparably technical in its division of the past into periods and cultures into

societies. Examples of historical periods include New Kingdom Egypt to the death of Thutmose IV, The Greek world 446-399BC, Rome: The Augustan Age 44BC-AD14; examples of ancient societies include Society in Old Kingdom Egypt, Persian Society at the time of Darius and Xerxes, Mycenaean society. Archaeological sites, including buildings, are also carefully decomposed – often with precise maps and architectural diagrams in support.

Turning to classification, it is important first of all in History to distinguish between specialised and technical terms (White, 1998). The specialised terms refer to concrete material objects from another time and place, objects that can be illustrated and described – for example *garum*, *inn, tavern, peddler*. Romans living in Pompei would have learned the meaning of these terms ostensively, by experiencing them in everyday life; but this life is of course well beyond the experience of contemporary students and has to be introduced to them. Garum for instance was a type of fermented fish sauce condiment that was an essential flavour in Ancient Roman cooking; it was prepared from the intestines of small fishes, macerated in salt and cured in the sun for one to three months, where the mixture fermented and liquified in the dry warmth, the salt inhibiting the common agents of decay. Because of the many containers found in the ruins of Pompei, and its role as a key item of trade, it is often mentioned in accounts of the explosion of Mount Vesuvius in AD79. In general specialised terms like garum tend not to be composed and decomposed, or classified and subclassified, as thoroughly or tightly as power words in Biology. We do not for example learn precisely how garum fits into an exhaustive account of the diet in Pompeii or read an ingredient list for recipes in which it plays its part; the focus on garum is simply due to the abundance of evidence (e.g. artifacts, frescoes, written records) reflecting its significance in the economy of another place in another time.

Alongside these specialised terms, History also makes use of a number of technical terms – terms like *trade, economy, society* and *culture*. These terms to not refer to concrete entities and so cannot be learned ostensively; they have to be construed through language. These power words are also less thoroughly composed and decomposed, and less clearly classified and subclassified, than those in Biology. Depending on the unit of work, textbook or exam to hand, *society* seems to cover some or all of economy, culture, social structure, politics, religion and possibly other things as well. Similarly *economy* variably covers trade, commerce, industry, agriculture, etc. – depending on support provided or not by primary sources and the significance of some particular aspect of the economy in explaining historical processes. From the perspective of science we might characterise these relatively loosely composed and classified technical terms as a kind of 'flexi-tech', whose weak classification allows them to be applied to a range of different historical societies and periods.[3]

To exemplify this point, we return here to an example discussed by Maton (this issue), where a History teacher is explaining the influence of Greek and Egyptian culture on life in Pompei:

[Text 1]

T	This is a little bit hard, H. THE INFLUENCE OF GREEK AND EGYPTIAN CULTURES. What does that mean. What would the influence of Greek and Egyptian cultures mean, okay? No idea, right. What it means is, if we started to, look at all the things in Pompeii and Herculaneum, what objects may be showing Greek design? Or Egyptian design? Or Greek mythology? Or Egyptian mythology? Or what building techniques, like columns? Are there Greek columns? Do, you know, are the themes of their artwork reflecting it? So, it's saying . . .remember when we started, we said that Pompeii had originally been settled by Greeks? Okay? . . . It looks hard, but all you've gotta do is have a look and think what things are there. Let me give you a big clue some of them are massive. Laah-la-lah-la- la-la-la-la-lahh, la-lah
S	Theatres
S	La-lahh
T	Theatres. Okay theatres are a Greek design. The Greeks invented the theatre, and then the Romans take the idea because they like it too. So, some of them are very obvious.

In this lesson culture seems to refer to design (e.g. theatres), mythology, building techniques (e.g. columns) and artwork (e.g. themes). Culture is the more abstract term, apparently condensing design, mythology, architecture and art, with theatres, building columns and fresco themes as evidence of imported design, architecture and artwork respectively. Fairly abstract relations of composition and classification are at play here, a rough sketch of which is provided as Fig. 10.

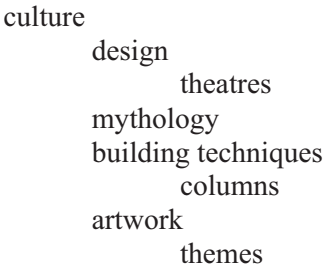

Fig. 10. Knowledge structure relations in text 1.

[3] For discussion of weakly classified –ism terms in Modern History see Martin, Maton, and Matruglio (2010).

Similarly in text 2 the flexi-tech term *trade* is sub-classified as involving commercial trade and aesthetic trade (glossed as 'trade in ideas'); and aesthetic trade is exemplified in terms of people visiting and diplomats going back and forth. But we can't be sure how exhaustive or precise an account of trade this is meant to be (cf. Fig. 11).

[Text 2]

T	So, there would be massive amounts of trade going on, and umm, you know people visiting their diplomats you know or their, their, ambassa. . . like their envoys and things like that all going back and forth across the countries. Sooo, ideas. When you get trade in ideas – you wouldn't have heard this word before – we call it 'aesthetic trade'. Have you heard of it? Yeah
S	You told us before
T	Ohh! Told you before great, *excellent*! You remember aesthetic trade! 'Trade in ideas'. So, of course, when you've got contact with the country you're gonna get the trade in ideas coming as well.

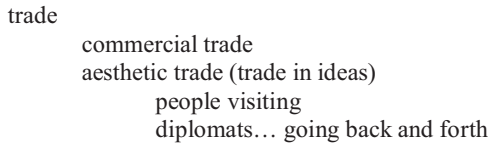

Fig. 11. Knowledge structure relations in text 2.

There is in fact more technicality to History than we recognised in our early work (Eggins, Martin, & Wignell, 1993); as Martin et al. (2010) point out Modern History deploys a range of terms canonically ending in –ism and involving axiological condensation from the perspective of LCT.

capitalism
communism (Marxism)
socialism
democracy
despotism (oligarchy, autocracy, monarchy, fascism)
imperialism (colonialism)
nationalism
internationalism
militarism
racism
. . .

Often these –isms will be precisely defined (from Dennett & Dixon, 2003):

> **Capitalism** is as economic and social system under which most of the means of production are controlled by private individuals or companies. [195]
> **Imperialism** is the rule of one country or a group of countries by another, more powerful, country. [475]
> **Nationalism** is a fierce loyalty to your country above all others. [196]

Some of these terms may be organised in relations of complementarity to one another (e.g. *capitalism & socialism, autocracy & democracy, imperialism & nationalism*). Beyond such complementarities, compositional and classificatory relations among –isms in History discourse are not well developed. The –isms also arguably qualify as flexi-tech in the sense that their definitions are loose enough that they can be applied to a wide range of situations (e.g. the Cold War, Indo-China, Palestine). Indeed, the meaning of some of these terms may be ideologically contested, as when historians argue about whether a country's government is truly democratic, or politicians and the media oppose communism to democracy or freedom to socialism – as if the terms opposed deployed were of the same conceptual order. A student jokes about axiological loading of this kind in text 3, positioning communism as 'un-Christian' for humorous effect:

[Text 3]

T	(teacher lets out a big breath) Where are we? David you're sitting there by yourself; you can tell us about communism. OK.
S	(David) Don't make me do that. That's against my Christian beliefs.
Ss	(laugh)

This reminds us that while the semantic density of a term may involve formal definitions as reviewed above, a term can also be loaded with feelings, political sensibilities, taste, values, morals, affiliations, and so forth (Maton, this issue).

Turning from power words to power grammar, History discourse is if anything more grammatically metaphorical than science. Semantic figures such as 'Mt Vesuvius erupting', 'Fiorelli excavating Pompei' or 'Pliny the Elder dying' are highly likely to be written and read as *the eruption of Mt Vesuvius, Fiorelli's excavations* or *Pliny the Elder's death*. And writing by senior students regularly codes semantic sequences as clauses, by way of explaining the past for assessment purposes. Here's an example with power grammar deployed to realise a causal relation between figures as a circumstance inside a clause (for this logical metaphor, the circumstance is underlined, its causal preposition is in italics, and nominal figures involving experiential metaphor are in bold):

> Andrew Wallace states that while Pompeii is one of the most studied of the world's archaeological sties, it is perhaps the least understood, *due to* past**neglect**,**damage**, and**a failure to document carefully if at all**.

The next example uses a process (italics below) to encode a sequential relation between figures:

> The revolution at Pompeii in regards to archaeological methods *began* with Fiorelli's stage of occupation in the 19th century.

And the following example realises temporal (*eventual*) and causal (*allowed for*) relations among figures inside the clause:

> . . .Fiorelli's stage of occupation *allowed for* greater documentation, more archaeological artifacts left in site and the breakthrough process of injecting liquid plaster into the body-shaped cavities made by solidified ash and the *eventual* decomposition of bodies.

Realising cause in the clause in History (Achugar & Schleppegrell, 2005) not only allows for a precise nominal formulations of potentially complex causes (e.g. *past neglect, damage, and a failure to document carefully if at all* above) and effects (e.g. *greater documentation, more archaeological artifacts left in site and the breakthrough process of injecting liquid plaster into the body-shaped cavities made by solidified ash and the eventual decomposition of bodies* above), but also makes available resources for fine tuning the causal impact of one figure on another that are not available in congruent spoken discourse. Consider for example the range of processes that a student might use to relate the study of art and architecture to modern knowledge of Pompei's social structure below:

> Study of art and architecture have also **influenced** modern knowledge of Pompei's social structure.
> Study of art and architecture have also (**significantly) affected** modern knowledge of Pompei's social structure.
> Study of art and architecture have also **conditioned** (**the nature of)** modern knowledge of Pompei's social structure.
> Study of art and architecture have also (**helped) shape** modern knowledge of Pompei's social structure.
> Study of art and architecture have also **impacted (heavily) on** modern knowledge of Pompei's social structure.

Appropriately nuanced causality is an important part any historian's toolkit as far as interpreting the past is concerned, and an invaluable resource in an apprentice historian's repertoire (Coffin, 2006; Martin, 2002b; Veel & Coffin, 1996).

5. Power composition

Crucial as power words and power grammar are to the construal of knowledge in Biology and History, knowledge is ultimately packaged as texts which store the descriptions and explanations constituting the field (Martin, 2002a). Each discipline draws distinctively on a range of genres for this purpose. One of History's genres (Coffin, 2006; Martin & Rose, 2008), the factorial explanation, is exemplified as text 4 below (based on the textbook explanation reproduced as Appendix A (Lawless, Cameron, & Young, 2008: 273–274)). Factorial explanations compile the factors resulting in a particular outcome, and as such are a favoured genre for assessment purposes (e.g. *What were the causes of WWI?*, *Explain the reasons for the success of the Long March?* and so on).

[Text 4]

Outcome

While Pompeii is one of the most studied of the world's archaeological sites, it has been plagued with serious conservation problems, including poor restoration work, damage from vegetation, pressure from tourism and poor site management.

Factor 1

Much of the restoration work on Pompeii has been done by local firms with no specialised knowledge of restoration techniques. For example the timber roof on the House of Maeger was so poorly designed it could not support the weight of the tiles and collapsed. Poor quality mortar has also been used to protect ancient stonework. Over time this mortar has cracked, allowing water and vegetation to penetrate.

Factor 2

A second problem is the incursion of uncontrolled weeds which have hastened the decay of the ruins. Over 30 different varieties have been identified, including ivy, fennel and fig. As the roots grow they open up further cracks, allowing even more weeds in.

Factor 3

Pompeii's position as an international tourist attraction brings half a million visitors each year. No special walkways for viewing platforms have been constructed, so tourists walk along ancient paths and enter buildings that are not roped off. In some places ancient lead water pipes have been exposed.

