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# Writing biology, assessing biology: The nature and effects of variation in terminology

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## Abstract

There has been substantial research into terminology as an issue in learning science, especially against the backdrop of concerns over school literacy in science and as sometimes reflected in the poor performance of high school students in assessment tasks. Relevant research has emphasized issues such as lexical load, complexity and metaphor. Variation in the use of terminology has, however,  been relatively under researched, although there is evidence that terminology   use does vary within and across high school textbooks of science. Drawing on an eclectic theoretical framework comprising transitivity analysis (Halliday 1994), legitimation code theory semantics (Maton 2013a), and the context-specific term model (Gerzymisch-Arbogast 2008), this article identifies and classifies variations in the terminology employed in three high school textbooks of biology in Nigeria. It then determines what impact assessment tasks which use terms  that differ from those employed in students' study materials have on students. Examples are found of variant terminology impeding science literacy and task performance, even though there is reason to suspect such variation might in fact have been leveraged to enhance cognition.

## 1.   Introduction

There has been substantial research into terminology as an issue in learning science. Lexical load has been one focus of this research, and the view here is that science textbooks tend to contain far too many new technical words which need to be simultaneously understood for sense to be made of texts (Snow 2010; Fang 2006; Groves 1995; Halliday and Martin 1993; Yager 1983). Complexity has been another thrust of the research, and it has been studied from the standpoint of the opacity of words of Greco-Latin origin for learners without a background in Greek and Latin (Harmon et al. 2005), or of opacity of grammatical metaphor, that is, the nominalization of entire clauses to facilitate thematic progression in scientific text (Halliday and Martin 1993). A third major perspective deals with ordinary lexical metaphors. Although metaphors may generally be seen as supportive of understanding because they facilitate conceptualization of new realities in terms of known entities, they sometimes can be misleading, as when a learner attempts to understand *field* in physics in terms of an arena for games, or *school* in ecology in terms of an educational setting. What is true of metaphors is also true of other ordinary words and expressions (e.g. *takeaway*, *root*,

*odd, power*) which have different meanings in subject-specific fields, for instance, in mathematics (Baker 2007, 174).

Variation in the use of terminology within and across textbooks, and between textbooks and assessment tasks, is, with the exception of a handful of examples, one dimension of terminology that has not received much attention in research on the learning of school science. Terminological variation has been defined "as the use of different forms for the same referent e.g. synonyms, orthographic variants and geographical variants in the same text or set of related texts, as well as hyponyms" (Rogers 2008, 109). As a result of the relative inattention to this phenomenon, precious little is known of typologies of variant terminology in these textbooks, the effects such terminology has on students, how any problems variant terminology poses might be addressed, or how to leverage the advantages associated with such variation.

In one study we could find (Evans 1976), the analysis showed that 13% of the terminology used across six Ordinary level biology textbooks in the UK varied. Evans notes that synonyms further "increase vocabulary burden and make it more difficult for a pupil to pass from one book to another" (Evans 1976, 19). Regrettably, this claim was not empirically investigated in Evan's study, and an understandable but hardly practicable recommendation was made: eliminate synonyms! This article, which builds on an earlier pilot (Antia and Kamai 2006), has the following objectives:

1.   to document variant terminology on select topics within and across three high school textbooks of biology used in Nigeria, and to analyze the clause structure within which these variant terms occur;
2.   to provide a typological description of variant terminology in the corpus analyzed;
3.   to ascertain the effects of variant terminology on the performance of students in an assessment task; and
4.   to reflect on strategies for overcoming any difficulties associated with variant terminology, including how variation can in fact be seen as a cognitive resource. The analysis envisaged here is one that requires in-depth knowledge of the subject matter. As a result, we use biology as our database because of our familiarity with this subject. Subsequent parts of this paper successively present a theoretical framework, the methods, the findings, a proposal on terminology literacy, and the conclusion.