Factor 4

Finally, there seems to be no overall management plan for the site. Damaged paths and walls have not been repaired, frescoes have not been preserved, and mangy dogs roam the site. Available finance has been poorly managed and no proper conservation and interpretation program has been put in place.

Wrap up

As a result of these factors, the description of Pompeii as a victim of state neglect and indifference and an archaeological catastrophe of the first order is an apt one. It's ongoing destruction since its discovery in the 1590s has arguably resulted in a greater disaster than it's initial destruction by the eruption of Mt Vesuvius one and a half millennia earlier.

Reading and writing in secondary school depends on gaining control of the relevant genres, and this means that consciously, or next to consciously, students have to master their structure – Outcome, followed by Factors, with an optional Wrap-up in the case of factorial explanations. In addition they have to master **power composition** in order to successfully scaffold the organisation of these genres for examiners, and phase their power words and power grammar into predictable waves of information. Power composition basically means organising writing as a rhetorical sandwich[4] in

[4] In American composition teaching this rhetoric is informally referred to as 'hamburger writing' as a search for this phrase on a web browser will show.

which you tell readers what you are going to write, write it and then tell them what you've written. In SFL this compositional rhetoric is referred to as periodicity (e.g. Martin & Rose, 2003/2007), and theorised as waves of information reflecting the Theme and New organisation of clauses at higher levels of text organisation. Basically higher level 'Themes' predict what is going to come in a text, and higher level 'News' consolidate what has already been developed. In Text 4 for example the opening paragraph introduces the factors that will be explored in the explanation (i.e. poor restoration work, damage from vegetation, pressure from tourism and poor site management) – its Macro-Theme. Then the first sentence of each Factor further specifies the problem to be explored – Hyper-Themes (or Topic sentences in traditional composition terms). The explanation concludes with a Macro-New, summing up and further interpreting the significance of what has been explored. Text 4 has been re-formatted below to highlight its display of power composition; an overview of periodicity in relation to scaffolding genre and building field is outlined in Fig. 12 (where indentation shows the move from a higher level macro-Theme or hyper-Theme to the information it predicts; the final paragraph is macro-New).

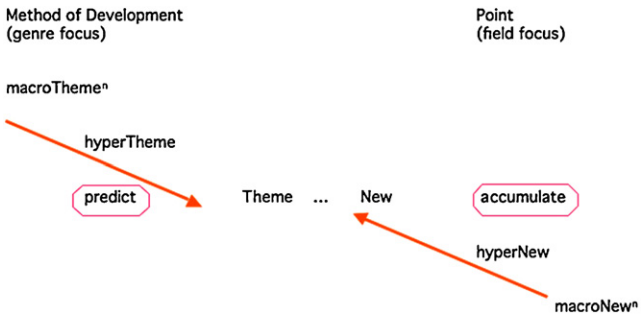

Fig. 12. Hierarchy of periodicity (power composition).

While Pompeii is one of the most studied of the world's archaeological sites, it has been plagued with serious conservation problems, including poor restoration work, damage from vegetation, pressure from tourism and poor site management.

Much of the restoration work on Pompeii has been done by local firms with no specialised knowledge of restoration techniques.

For example the timber roof on the House of Maeger was so poorly designed it could not support the weight of the tiles and collapsed. Poor quality mortar has also been used to protect ancient stonework. Over time this mortar has cracked, allowing water and vegetation to penetrate.

A second problem is the incursion of uncontrolled weeds which have hastened the decay of the ruins.

Over 30 different varieties have been identified, including ivy, fennel and fig. As the roots grow they open up further cracks, allowing even more weeds in.

Pompeii's position as an international tourist attraction brings half a million visitors each year.

No special walkways for viewing platforms have been constructed, so tourists walk along ancient paths and enter buildings that are not roped off. In some places ancient lead water pipes have been exposed.

Finally, there seems to be no overall management plan for the site.

Damaged paths and walls have not been repaired, frescoes have not been preserved, and mangy dogs roam the site. Available finance has been poorly managed and no proper conservation and interpretation program has been put in place.

As a result of these factors, the description of Pompeii as a victim of state neglect and indifference and an archaeological catastrophe of the first order is an apt one. It's ongoing destruction since its discovery in the 1590s has arguably resulted in a greater disaster than it's initial destruction by the eruption of Mt Vesuvius one and a half millennia earlier.

Power composition interacts with power words and power grammar in significant ways. From the perspective of LCT it organises writing as a series of semantic waves, with semantic density peaking in higher level Macro-Themes and Macro-News; paragraph level Hyper-Themes and Hyper-News scale technicality and abstraction down to a level where it can be specified in lower semantic density discourse (the filling of the rhetorical sandwich). This makes it possible for academic writing to sound both critical and objective, with semantically dense interpretations firmly grounded in evidence.

In Text 4 for example, the predictive power of the Macro-Theme depends on power grammar as parts of the nominal group complex *poor restoration work, damage from vegetation, pressure from tourism and poor site management* are picked up in Hyper-Themes (*much of the restoration work, the incursion of uncontrolled weeds, an international tourist attraction, no overall management plan*). The power grammar enables the strength of semantic density required for one part of the text to predict another. It follows that without power grammar students will not be able to compose the waves of information that tell readers where a text is going and where it has been, and equally seriously may not be able to recognise this scaffolding of information in the reading on which so much of their learning depends.

Power words also interact with power composition, once again with stronger semantic density associated with higher level Theme and New. This association in exemplified for text 4 below, with specialised and technical terms highlighted in bold.

While **Pompeii** is one of the most studied of the world's **archaeological sites**, it has been plagued with serious **conservation** problems, including poor **restoration work**, damage from vegetation, pressure from **tourism** and poor **site management**.

Much of the **restoration work** on **Pompeii** has been done by local firms with no specialised knowledge of **restoration techniques**.

For example the timber roof on the **House of Maeger** was so poorly designed it could not support the weight of the tiles and collapsed. Poor quality mortar has also been used to protect ancient stonework. Over time this mortar has cracked, allowing water and vegetation to penetrate.

A second problem is the incursion of uncontrolled weeds which have hastened the decay of the **ruins**.

Over 30 different varieties have been identified, including ivy, fennel and fig. As the roots grow they open up further cracks, allowing even more weeds in.

Pompeii's position as an **international tourist attraction** brings half a million visitors each year.

No special walkways for viewing platforms have been constructed, so tourists walk along ancient paths and enter buildings that are not roped off. In some places ancient lead water pipes have been exposed.

Finally, there seems to be no overall **management plan** for the **site**.

Damaged paths and walls have not been repaired, **frescoes** have not been preserved, and mangy dogs roam the site. Available **finance** has been poorly managed and no proper **conservation and interpretation program** has been put in place.

As a result of these factors, the description of **Pompeii** as a victim of **state** neglect and indifference and an **archaeological** catastrophe of the first order is an apt one. It's ongoing destruction since its **discovery in the 1590s** has arguably resulted in a greater disaster than it's initial destruction by the **eruption of Mt Vesuvius one and a half millennia** earlier.

As we can see from the concentration of power words and power grammar in higher level Themes in text 4, the text does more predicting than consolidating – there is a Macro-New, but none of the Factors pull things together with a Hyper-New. This kind of front-loaded writing generally involves editing alongside writing to a plan. A more exploratory style might lighten up the power words and power grammar in the Macro-Theme, and replace the Hyper-Themes with Hyper-News. This style is equally powerful, and might be more suitable for writing under exam conditions, where little time for planning and scope for editing is available. In general, a text including a higher level Theme or New wherever possible will read as overly composed (and perhaps felt to be repetitive, pedantic, labouring the point and so on); a skewed front-loaded or back-loaded style tends to be preferred.

6. Let's go surfing now. . .

In general the Biology and History units we observed 'begin' with reading students are expected to have done (a textbook, screen text or photocopied handout) and 'end' with writing for assessment purposes. Since students have to learn more than can be covered in class and are evaluated based on their writing, reading and writing are high stakes tasks. Outside our interventions, we observed that reading and writing were not taught; rather it seemed to be assumed that students have acquired the necessary skills in primary school – an absurd assumption given the many unfamiliar genres packaging knowledge in secondary school and the unfamiliar power grammar students have not been expected to read or write before. In our observations, what knowledge building did occur happened in spoken interaction, ideally with teachers unpacking unfamiliar technicality and abstraction and then re-packing it orally and in notes on the board to consolidate it in preparation for writing – strengthening semantic density as the unit unfolds (as imaged in Fig. 13).

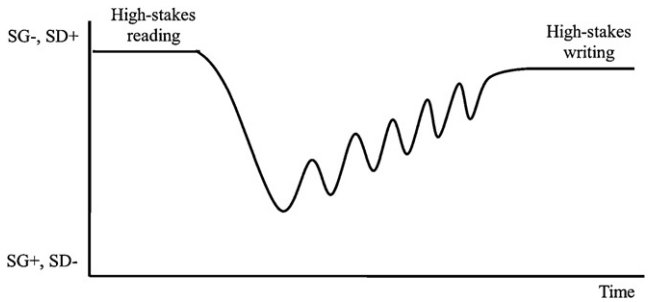

Fig. 13. High-stakes reading and writing in relation to knowledge-building.

Most of the time however, as Maton (this issue) highlights, teachers did not re-pack. Power words, and occasionally power grammar, were unpacked in common sense terms, as if everyday translations of Biology and History were all that was required for accumulating knowledge. In a sense, students were continually stranded in common sense, with lessons progressing by skipping from one fragment of knowledge to another instead of by building knowledge. A crude map of this process (deconstruction without reconstruction one might say) is presented in Fig. 14.

The dearth of repacking has serious consequences. It means that knowledge remains fragmented, with lessons keying on power words and skipping from one power word to another without mapping the composition and classification relations that relate power words to one another. It means that beyond their reading (if they in fact bother with it) students are not presented with additional models, spoken or written, of the consolidated knowledge they will need to produce for assessment purposes. It means that the issue of power grammar is not directly addressed, since stratal tension is not explicitly explored;

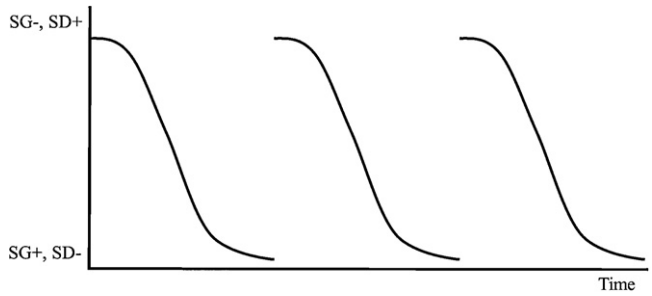

Fig. 14. Iterative unpacking in Biology and History lessons (without re-packing).

students have to learn from the occasional paraphrase what it means to realise figures as participants and causal relations inside a clause. And it means that power composition, which is more a feature of written than spoken discourse, is not considered, since teachers talk but never model writing for their class. All this, in conjunction with the fact that reading and writing are not taught, results in a highly stratified set of outcomes, since only students from the right background are positioned to learn by osmosis what has to be learned but is never made explicit.

In schools oriented to building semiotic resources in and across disciplines, students would be taught to read the power words, power grammar and power composition in the unfamiliar genres each discipline uses to package knowledge. In this power pedagogy students would be taught to write the power words, power grammar and power composition they need to compose semantic waves for assessment purposes. This would mean taking time away from the IRF 'guess what's in my head' routines teachers currently negotiate with a small group of three or four abler students and spend more time learning to read and writing to learn (Christie, 2002; Rose & Martin, 2012). The reaction of most secondary classroom teachers to proposals of this kind is that the curriculum is so full that they have no time to teach reading and writing. However, given the incredible inefficiency of most of the oral communication that goes on, stranding most students in common sense over and over again as it does, perhaps it is time for a re-appraisal of what matters as far as knowledge building is concerned. Accumulating disciplinary knowledge (Freebody, Maton, & Martin, 2008) is after all something every teacher (excepting of course mother tongue language teachers) can agree on. What seems to be missing is awareness of what knowledge is, how it is organised and how power words, power grammar and power composition privilege writing as the mode of communication where uncommon sense knowledge is stored. Spoken language has a role to play, and its role has been carefully designed in the genre-based reading and writing programs of the Sydney School (Feez & de Silva Joyce, 2012; Rose & Martin, 2012). But advanced literacy is the key. It's time to reclaim curriculum and pedagogy on behalf of all students, not just a privileged few, and start teaching the written discourse all students need to accumulate the high stakes knowledge secondary and tertiary education was intended to provide.

Appendix A.

The site today

As an archaeological site Pompeii has been described as a 'victim of state neglect and public indifference', 'an archaeological tragedy of the first order' and a 'catastrophe'. How could such a significant site have fallen into this disastrous state? There are many reasons.

Poor restoration work

Much of the restoration work on the site has been done by local firms who have no specialised knowledge of restoration techniques. In some places wrong materials and incorrect construction methods have been used. A new timber roof was erected on the House of Meleager but it was poorly designed and could not support the weight of the tiles. It collapsed. Steel reinforcing beams have been used in contact with concrete. Where the concrete has flaked away and exposed the beams, the steel has rusted and expanded, causing more damage.

Poor quality mortar has been used to protect ancient stonework. Over time, this mortar has cracked, allowing water and vegetation to penetrate, contributing to further destruction. Attempts to re-attach ancient painted plaster to the walls have been unsuccessful. This process requires the replacement of ancient mortar behind the plaster with modern mortar. A reaction takes place between the two materials which causes cracks to form. Whole walls of plaster have been destroyed using this process of 'restoration'.

Damage from vegetation

Weeds have invaded the ruins and are hastening their decay. Over 30 different varieties have been identified, including ivy, fennel, fig, valerian and a number of brambles. They take root in bare patches of earth, on the tops of walls, in cracks in the ruins and gaps in mosaic floors. As the roots grow they open up further cracks. Vines and brambles attach themselves to walls, penetrating plaster surfaces. It has been estimated that thousands of square metres of floor surfaces, including mosaics, have been destroyed by the invading weeds.

Pressure from tourism

Pompeii is an international tourist attraction with over half a million visitors to the site each year, and more than 20 000 on Italian public holidays. No special walkways or viewing platforms have been constructed so tourists walk along ancient roads and footpaths. Any that are not paved with stone have been worn down. Along the Via dell'Abondanza the footpath has been worn down to the same level as the road. Footpaths were edged with volcanic tufa or limestone, relatively soft stones which are chipped and worn down by constant use. In ancient times they would have

Lead water pipes exposed where the surface of the footpath has been worn away

been replaced, but this is not happening today. In some places ancient lead water pipes laid under paths have been exposed and damaged.

Deliberate damage by tourists

Because the site is so poorly managed there are many opportunities for vandalism. In 1986, Henri de Sain-Blanquat described a group of tourists pushing over stone columns in the atrium of a house which was not open to the public. David Mellor, who visited the site in 1993, described extensive modern graffiti and a tourist banging her fist against a painted plaster wall. Mosaic tiles, pieces of painted plaster, fragments of pottery or marble are picked up and pocketed by tourists. Even copies of antique objects placed in the position of the originals have been stolen.

Poor site management

There seems to be no overall management plan for the site, instead there is an atmosphere of indifference and neglect. Damage from the 1980 earthquake has not been repaired, some painted plaster walls are not cordoned off, and whole areas of the site are unsupervised. A recent visitor found the Building of Eumachia in the forum occupied by mangy dogs who terrorised tourists. Such inadequate supervision over the years has encouraged theft and vandalism.

Another major shortcoming of the site's management is the lack of educational information. Proper signs and explanations would encourage more interest and respect and help sensitise tourists to the great significance of this fascinating site and what it can tell us about the people who lived there almost 2000 years ago.

Lack of finance is usually given as the reason for poor site management, but in this case it is only part of the problem. In 1984 the European Community gave 36 billion lire for the restoration of Pompeii and at the same time admission charges were increased. Corporate sponsorship was gained for particular projects associated with the site, such as the NEAPOLIS project sponsored by IBM Italia and Fiat Engineering. This project is a vast database of all known archaeological remains and archival documents relating to Pompeii. There is great interest in the site from Italian and international bodies. What seems to be lacking is the establishment of an authority with the ability to coordinate and implement an effective management plan for the site now, before any more damage is done.

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Linguistics and Education 24 (2013) 38–49

Contents lists available at SciVerse ScienceDirect

Linguistics and Education

journal homepage: www.elsevier.com/locate/linged

Time travel: The role of temporality in enabling semantic waves in secondary school teaching

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ARTICLE INFO

Available online 29 December 2012

Keywords:
Legitimation Code Theory
Systemic functional linguistics
Temporality
History
Semantic gravity
Semantic density

ABSTRACT

Based on the theoretical understandings from Legitimation Code Theory (Maton, 2013) and Systemic Functional Linguistics (Martin, 2013) underpinning the research discussed in this special issue, this paper focuses on classroom pedagogy to illustrate an important strategy for making semantic waves in History teaching, namely *temporal shifting*. We begin with a brief contextualisation of how Legitimation Code Theory (LCT) and Systemic Functional Linguistics have been used together to investigate cumulative knowledge-building before outlining how the LCT concepts of *semantic gravity* and *semantic density* were enacted in linguistic terms for this research in order to understand the linguistic resources marshalled by actors in making semantic waves. The paper then moves on to consider temporality from both linguistic and sociological perspectives and to demonstrate how it is implicated in movements up and down the semantic scale to create semantic waves.

1. Introduction

When it comes to cumulative knowledge-building, time is of the essence. Time is, of course, implicated in the very notion of cumulative knowledge-building, which involves both looking backwards to previous ideas and looking forwards to future contexts in which current knowledge can be applied and extended. However, this is but one facet of the role of temporality in cumulative pedagogic practice. Maton (2013) highlights the significance for knowledge-building of making 'semantic waves' in the knowledge being expressed in classroom discourse (as well as other practices). These semantic waves involve recurrent movements in the 'semantic gravity' and 'semantic density' of knowledge, or (simply put) the context-dependence and condensation of meaning (see Section 3, below). As we shall discuss, time travel or shifting the temporal and spatial coordinates of discussion, can be a key pedagogic strategy for making semantic waves and thereby enabling recontextualization of knowledge. In particular, strategies aimed at metaphorically locating students in the time of the historical context being discussed can be used in the classroom to enable students to traverse the distance created by texts situated in unfamiliar contexts and which use condensed and archaic language. That is, they enable knowledge to be recontextualised: from historical contexts to current classroom contexts; and from complex constellations of historical meanings into simpler current meanings. Such strategies thereby involve changes in semantic gravity and semantic density, making semantic waves in order to build cumulative knowledge.

This research is part of a larger inter-disciplinary project which investigates the question of how better to enable cumulative teaching in schooling by using approaches from systemic functional linguistics (SFL) and Legitimation Code Theory (LCT) in tandem. The Disciplinarity, Knowledge and Schooling (DISKS) project (Freebody et al., 2008) continues the long and fruitful dialogue between SFL and the tradition of code theory from the sociology of education which began with discussions

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0898-5898/$ – see front matter © 2012 Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.linged.2012.11.007

between Halliday and Bernstein in the early 1960s and continues into the present day (Christie & Martin, 2007; Christie & Maton, 2011). The project's focus on cumulative knowledge-building stemmed from concerns, explicitly raised over the past decade by social realist sociology of education (Maton & Moore, 2010), that research and policy in education has neglected the role of knowledge. As Maton (2013) highlights, what he terms 'knowledge-blindness' has been a symptom in educational contexts for several decades. The DISKS project aimed to redress the balance and bring knowledge back into the educational picture by investigating how cumulative knowledge is built in schoolteaching, specifically focusing on secondary school History and Biology.

These investigations into knowledge-building and the role language plays in cumulative schoolteaching have generated new insights into History and Biology in secondary schooling (Martin, Maton, & Matruglio, 2010). A key problem to emerge was the issue of how teachers can facilitate traversing what Maton (2013) calls the 'semantic gap' between the knowledge that resides in high-stakes reading to the knowledge that students need to express in high-stakes writing for assessment (see Figs. 2 and 8 in Maton, 2013). Analyses of teaching texts and students' assessments suggest these both exhibit weaker semantic gravity and stronger semantic density than the knowledge expressed in classroom discourse. Simply put, the knowledge expressed in classroom discourse is typically more context-dependent and less condensed, that is it involves simpler and fewer meanings than the knowledge expressed in the written texts that students must read and write. This raised the question of how classroom practice may move between highly condensed, abstract and generalised knowledge and more concrete, contextualised, situated, commonsense knowledge. The project showed that teachers were adept at moving from the former to the latter through 'unpacking' what they perceived as difficult passages of reading for their students. However, movements back up to less context-dependent and more condensed technicalized meanings occurred much less frequently in the data. In this paper we continue the exploration began by Maton (2013) and Martin (2013) into the nature of these different forms of knowledge, the complex linguistic resources they involve, and, crucially, how to enable movements in both directions along the semantic scale to create semantic waves.

In preceding papers, comparison of the language that teachers use when 'unpacking' texts for students and the language of the original texts themselves has yielded insight in how language is used to enable movement up and down the semantic wave. Technicality, specialised language and grammatical metaphor have all been found to be necessary for mastering semantic waves in school learning and thus enabling achievement and have been reported on elsewhere (Martin, 2013; Martin et al., 2010). In addition to these resources, the strategy of *temporal shifting* is also implicated in movement along the semantic waves and is used in classroom talk. This paper will focus on the language of classroom pedagogy to explore some of the ways that time is manipulated in the oral language of the classroom in order to facilitate cumulative knowledge-building in teaching and learning. This paper focuses on senior school History lessons and explores temporality from both a linguistic and sociological perspective. Following a brief explanation of our understanding of time in schooling to date, this paper will then focus on temporality and how it is used in the classroom to make semantic waves and so enabling cumulative knowledge-building. First we focus on how time is manipulated in history teaching to bring students out of the time of the classroom and into the time of the text. Secondly we explore how this temporal shifting is implicated in constructing the commentary and comment modes of history. Finally we conclude with a brief example of how time travel is also an issue in the study of Biology, and point to avenues for further research into temporality and knowledge-building.

2. Time in history writing

Existing research in the context of secondary schooling has focused on how time is used in the written texts of schooling rather than in the language used in classroom practice. However, this work provides an important starting point for thinking about the use of time in classroom pedagogy. We will therefore comment briefly on the most relevant aspects of this research before considering the language of the classroom.