## 2.   Theorizing variation in terminology

Even though the focus has seldom been on educational discourses, variation in terminology is the subject of established theorization as countless publications in this journal show. Generally, a range of explanations have been proposed for variant terminology. First, the need to create texts that are coherent, and to do so in a way that avoids monotony, means that, apart from simple lexical repetition (which would guarantee consistency), there would be such other forms of lexical cohesion like synonymy, hyponymy, complex repetition, simple and complex paraphrases (Hoey 1991; Halliday and Hassan 1976) — all leading to variation in terminology. Second, the dictates of economy in communication would suggest that, following

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the first use of the citational form of a multi-unit term in text, subsequent references may use elliptical forms, including but not limited to abbreviations or acronyms (Rogers 2008). Third, the need to focus on specific dimensions of complex multidimensional objects, the observation that complex conceptual categories are understood differently according to standpoints, or that use and understanding of terms are inherently social constructivist processes — these would all justify variations in terms and definitions (Temmerman 2000; Bowker 1987; Rogers 2007).

To analyze the phenomenon of variant terminology in school textbooks, we draw on an established (but insufficiently exploited) framework within terminology (Gerzymisch-Arbogast's context-specific term model; cf. Gerzymisch-Arbogast 1996, 2008). We also apply to terminology frameworks developed elsewhere, namely, Maton's legitimation code theory (LCT) semantics (Maton 2013a, 2013b) and Halliday's transitivity analysis (Halliday 1994). Gerzymisch-Arbogast's model provides a typology of variation; Maton's LCT semantics explains the pedagogical functions of variation; and Halliday's transitivity analysis provides a grammar for identifying variant terminology and for hypothesizing conceptual equivalence. Maton's legitimation code theory (LCT) is a response to a perceived knowledge-blindness in much of the research on education and knowledge, where the focus has been on knowers and on the process of knowing, rather than also on knowledge itself (Maton 2013a). Semantics, one of several dimensions of LCT, offers codes for unlocking how knowledge is built up across disciplinary orientations, how meaning is made and mediated in a pedagogical context, and what knowledge performances are considered valid achievements or consistent with 'conventional' practice in a given discipline (Maton 2013b; Jackson 2015; Szenes et al. 2015).

LCT semantics operates with two codes: semantic gravity and semantic density. Given that all meanings are dependent on some kind of context, semantic gravity may be seen as referring to the degree to which meanings are heavily or not heavily dependent on specific kinds of context; in other words, semantic gravity refers to the degree to which meanings communicated are more abstract or less abstract, more decontextualized or narrowly context-dependent. Thus, while the term *Sodium chloride* and its symbol *NaCl* do come with a context, that context is more general or abstract than the one for, say, *table salt*. So, *Sodium chloride* may be coded *SG–* (low semantic gravity) to indicate it is relatively less context-dependent, more generic, while *table salt* might be coded *SG+* (high semantic gravity) because the context of its meaning is more circumscribed.

Semantic density, on the other hand, refers to just how much knowledge goes into constituting a given meaning and, conversely, how much knowledge or effort is required to unpack that meaning. The concept underlying the term *Sodium Chloride* would, in many situations and as evidenced by conventional definitions, require quite a bit of disciplinary knowledge to be unpacked, whereas comparatively much less information may be required to explain or understand *table salt*. In other words, there is greater condensation of meaning in the former than in the latter. On this reading, then, *Sodium Chloride* would be coded *SD+* to indicate a higher level of meaning condensation than *table salt* which would be coded *SD–*.

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Of course, what is described as having higher/lower level of density/gravity is relative, for instance, to the specific terms in comparison and to the knower. There may sometimes be an entailment of the one code specification in the other. Thus, *SG–* (less context-dependence) may entail *SD+* (richer, more layered, condensed or complex meaning), while *SG+* (greater context-dependence) may entail *SD–* (simpler meaning). As a result, for several kinds of analysis, it is arguably sufficient to use one code specification (Maton 2013: 13).