Most, if not all the research already conducted into time in the written texts of schooling has been concentrated in the subject of History, where time is an obvious and central issue. There has been little, if any, previous research into the role of time in, for example, science writing. The construal of time in the genres of History, however, has already been the subject of detailed investigation in the field of SFL (see among others Coffin, 1996, 1997, 2006; Martin, 2002, 2003). In Coffin's research on the configuration of time in the school History curriculum (2006), she identified six categories for the construal of time in school History. These are given below along with examples provided by Coffin to illustrate each category (temporal realisations in italics):

Sequencing	after coming to power in 1959, (Castro. . .)
Segmenting	the Great Depression
Setting	(25 million suffered malnutrition) in 1928
Duration	(he maintained his position) *for 50 years*
Phasing	*the onset* (of the Great Depression)
Organising	firstly. . .secondly. . .finally

Coffin found that as students progressed through the curriculum they used fewer resources for sequencing and setting in time and more for segmenting time. This was also accompanied by a movement away from personal construals of time towards a more institutionalised understanding of time:

> The movement from the representation of more familiar and directly experienced stretches of time to larger historically labelled stretches suggests that successful learning of the discourse of History is partly a process of shedding personally

> oriented construals of time and expanding a more publically oriented 'technology' of time. This means that, as students develop their control of historical discourse, perceptions of time that are internally influenced by the individual's subjective sense of pace and movement through time are superseded by a conventionally agreed upon objective public or social temporality. As part of this process, the distance between past and present intensifies.
> (Coffin, 2006:228)

Alongside this institutionalised interpretation of time in historical discourse, we need to note that some sources in History are based on particular historical knowers; for example, in a secondary school unit on Pompeii and Herculaneum, a personal recount of events by Pliny the Younger is used. Engaging effectively with the texts written by such writers, which often comprise personal correspondence written in the first person, requires students to traverse the distance between past and present to understand the context, content and relevance of such documents. This requires an ability to, as it were, shift through time. Students first have to be able to negotiate differences between their present realities and that of the time of the text. This involves at least an understanding that the source document was written in a period where social practices and ways of speaking and writing may differ markedly from what they are presently accustomed to. They must also read somebody else's 'personally oriented construal of time' and distance themselves from the subjectivity of that text as it is written to appreciate the historical significance of it in the course of senior studies in school History. In short, it requires them to travel into the time of the text and then back out of it to interpret what the text may mean for the present-day historian.

The classroom data collected in the DISKS project indicates that teachers perceive these shifts as challenging for students. Accordingly, when students have to engage with historical sources from the ancient world, these texts are often mediated by the teacher through an iterative pattern of reading sections from the text followed by an interpretation or explanation of these by the teachers. These stretches of classroom discourse around the primary source text give us an indication of how teachers try to manage the task of helping students cross the distance between past and present in order to understand and then recreate the distance so they can build cumulative knowledge.

3. Understanding semantic waves

The practice of mediating the written text within classroom talk through the process of 'unpacking' can be understood in terms of making semantic waves. As Maton (2013) describes, the notion of semantic waves begins from two concepts from LCT: *semantic gravity* and *semantic density*. Semantic gravity refers to the degree of context dependence of meaning; semantic density refers to the degree of condensation of meaning. They both vary along independent continua of relative strengths and weaknesses. These concepts can be used in a variety of ways, including to trace changes in knowledge through time as *semantic profiles*. As Maton (2013) explains, for simplicity we here focus on describing semantic profiles using a 'semantic scale' where semantic gravity and semantic density are moving inversely. Fig. 1 illustrates a single semantic wave using such a scale. This shows how a semantic wave involves movements between positions higher and lower on the semantic scale, or between weaker and stronger semantic gravity and stronger and weaker semantic density.

The language of textbooks and lesson handouts often displays stronger semantic density, in that a lot of ideas are condensed within terms, while at the same time displaying relatively weaker semantic gravity in that the knowledge is not necessarily dependent upon a particular context but instead deals with more abstract principles or generalised phenomena. This technicalised language is often 'unpacked' by the teacher in their explanation of the handout or textbook. This can be achieved through provision of concrete examples that strengthen semantic gravity and simpler explanations of technical terminology into everyday language that weaken semantic density. This is to move down the semantic scale (the first part of the wave in Fig. 1). A shift up the semantic scale involves abstracting and generalising away from particular contexts and

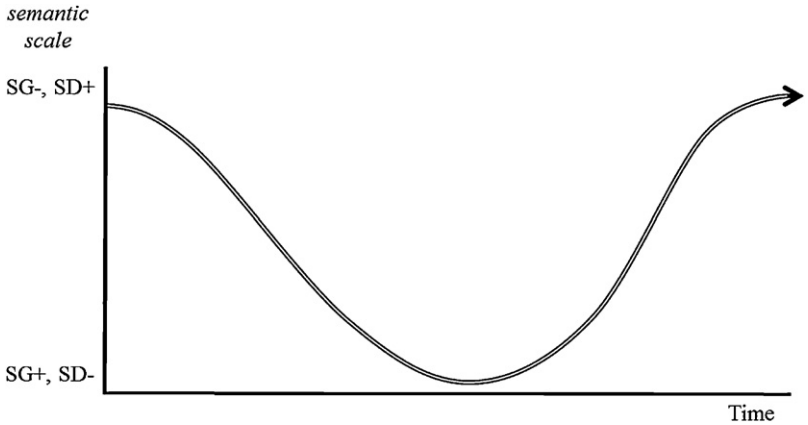

Fig. 1. A semantic wave.

condensing a large range of meaning into terms and concepts. These shifts both up and down the semantic scale can result in the creation of a semantic wave, as illustrated in Fig. 1. As Maton (2013) emphasises, such waves may begin and end anywhere on the semantic scale and are part of larger patterns of waves.

Research into classroom discourse around text has centred around developing an understanding of how these movements up and down the semantic scale are achieved in the language of the classroom. This has involved both the identification of passages of teaching in which we could identify changes in semantic gravity or semantic density or both, and then careful analysis of the language using conceptual tools from both LCT and SFL. Through this process of analysis, the manipulation of time in the classroom emerged as a significant issue for facilitating movements up and down the semantic scale. We will therefore now turn to an analysis of how temporal shifting facilitates such movements before investigating the systems of language that come into play when such changes are made.

4. Time in history teaching

The following text is an excerpt from a letter written by Pliny the Younger to Tacitus describing the eruption of Mount Vesuvius in AD79. It was written in about AD104 and is letter 16 in volume six of his collected letters. It was used in a History lesson recorded for the DISKS project and brief references to the letter can be found in multiple lessons in this unit of work. The letter is referred to in the core unit on Pompeii and Herculaneum for the final year of Ancient History studies in New South Wales secondary schooling due to its importance in understanding the eruption of Vesuvius. Not only does it provide a first-hand account of the events, but it also forms the basis for naming the particular *type* of volcanic eruption represented by Vesuvius, which is now known as a 'plinian eruption'. The first few paragraphs of the letter are provided below as an orientation to the style and language of the letter:

> You ask me to write to you about my uncle's death, so that you can hand down a truthful report to those who will come after us. I am grateful; for I am aware that he will have an immortal glory, if his death is made known to others by you. He died in the calamity of those most exceedingly beautiful of lands memorable for the people and cities destroyed and thus will always be remembered. He himself wrote many lasting works but the immortality of your writings will add more still to his immortality.
>
> I consider equally blessed either those men to whom the gods have granted the ability to do something worth writing about, or those who have the ability to write something worth reading. The most blessed, however, are those who can do both. Just such a person was my uncle as both his books and yours will show. You impose on me the task that I would demand for myself and I undertake it very willingly.
>
> He was at Misenum in active command of the fleet. The ninth day before the Kalends of September my mother pointed out to him a cloud of unusual size and appearance. He had been out in the sun, then had taken a cold bath, had lunched lying down, and then was studying. He demanded his shoes and climbed to a place from which he was able to have the best view of the marvelous thing. . .

As noted above, texts such as these are often read in iterative cycles where the teacher or student reads a section of the text and the teacher then interrupts the reading to 'unpack' it for students by explaining in commonsense terms what the class has just read together. This seems to be motivated by a desire to make sure that students have understood what has been read and to bring to attention points of importance that students need to remember for the future. In the excerpt which follows, taken from a transcription of the lesson on this text, CAPS are used for what is read aloud from the text and normal font is used for the teacher's commentary on it.

> ALTHOUGH NOT YET IN IMMEDIATE DANGER WAS AWARE THAT IT WOULD COME NEARER AS IT SPREAD. HE HAD PUT HIS LUGGAGE IN THE-BOATS DETERMINED TO FLEE IF THE OPPOSING WIND ABATED. THE WIND AT THAT TIME WAS VERY MUCH IN MY UNCLE'S FAVOUR AND HE REACHED LAND. HE EMBRACED THE ALARMED MAN CONSOLED HIM AND ENCOURAGED HIM. IN ORDER TO CALM HIS FRIEND'S FEAR BY HIS OWN LACK OF CONCERN HE ORDERED A BATH. HAVING BATHED HE LAY DOWN AND ATE CHEERFUL, OR AND THIS IS JUST AS GREAT, AT LEAST PRETENDING TO BE FULL OF CHEER
>
> . . .There's all pumice on the top and they're trying to row through the stones and they're rowing, and he, and he's thinking 'oh my god what are we gonna do' and the helmsmen saying 'oh we've gotta go back, go back, go back,' and um, poor old Pliny's saving, what does he say? Fortune favours brave men. Even though he mightn't believe it he says it, and so they keep rowing on, and there's Pomponianus standing on the shore, with his luggage, and a bit of a panic and they get him into the boat, or they get to shore and Pliny the um, Elder, is trying to appear calm and everything's alright, I'll just go and have a bath!

Differences between the language of the text as it is written and the language that the teacher uses in paraphrasing it are revealing. In the spoken paraphrase of the text, the teacher has modernised the language from an archaic form of prose to a more contemporary spoken form. This 'translation' of the language can be seen by the two pairs of text and commentary below. The parts of the text that have been reconstrued in more modern spoken language are rendered in **bold** for each pair.

IT WAS APPARENT TO SO LEARNED A MAN THAT **THIS WARRANTED CLOSER INSPECTION**. HE ORDERED A FAST SAILING VESSEL TO BE PREPARED AND TOLD ME THAT **I COULD COME IF I WANTED**. I REPLIED THAT **I PREFERRED TO STUDY**

Pliny the Elder says 'ooohhh! **Better see what's here**! Do you **wanna come with me**?' And I love Pliny the Younger. He says '**oh no I have to study**'

NOW, AS THE SHIPS DREW NEAR, **ASHES WERE FALLING HOTTER AND THICKER**. NOW PUMICE AND BLACKENED STONES, CHARRED AND CRACKED BY FIRE. NOW THEY WERE IN SHALLOW WATER AND THE **SHORE WAS OBSTRUCTED BY DEBRIS** FALLEN DOWN FROM THE MOUNTAIN.

They're rowing and rowing and as they get closer **it starts to rain pumice and hot ashes** and the **sea is starting to get full of garbage** and you can just imagine the oarsmen are trying to go through and there's pumice it floats, there's all pumice on the top and they're trying to row

This movement between written text and spoken explanation in the discourse of the classroom represents, in part, a time shift from a language from the past to a language in contemporary use. Modernising the language by paraphrasing the text is one way that the teacher tries to 'unpack' the source for the students and therefore to bridge the distance between the students present realities and the past world as represented by the source. Essentially this shift in language is about making knowledge in the text accessible by presenting the information in more recognisable language so that the students can understand the text and its context. This *temporal shifting* between past and present language is maintained throughout the reading and explanation of the whole text in the particular lesson recorded.

This movement in time from past to present language is a strategy which has the effect of weakening the semantic density and strengthening the semantic gravity of the text, resulting in a downward movement on the semantic scale (see 'Modernise the language' in Fig. 2). The archaic terms are understood by the teacher as incorporating meanings inaccessible to students and she therefore renders them in more spoken-like contemporary language. In the process of this 'translation' into contemporary language, the teacher weakens their semantic density by reconstruing processes or descriptions from their nominal to their more congruent forms (Martin, 2013).

This warranted closer inspection → better see what's here
As remedy for their fear → he's trying to keep everybody calm

Additionally, in her translation of the archaic language of the text, the teacher focuses on only some of the meanings of the original (weakening semantic density). In the following example, it is the translation of 'debris' into 'garbage' which draws the teacher's focus along with the manner in which this creates an obstruction, rather than the location of the shore (Fig. 3).

Shore was obstructed by debris → sea is starting to get full of garbage and you can just imagine the oarsmen are trying to go through. . .

In this example the teacher strengthens the semantic gravity of 'shore was obstructed' by giving the students a concrete picture of what was happening at the time (imagining the oarsmen trying to row). She also weakens the semantic density of the expression 'obstructed by debris' by using everyday language. In the final example below, the teacher unpacks by explaining *how* he will have an immortal glory, which remains implicit in the original text. This strengthens semantic

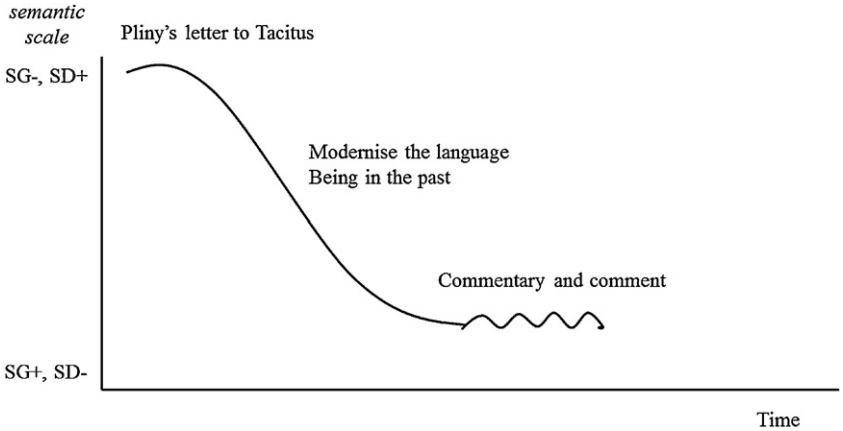

Fig. 2. Waving and bobbling.

gravity, as the teacher is grounding the idea that Pliny the Elder will have an immortal glory in the concrete actions of individuals which will produce this immortal glory.

> He will have an immortal glory → people read about him for ever and ever

A relatively abstract concept which is initially unrelated to concrete action has therefore been glossed by reference to what will produce this state of immortality. These unpackings from archaic to contemporary language, and many similar unpackings throughout the lesson, shift the knowledge being expressed down the semantic scale, from condensed and archaic language to more contemporary speech (see Modernise the language' in Fig. 2). They focus on what is often only part of the meaning of the original and ground it in some less condensed particulars for students to focus on. Maton (2013) explains this phenomenon whereby 'unpacking' a term weakens its semantic density by explaining that in its original context, meanings such as those being translated by the teacher form part of 'constellations' pertinent to their original context. In their original context the terms condense meaningful links and references to a swathe of other related terms to which students in the present context of their classrooms do not yet have access. Not only are words like 'glory' relatively scarce in the discourse of the present-day teenager, they meant something different in the time of Pliny the Younger, they condensed a different and complex range of meanings and relations. In their 'translation' from archaic to everyday, and the teacher's focus on often what is only part of the meaning of the original, the semantic density of the terms is thus weakened as the meanings contained in the original term are transformed from the complexities of their original context to a simpler, more singular meaning expressed in present-day language.

Alongside strengthening semantic gravity and weakening semantic density of the archaic language and making the meanings contained in the language accessible by 'translating' into contemporary language, the teacher further increases the semantic gravity of the knowledge contained in the written text by moving the students metaphorically through time in their consideration of Pliny's letter ('Being in the past' in Fig. 2). The shift from language of the past to language of the present is also echoed by a shift in the discourse of the classroom from past to present *tense*. Although the original source document is written as a recount in the past tense, the teacher's explanation and commentary on the text is construed in the present tense, as illustrated in the following example.

> HE WAS AT MISENUM IN ACTIVE COMMAND OF THE FLEET. THE NINTH DAY BEFORE THE KALENDS OF SEPTEMBER MY MOTHER POINTED OUT TO HIM A CLOUD OF UNUSUAL SIZE AND APPEARANCE. HE HAD BEEN OUT IN THE SUN, THEN HAD TAKEN A COLD BATH, HAD LUNCHED LYING DOWN, AND THEN WAS STUDYING. HE DEMANDED HIS SHOES AND CLIMBED TO A PLACE FROM WHICH HE WAS ABLE TO HAVE THE BEST VIEW OF THE MARVELOUS THING.
>
> they're across up this end, and they're looking across to, um Pompeii, so there's quite a distance, and it's mum who first sees this strange cloud coming out of the volcano, and you know they'd all just been having a normal day lying in the sun 'I'm hot now! No swimming pool I'll just go and have a, a cold bath, um study,' don't you like it, you know, all of a sudden Pliny the Elder says 'ohhh! Better see what's here! Do you wanna come with me?

The effect of the change in tense is to reconstrue the events recounted in Pliny's letter as a kind of dramatically unfolding imaginative re-enactment in the present. This kind of temporal shifting of knowledge also aims to metaphorically shift students through time by positioning them within the time of the action being investigated. That is, as the text is re-told in the present tense, the students can become vicarious participators in the action as they are invited to move outside their current context of a twenty-first century classroom. From the perspective of the classroom, the knowledge being expressed by Pliny has relatively weak semantic gravity: its meanings are weakly dependent on the classroom context. However, with the imaginative re-enactment of the letter, the students are given the option of shifting their focus out of the context of the classroom and into the historical time of the eruption of Vesuvius in order to help them bridge the gap between past and present. This strengthens the semantic gravity of the knowledge which was originally expressed in written form in the text, as the students are offered an opportunity to enter the context of the happenings themselves. They are invited by the teacher to imagine the events as if they could see them unfold, and also to imagine what they would do in similar circumstances. They are, in a sense, asked to put themselves in Pliny's shoes.

> and you can just imagine the oarsmen are trying to go through and there's pumice. . . and Pliny the um Elder is trying to appear calm and everything's alright, I'll just go and have a bath! You know which is what you'd do wouldn't you? Disaster happening! Things going on! Oh! Better have a bath! Better have a bath. . . Um, meanwhile. . .

Additionally, as they are positioned by the teacher within the unfolding event, they may partially imagine Pliny's gaze and through this perhaps achieve some sort of historical 'empathy' with him as a historical figure experiencing the eruption of Vesuvius. Thus temporal shifting represents a strategy for enabling students to understand Pliny as a knower of History. The use of the present tense to relay events as if they are presently happening aims to locate students metaphorically in the boat along with Pliny in order to participate vicariously in the action. Events of the past are presented in a human context and the dispositions, actions and emotions of historical actors are presented in the present tense so that students can engage with a historical knower in order to learn about the past. They can, if they choose, imagine themselves in his shoes and do not have to *be* Pliny the Younger to know. The teacher has strengthened semantic gravity, ameliorating the distance between the classroom context and that of the events.

However, the students' vicarious participation in the events being related is on occasion disrupted as the teacher relates the events of the drama and then comments on them. As shown in the text excerpt above, the teacher sometimes shifts from the present tense dramatic re-creation of events into a kind of commentary which disrupts Pliny's gaze and positions the students as observers looking in. The dramatic retelling of the past events in the present tense identifies students with *Pliny* as a knower in history, however the teacher's commentary on those events positions the students with the *teacher* as a knower of History. The teacher's commentary also creates implicit evaluation through comments such as 'even though he mightn't believe it he says it!' and 'which is what you'd do wouldn't you?' for example and provides the basis for development of a historian's gaze. This shifting from vicarious participation through Pliny to commentary on Pliny implicates a small but significant movement back up the semantic scale, as illustrated in Fig. 2. Students are invited to shift from the concrete experiences of a particular historical knower, grounded in the context, to weaken semantic gravity slightly by stepping back to comment and generalise about these experiences. Thus, if modernising the language can be represented as bringing the students partway down the semantic scale, the cycling between participation and commentary can be seen as a kind of 'bobbing' up and down the scale, as students are located within the action then step back to consider it from an outsider's perspective.

Thus far the teacher has transformed the knowledge from the written text through a double move: shifting the language from the past into the present and shifting (or at least attempting to shift) students mentally from the present into the past ('Modernise the language' and 'Being with Pliny' in Fig. 2). These both work to strengthen semantic gravity and weaken semantic density, moving the knowledge down the semantic scale towards a first-person, commonsense understanding of the events in the text. However, in order to demonstrate mastery of the pedagogic discourse of History, which is more than personal narrative and involves an array of specialised terms, students must display knowledge in assessments that involves weaker semantic gravity (by, for example, discussing events with more 'objective' detachment) and stronger semantic density (through, for example, marshalling technicalised terms). Students must reason about the relevance and importance of the source for the study of History. This necessitates moving back up the semantic scale.

It is useful at this point to consider what it is that students need to take from sources like this in order to be able to conceive of how a shift back up the scale might be managed. This particular source is an eyewitness account of the eruption of Vesuvius which is used for its importance in describing the type of volcanic eruption represented by the one that destroyed Pompeii. This source text, which describes the eruption of Vesuvius in AD79 has become the basis for naming a whole category of eruptions and is therefore an important historical source. The teacher explains its relevance to the students in the following way.

> we keep referring to Pliny's letter, okay? Pliny's letter explaining. . . the eruption. And describing the eruption, and we've been talking about it and you've had extracts. But I thought you might like to see the letter. . . in total. . . Right! We're looking at the eruption of Vesuvius! It's a letter of Pliny the Younger to Tacitus, containing a description of the eruption of AD seventy-nine. So, we've talked about the eruption we keep referring to a plinian eruption, we keep referring to the letter that was written. . .
>
> . . .interestingly, this is where we get the pine tree. Now did you notice in one of the, um information stencils you got yesterday it, it it said umbrella? Did anybody pick it up? That it said umbrella, but I would rather you use the pine, because let's use the ancient source, okay go back to the ancient source. If it's good enough for Pliny, it's good enough for us to describe the cloud as a pine tree, okay? Even though they said an umbrella. . . You know so we won't crucify them for saying umbrella but I think a pine tree is more accurate.

This source, then, is important for more than just its description of events surrounding the eruption of Vesuvius and the resulting destruction of Pompeii. Its relevance also involves the use today in naming a type of volcanic eruption. Students therefore need to weaken semantic gravity significantly in order to transition from this particular incident in AD79 to generalise across a category of volcanic eruptions, and to move away from Pliny the Younger himself as a knower in History to the significance of source documents in the field of History. In this particular context, they are being asked to go from a starting point of Pliny's letter to Tacitus, through a process of imagining they were Pliny in the unfolding action, to a comprehension of the relevance of the letter as an historical source document.

This movement, if it were achieved, would represent a semantic wave. However, with notable exceptions, the majority of lessons recorded in the DISKS project involved repeated movements downwards through recurrent 'unpacking' of written sources (Maton, 2013; Martin, 2013).