In several studies in which this toolkit has been used to analyze pedagogical discourses (Matruglio et al. 2013; Martin et al. 2013; Martin 2013), the finding has frequently been that knowledge in school textbooks and in teacher talk proceeds as waves of: (a) meanings that are relatively more abstract/decontextualized (*SG–*) and dense/richly layered (high semantic density, *SD+*), (b) meanings that are relatively more context-bound (high semantic gravity, *SG+*) and less layered or dense (so-called low semantic density, *SD–*), and (c) back to (a). The rationale for getting back to (a) is that, while (b) serves to unpack the meaning, so it is properly understood, such understanding would need to be demonstrated using (a)-type formulations because it is in such formulations that the basis of achievement (e.g. in assessment tasks) lies. Needless to say, determinations of simplicity and complexity are made relative to the students.

The 'semantic profile' created from these successions of abstract/complex meanings and, contextualised simpler meanings is called a semantic wave. But there are other profiles as well, for instance, a semantic flatline, which can be 'high' if, over a stretch of text or talk, meaning is made consistently at a decontextualized/dense level, or 'low' if, over a stretch, meaning is made consistently at a simpler/more contextualised level.

From the standpoint of this article's interest in terminology variation, LCT semantics makes the following points: terminology variation is indexical of the sources or kinds of knowledge that are combined in pedagogy — e.g. Bernstein's (1999) vertical discourses (academic knowledge) and horizontal discourses (every day or common knowledge); within each of these sources of knowledge but also across them, variation is a matter of degrees (as terms do not vary only across the specialised vs. non-specialised usage divide, but also according to levels within each domain); variation is functional, and seeks to support both understanding and expression; it is the non-recognition of the function of variation that sees it becoming a problem; the notion of the semantic wave profile suggests that variation is potentially systematic as it responds to logics of conceivably different types:
e.g. proximity/alternation (term 1, and variant 2 which occurs in apposition to term 1), but also across modes (running text vs. graphics); finally, the codes (e.g. *SD+*, *SD–*) also provide a metalanguage to describe variant terminology. Let us turn to a second framework.

In her context-specific term model, Gerzymisch-Arbogast (1996) uses 'contamination', a rather infelicitous term (even in the German original), in her account of how system-level specifications of the form and meaning of terms (e.g. in dictionaries, authoritative texts) are actually realized at the parole-level of texts in special-purpose communication. Insight into a