5. Semantic waves and the modes of history

To address how better to enable movements up the semantic scale we need a better understanding of the systems of language which come into play in weakening and strengthening semantic gravity and/or semantic density. First, it should be emphasised that there is no simple one-to-one relation between these organising principles of knowledge and language resources. One cannot equate 'semantic gravity' or 'semantic density' with single linguistic equivalents. Stronger or weaker semantic gravity and semantic density are realised differently according to the object of study; the language resources associated with their strengths similarly vary according to the object of study. For example, strengthening semantic density in Biology may involve a different complex of language resources to strengthening semantic density in History (see Martin,

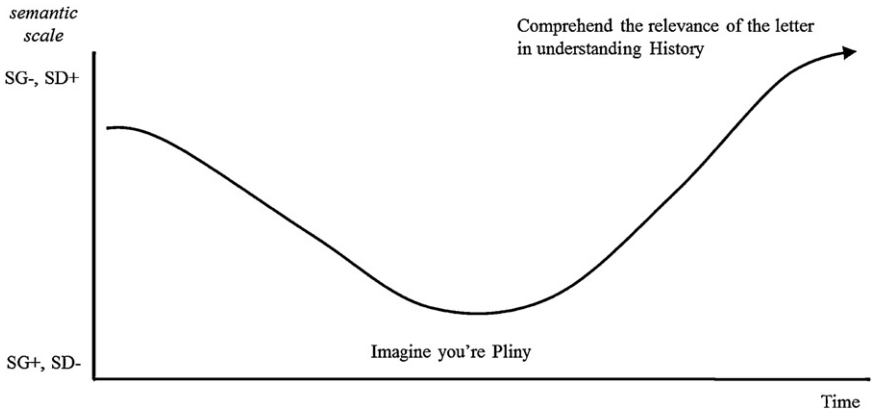

Fig. 3. From Pliny's letter to historiography.

2013; Martin et al., 2010). This cuts both ways: there is no sociological concept equivalent to, for example, the linguistic concept of grammatical metaphor. The search for one-to-one equivalents (typically as a precursor to dispensing with the original concepts) is futile, and typically a nervous attempt to avoid the pertubations of inter-disciplinarity that then fails to gain the greater explanatory power generated by bringing two complementary approaches to bear. Nonetheless, the attempt to explore the language resources involved in, for example, semantic waves is worthwhile, as it provides new insights into how complexes of language resources are marshalled to achieve changes in the forms of knowledge being communicated.

Although we do not yet have an exhaustive understanding of the language systems at stake, we can partly understand movements in semantic gravity as implicating mode shifts from language as action to language as reflection. These are typically achieved in the History classroom through manipulation of deixis and grammatical metaphor (Martin & Matruglio, in press). The use of specific participants and particular processes (e.g. *Tacitus, Pliny, Rome; the volcano erupts*) could be said to represent stronger semantic gravity, while the use of generic participants and recurrent processes could be said to represent relatively weaker semantic gravity (e.g. *diplomats, theatres; people walked around selling*). Similarly, nominalised process (e.g. *the excavations of Pompeii)* and verbalised time and/or cause (e.g. *a career that culminates in his governorship; the treatment of skeletal remains has evoked impassioned debate*. . .) could be said to represent weaker semantic gravity than the congruent expression of these. Semantic density, on the other hand can be at least partly understood as implicating technicality, either through distillation of ideational meaning into subject-specific terminology (e.g. 'cilia', 'the immune response'), or through iconisation (Martin, 2009) to produce axiologically loaded 'flexi-tech' as in the –isms of History (e.g. colonialism, nationalism, imperialism) (Martin et al., 2010).

These language resources however do not give a full account for what occurs in the process of creating semantic waves. As described above, classroom data collected in the course of the project also revealed interesting manipulations of time in the pedagogy of History classrooms as sections of source documents were read through and then explained or commented on by the teacher before moving on to reading the next part of the text. It is therefore important to consider the different uses of language which are necessitated by these time shifts in order better to understand how shifts along the semantic scale are achieved in the language of the classroom.

As exemplified above, the iterative process of reading and explaining the source text involved a kind of dramatic re-interpretation of the original text as a kind of unfolding drama for the students. As the teacher moved through alternate phases of reading and explaining the text, she switched between the past tense in which the document was written and a present tense explanation of the events in commonsense terms. This temporal shifting is illustrated here with an example repeated from above.

> HE WAS AT MISENUM IN ACTIVE COMMAND OF THE FLEET. THE NINTH DAY BEFORE THE KALENDS OF SEPTEMBER MY MOTHER POINTED OUT TO HIM A CLOUD OF UNUSUAL SIZE AND APPEARANCE. HE HAD BEEN OUT IN THE SUN, THEN HAD TAKEN A COLD BATH, HAD LUNCHED LYING DOWN, AND THEN WAS STUDYING. HE DEMANDED HIS SHOES AND CLIMBED TO A PLACE FROM WHICH HE WAS ABLE TO HAVE THE BEST VIEW OF THE MARVELOUS THING.

> they're across up this end, and they're looking across to, um Pompeii, so there's quite a distance, and it's mum who first sees this strange cloud coming out of the volcano, and you know they'd all just been having a normal day lying in the sun 'I'm hot now! No swimming pool I'll just go and have a, a cold bath, um study, don't you like it, you know, all of a sudden Pliny the Elder says 'ohhh! Better see what's here! Do you wanna come with me?' You'll have to talk about tense and process type, cos mental processes here and they take simple present tense, and present in present for something beginning to be sensed

Not only does the teacher make the shift from the past tense of the original source to the present tense of her 'unpacking', but she also uses two different types of present tense in her explanation of the source text. These changes in tense seem to broadly mark out differences in the construction of the events of the original text as an unfolding drama, in which the

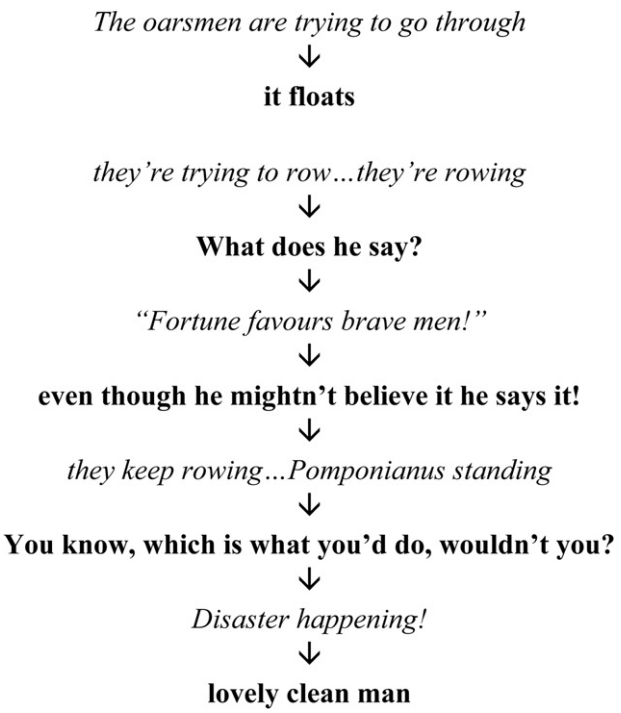

Fig. 4. Participation and commentary in history pedagogy.

students are invited to participate vicariously, which is presented as present-in-present (Halliday & Matthiessen, 2004), and comment on the events or personages presented in the simple present tense. These seem to represent two different modes of History: (i) commentary, which invites students to participate vicariously in the unfolding action; and (ii) comment, which invites students to make evaluations and assessments of the events and actors being described. These two modes of History are indicated on the excerpt below with commentary in *italics* and comment in **bold.**

> **and you can just imagine** the oarsmen are trying to go through and there's pumice, **it floats**, there's all pumice on the top and they're trying to row through the stones and they're rowing, and he, and he's thinking 'oh my god! What are we gonna do' and the helmsmen saying 'oh! We've gotta go back! Go back! Go back!' And um, poor old Pliny's saying, **what does he say?** 'Fortune favours brave men.' **Even though he mightn't believe it he says it!** And so they keep rowing on and there's Pomponianus standing on the shore with his luggage and a bit of a panic and they get him into the boat or they get to shore and Pliny the um Elder is trying to appear calm and everything's alright, I'll just go and have a bath! **You know which is what you'd do wouldn't you?** Disaster happening! Things going on! Oh! Better have a bath! Better have a bath. **So, lovely clean man. Um, meanwhile**. . .

In this excerpt, there is what appears to be a sequence of mode shifts, from commentary to comment and back again, largely managed by the shift from the simple present to the present-in-present. Within the commentary mode itself, however, there are also phases of punctiliar completed events which are tracked through the use of the simple present for material and behavioural processes ('they get him into the boat') within the broader context of the drama unfolding in the present-in-present. This seems to occur in places where the teacher wants to speed up the activity sequence (simple present tense is used in a similar way in sports commentary, to keep up with fast-paced sequences of play). In broad terms then we can characterise commentary mode as involving present-in-present tense across process types for presently occurring and incomplete actions and the simple present tense for completed actions; note however that because the concept of an activity being finished or not does not make sense for relational processes these keep the simple present tense – e.g. *there's all pumice on the top*).[1]

The mode shifts between commentary inviting vicarious participation which is expressed in present-in-present and comment expressed in the simple present is represented diagrammatically in Fig. 4.

These two modes of History have other distinct features aside from the differences in tense. Commentary mode also features ellipsis, e.g. *Disaster happening! Things going on!* and quoting '*Fortune favours brave men!*' The quoting itself features mood variation, '*go back!*', modulation '*We've gotta go back!*' and expletives '*oh my god!*'. Commentary is mainly

[1] An apparent exception to this characterisation is the simple present tense keep in *they keep rowing on* where a verbal group complex involving phased action is used instead of present in present tense to indicate extended activity.

in the third person and may include interludes of comment as the teacher steps back to interrupt the action: *so, lovely clean man*. Comment mode on the other hand is construed in the simple present tense and also contains a great deal of mood variation, including rhetorical questions *which is what you'd do wouldn't you?* This mode is mainly delivered in the second person (*you can just imagine*) and also contains humour *lovely clean man* and modalization *even though he mightn't believe it*. Comment mode also includes the use of the simple present tense for material processes to indicate a habitual process. An example of this occurs in the extract above when the teacher is talking about pumice and she comments *it floats*. This use of the simple present is unlike its use for punctiliar completed events in commentary mode as it indicates a step, albeit briefly, out of the commentary mode to generalise about a particular aspect of the unfolding action.

Commentary mode is a kind of moment-by-moment narration of events which constructs an event as 'live action' and invites the students to participate vicariously along with the historical actors. In this sense they can partially adopt Pliny's gaze and the distance between the past and the present is narrowed. Comment mode complements commentary by beginning the process of distancing the action as students attention is directed to observe certain features of the events ('what does he say?') and implicit evaluation of the actors ('you know, which is what you would do, wouldn't you?') and events is offered. Although it is still located in a particular time, the comment mode operates as a kind of 'freeze frame' in which students' attention is directed to certain features before returning once again to the unfolding events in the episode.

These two modes of History can be compared to the more reflective modes of recount and generalisation. The mode of recount is best illustrated by the source text, which is written-like, while the comment and commentary modes are spoken-like. The recount mode is construed in past tense in contrast to the present tense of the commentary and comment modes.

> AS HE WAS LEAVING THE-HOUSE, HE RECEIVED A NOTE FROM RECTINA, WIFE OF TASCUS, WHO WAS TERRIFIED BY THE DANGER HANGING OVER HER AND WHOSE VILLA LAY UNDER THE MOUNTAIN SO THAT THERE WAS NO ESCAPE, EXCEPT BY BOAT. SHE BEGGED HIM TO SNATCH HER AWAY FROM SUCH DANGER. HE CHANGED HIS PLAN AND THAT WHICH HE HAD BEGUN IN A SPIRIT OF STUDY, HE ENDED IN A MIGHTY MANNER. HE LAUNCHED VESSELS WITH FOUR BANKS OF OARS AND WENT ON BOARD HIMSELF IN ORDER TO BRING AID NOT ONLY TO RECTINA BUT TO MANY OTHER PEOPLE, FOR THE BEAUTIFUL COASTLINE WAS CROWDED WITH RESIDENTS. HE HURRIED TO THAT PLACE FROM WHICH OTHERS WERE FLEEING, AND WITH A FIRM GUIDANCE HE STEERED A STRAIGHT COURSE INTO THE DANGER. HE WAS FREE FROM FEAR AND HE NOTED DOWN AND DESCRIBED ALL THE MOVEMENTS OF THE PHENOMENON AND ITS DIFFERENT SHAPES EXACTLY AS HIS EYES HAD TAKEN THEM IN.

Generalisation mode is used for timeless and recurrent events and is often used in definitions or explanation of technicality in the subject. Although there are no examples of the generalisation mode in the transcript of this lesson with its focus on a text recounting specific events, examples of this mode can be found in transcripts of other lessons. In the following case, the generalising mode is used to explain the term 'aesthetic trade'.

Teacher	. . .So there would be massive amounts of trade going on, and umm, you know people visiting their diplomats you know or their, their, ambassadors. . .like their envoys and things like that all going back and forth across the countries. Sooo, ideas. When you get a, ah trade in ideas you wouldn't have heard this word before, we call it aesthetic trade. Have you heard of it? Yeah.
Student	You told us before.
Teacher	Ooh! Told you before. Great, excellent! You remember aesthetic trade! Trade in ideas. So of course, when you've got contact with the country you're gonna get the trade in ideas coming as well. So that's what that one is.

These four modes of History can be plotted along a continuum representing degrees along a cline between language in action and language as reflection, as illustrated in Fig. 5. One of the important effects of changing into the present tense when interacting around source documents is changing into commentary or comment modes and therefore shifting towards action rather than reflection. In other words, when the teacher feels that a text needs 'unpacking' s/he grounds it more in the everyday by metaphorically 'inserting' the students into the action and talking about past events as though they were occurring in the present. In LCT terms, the teacher strengthens the semantic gravity of particular knowers by narrating events in such a way as the students vicariously participate in the action along with the historical figures. Events thus become grounded and contextualised while at the same time the language is modernised by the teacher, thus weakening semantic density in knowledge made available to the students. This represents a shift down the semantic scale.

The main features of the four modes of History are summarised below in Table 1 along with illustrative examples in *italics*.

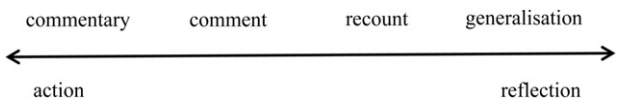

Fig. 5. The four modes of composing history.

Table 1
The modes of history.

Commentary	Comment	Recount	Generalisation
Present-in-present *the oarsmen are trying to go through*	Simple present *And you can just imagine*	Past tense *He changed his plan and that which he had begun in a spirit of study he ended in a mighty manner*	Simple present tense *When you get trade in ideas*
Quoting sayings of characters *Fortune favours brave men!*	Mood variation *Which is what you'd do, wouldn't you?*		Generic participants *People, diplomats, ambassadors*
Quoting with mood variation *Go back!*	Humour *Lovely clean man!*		Generic processes *visiting*
Quoting with modulation *We've gotta go back!*	Modalization *Even though he mightn't believe it*		
Quoting with expletives *Oh my god!*	Generic statements *It floats*		
Exclaiming finite ellipsis *Disaster happening! Things going on!*	Evaluation *Lovely clean man.*		

6. Time in the future

We have demonstrated here how temporality is implicated in semantic waves. It can be used to weaken semantic density through modernisation of language and strengthen semantic density by linking events such as the eruption to concepts such as that of a *plinian* eruption. It can also be used to strengthen semantic gravity through the use of the participatory mode to enable identification with certain historical actors and weaken semantic gravity of particular knowers in History (i.e. you do not have to be Pliny to know about the eruption of AD79). In this sense we have added to the rich description of the use of language in History by contributing research that begins to look at the language of pedagogy.

There remains considerable work to be done in the investigation of language use in the classroom and particularly with respect to the manipulation of time in pedagogy. One question concerns the underlying beliefs about the students' learning which underpins the use of this kind of temporal shifting in the classroom. Does the teacher's use of this strategy indicate that she considers the students' control of historical perceptions of time to be underdeveloped such that it needs scaffolding in this way? Another question concerns the 'empathy tasks' and role plays that seem to appear in History teaching, even in the senior years. Are these empathy tasks and role plays an artefact of inquiry-based approaches to the teaching of History or is something else at stake in activities such as a senior History class role playing the Geneva conference as part of their studies on the Vietnam War, for example? Evidence seems to point towards these types of activities as ways to manage semantic waving however it is not yet clear how or why. Further investigation into how time is managed in the pedagogy of History should help to begin to tease out the basis for these kinds of classroom activities and discussion.

More research is also needed in investigating to what extent and in what ways temporal shifting is used in pedagogy in other discipline areas. Data collected for this project also revealed the use of temporal shifting in the senior Biology classroom, involving the location of students in a present tense retelling of an experimental procedure from the previous lesson. The teacher leads the students through a symbolic mental re-enactment of the procedure in order to enable connections to be made to the theoretical principles underlying the practical lesson. That is to say, the symbolic mental re-enactment enables the opportunity for a connection to be made between the higher gravity concrete lived experience of a practical lesson and the weaker gravity theoretical concepts underlying certain procedures in Biology. This is exemplified briefly in the excerpt from a Biology lesson transcript below.

T: So we've now, sterilised ohh! Ahn how do we sterilise the loop. How do we move it through the Bunsen burner
S: Yeah we um, move the loop halfway
T Beautiful! So through it halfway back again good, until when?
S Until the, the loop is red
T: Red hot, beautiful. Okay Alison, we're now up to cooling it. How do you do that
S: You hold it ((inaudible – too far from mic)))
T For about how long. Thirty seconds to one minute. Okay. Cathy why do we have to cool it.
S Because the flame on the Bunsen burner also hits the air around-it the actual Bunsen burner so there's less microbes in that area?
T Beautiful so where you're cooling it, the convection currents have moved the microbes away. Why don't I Melissa put it straight into my sample.
S: (Um because ((inaudible – too far from mic)))
T Exactly it will boil them! And then if you actually touch an agar plate I didn't say that last time but you'll melt the agar okay? So that's why we cool it. Alright so, we are now up to, plate umm, doing our, what do we call it
S: Streaking
T: Streaking, so (Kavuk) how do we streak

In this example, the teacher uses a similar strategy to temporal shifting. In this case, however, the shift is not from a past tense account to a present tense dramatic reconstrual of that account, but from a past enactment of a process to a present tense mental re-enactment of that process. This gives the teacher the opportunity to then comment on the theoretical

reasoning behind certain activities in the practical lesson thus weakening semantic gravity from specific acts located in time and space to more general scientific principles underlying these acts. It also gives her the opportunity to strengthen semantic density as she can connect and package up meanings into the technicality of science, such as *convection currents*. More research is therefore warranted into links between temporal shifting and the semantic scale in History, Science and beyond if we are fully to understand the language of the classroom and how it can enable or constrain cumulative learning. A further step is also to investigate, together with teachers, how better to enable movements up the semantic scale to enable semantic waves. If temporal shifting as described above can move students *downward* and leave them at the bottom of the wave, how do we enable them to move confidently towards the top? How do we get them from the action of the story into historiography? We have raised more questions than we can answer. However, thinking in terms of semantic waves offers, we believe, a fruitful and productive way of addressing these questions, in time.

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Linguistics and Education 24 (2013) 50–63

Contents lists available at SciVerse ScienceDirect

Linguistics and Education

journal homepage: www.elsevier.com/locate/linged

Jointly constructing semantic waves: Implications for teacher training

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ARTICLE INFO

Available online 29 January 2013

Keywords:
Systemic Functional Linguistics
Legitimation Code Theory
Teacher-training
Biology
Semantic waves
Classroom interaction

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.

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 (2013) conceptualises 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. Fig. 1 illustrates a single semantic wave using such a scale: this one involves a downward shift from abstract, generalised and condensed meanings to concretised, specified and simpler meanings, and then an upward shift to complete a single wave.

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 generalised, abstract and highly condensed meanings, often in technical language, towards more context-dependent and simpler meanings, often in everyday language (see Fig. 3 in

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http://dx.doi.org/10.1016/j.linged.2012.11.008

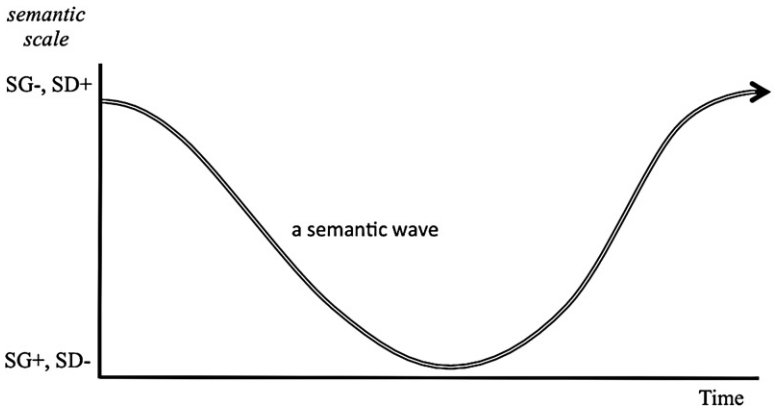

Fig. 1. A semantic wave.

Maton, 2013). 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 wording 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 (2013) demonstrate, specialised discourse of academic subjects comprises 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 (2013) 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 do not represent 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, Maton, and Martin (2013) 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 organising 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 (2013) 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 highscoring 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.

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

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 helps 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**.

As Fig. 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, 2013). 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 sum, in 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.

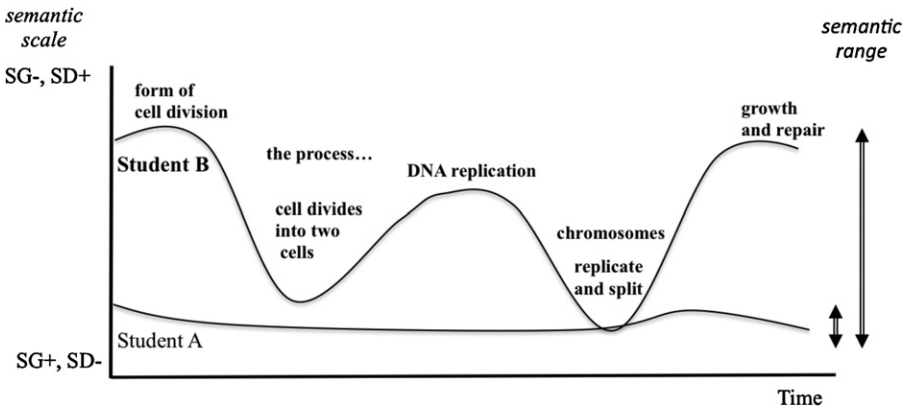

Fig. 2. Explaining mitosis in semantic waves.

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 (2013) 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 (2013) 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 Fig. 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*.

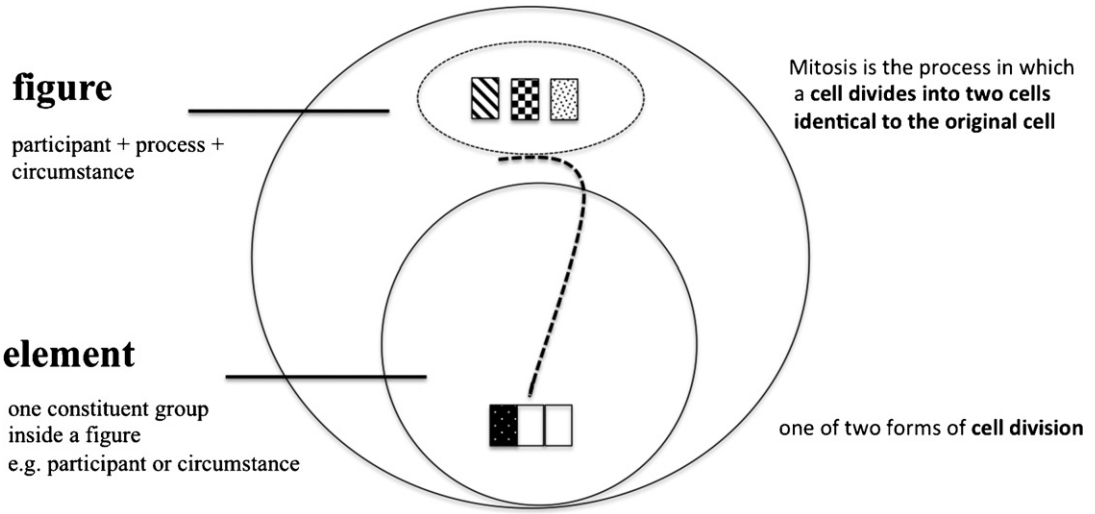

Fig. 3. The metaphorical encoding of discourse semantic figures as elements (based on Martin, 2013).

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 symbolising and drawing together clause range of meaning beyond this single clause (Martin, 2013). 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, 2013), 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 operationalising 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). 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 (2013) 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 Fig. 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.

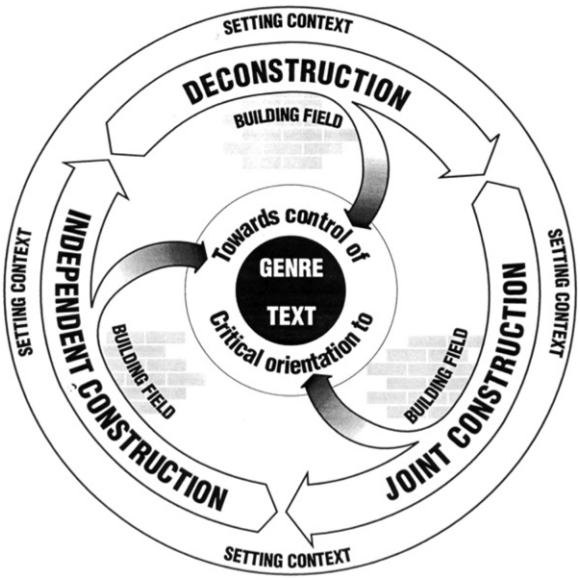

Fig. 4. The Teaching and Learning Cycle (Rothery, 1994).

The Teaching and Learning Cycle (TLC) was first developed in the Metropolitan East Region Disadvantaged Schools Programme 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 Dreyfus, Macnaught, and Humphrey (2011), Humphrey and Macnaught (2011) and Martin and 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 emphasises 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 (Christie, 2002; Edwards & Westgate, 1994; Gibbons, 2006; Mehan, 1979; Nassaji & Wells, 2000; Nystrand & Gamoran, 1991; Nystrand, 1997; Rose, 2004; Sinclair & Coutlhard, 1975; Tharp & Gallimore, 1991; van Lier, 1996; Wells, 1999).

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 Fig. 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 and Macnaught (2011) have referred to this stage as *Bridging*. From the perspective of field-building patterns in SFL (Martin

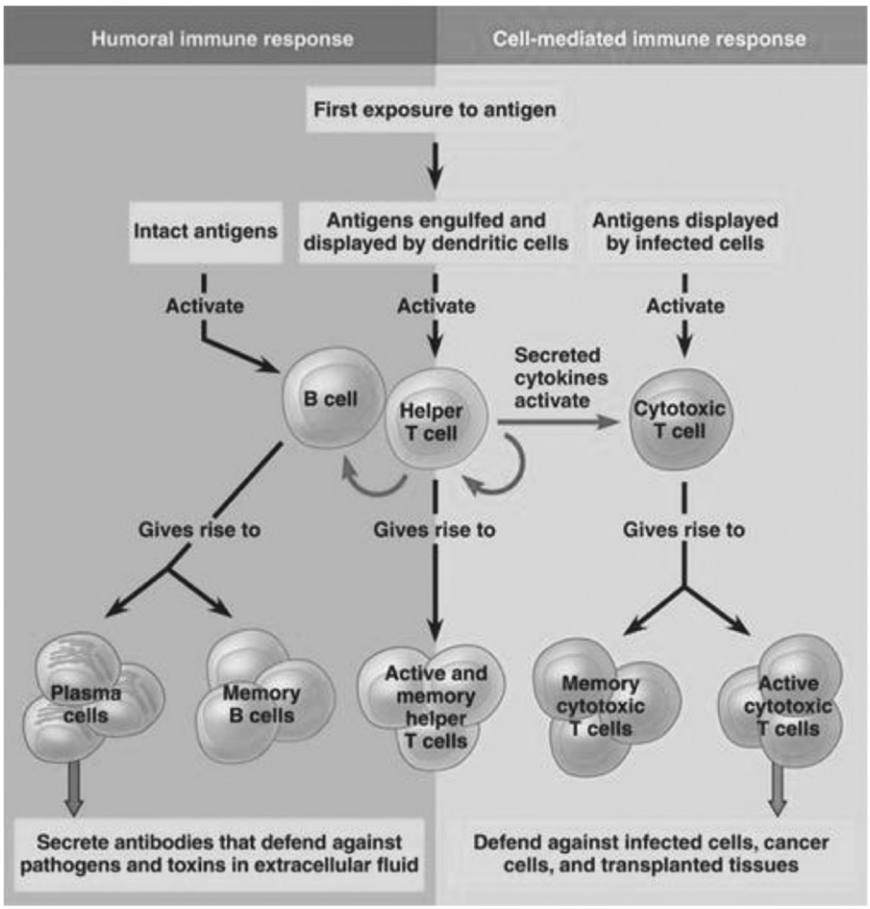

Fig. 5. The immune response represented as an implication sequence (http://bthsbioteacher.wikispaces.com/The+Immune+System).

& Rose, 2007; Martin, 2013), 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 Fig. 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.

The core stage of Joint Construction, *Text Negotiation*, involves eliciting and mediating suggestions as the text is gradually scribed. (See Dreyfus & Macnaught, in press; Dreyfus et al., 2011; Martin & Dreyfus, 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 (2013) highlights, semantic waves take a host of forms. Fig. 6 traces one semantic wave profile. It plots teachers' suggestions as they take on the role of text-creating participants.

Fig. 6 relates to suggestions between turns 9 and 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

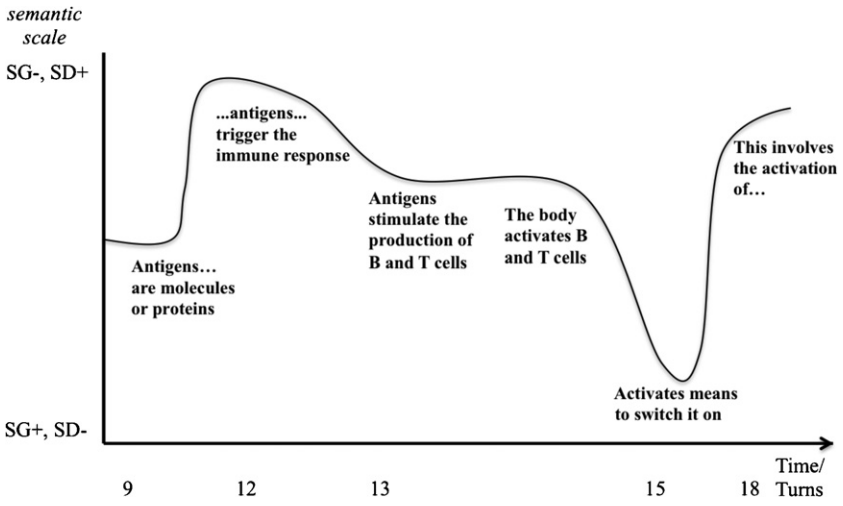

Fig. 6. Semantic waving during Joint Construction.

text, the choice of *activation of B and T cells* allows the writers to start building a precise implication sequence (Martin & Rose, 2007: p. 102) that increases in complexity.

As the semantic profile in Fig. 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 recognised 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 and 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

Table 2
Spoken suggestions during Joint Construction.

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

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*. . .

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, 2013). 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.

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 specialised 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

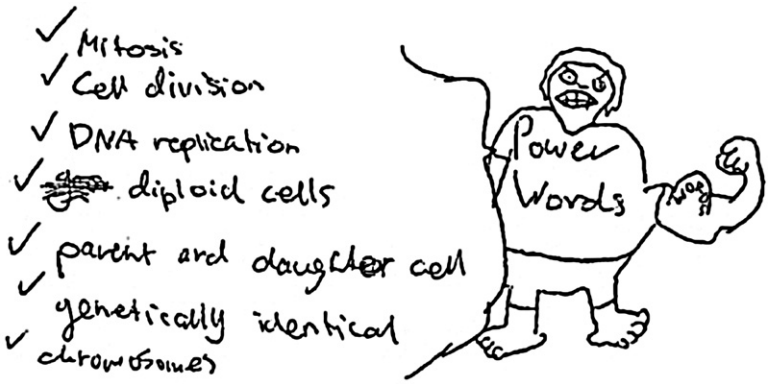

Fig. 7. Students' power word checklists in Independent Construction.

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 Fig. 7) of power words in their independent writing.

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 (2013) 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. Reorganising 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 Fig. 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.

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

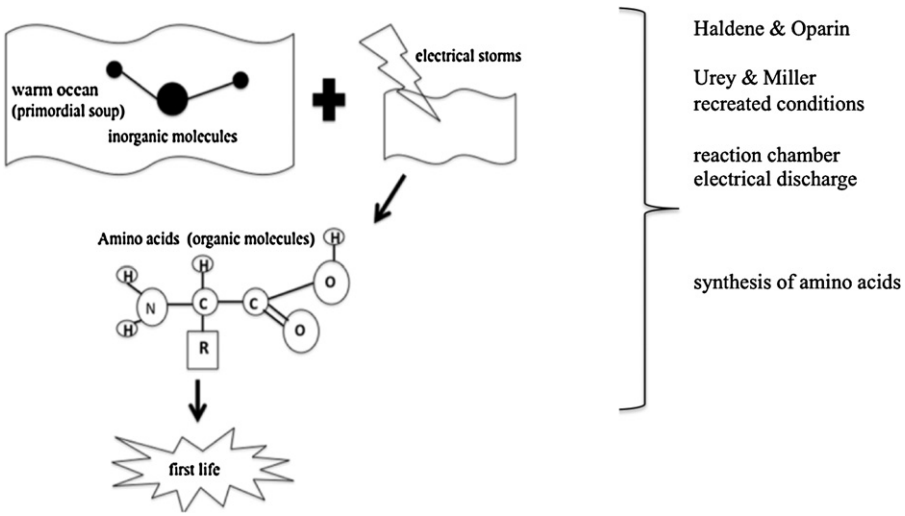

Fig. 8. The reorganisation of power word lists into an implication sequence.

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* ***led 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 recognised 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 <u>was able to start</u>.*
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 Fig. 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 and 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

Table 4
The third jointly constructed text.

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 the development 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*** magnification and resolution. This ***enabled*** the observation of internal structures (micro-anatomy). This ***led to*** the classification 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.

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).

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 specialised equipment and their nominalised 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, 2013), 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 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, 2013) and the notion of the power trio (Martin, 2013) 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.

[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*.

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 operationalised 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, Wilson, Barrar, & Fung, 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 (Alexander, 2008; Cazden, 2001; Gray, 2007; Rose, 2005), 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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