rather complex account is perhaps better provided by commenting on Figure 1 which is an adapted and simplified form of Gerzymisch-Arbogast's original model. In reading Figure 1 anti-clockwise from the bottom right pane, we assume that in the disciplinary space of interest to specialists in a given field (e.g. geologists, lawyers), there is a set of material or immaterial objects $l_1-l_8$ and features $P_1-P_{11}$ available for identifying these objects both positively and negatively. These features or properties provide a basis for the formation of disciplinary concepts by abstraction of common or shared features. Thus, we notice that objects $l_7$ and $l_8$ share a common feature $P_1$ which provides the basis for forming a concept $C_0$. To exemplify, the features of the material object we call *coal* are constituted differently by different disciplines. In geology, it is a rock; in power generation, it is a source of electricity; in economics, it is a commodity; and so on (Felber 1994, 213). This, in a sense, illustrates the anti-essentialist position taken in social constructivism.
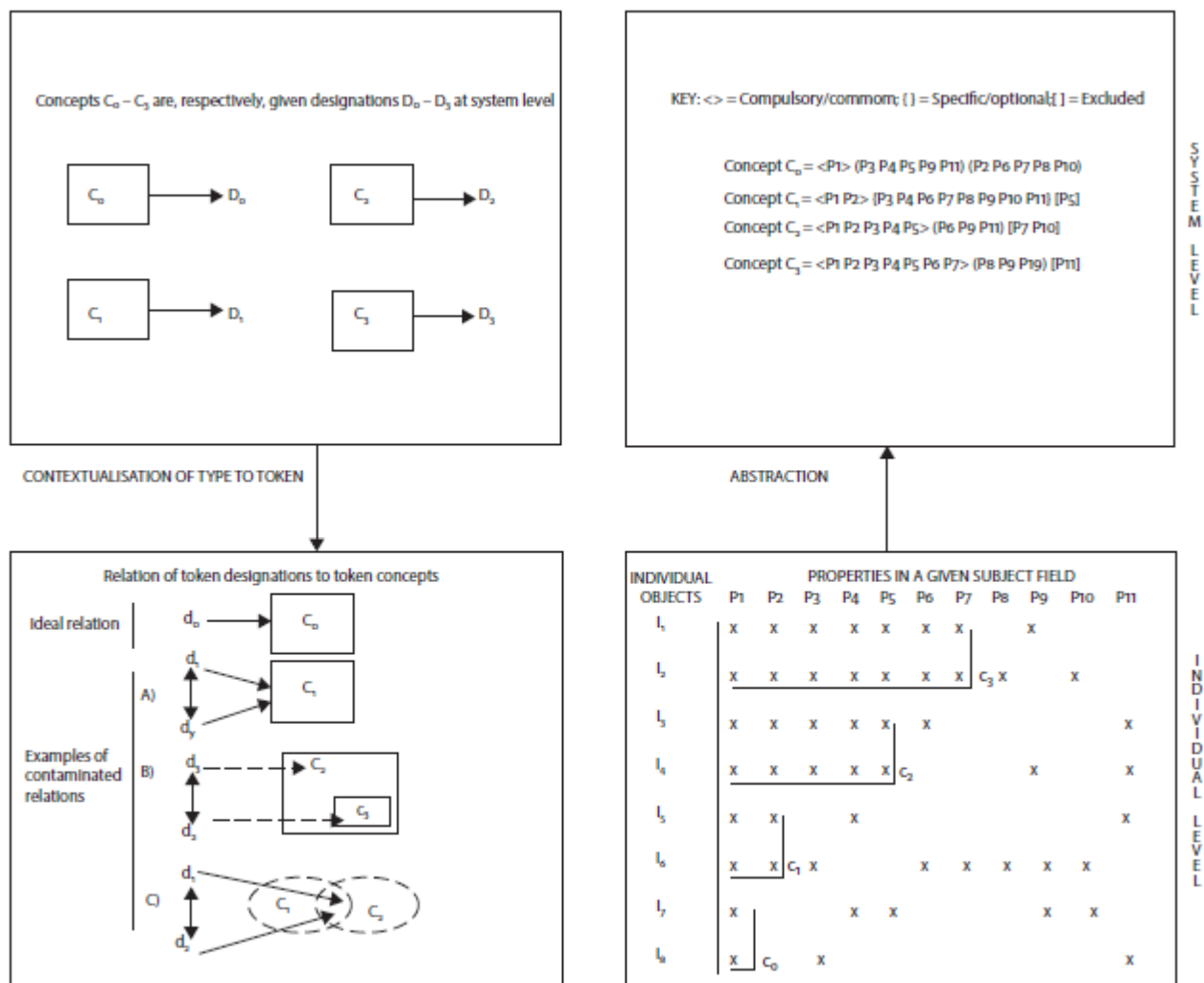


Figure 1. Adaptation of Gerzymisch-Arbogast's context-specific term model

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In the top right pane, which is the system or citation level for concepts, the features or characteristics of each of concepts $C_0$ to $C_3$ are specified according to three kinds of criteria: features which in the given discipline are (by consensus) considered compulsory or common to all instances of a particular concept; features that are optional or can also be read into the particular concept; and features that are excluded. Thus, in the concepts at the system-level, concept $C_0$ has $P_1$ as compulsory characteristic; $P_3$, $P_4$, $P_5$, $P_9$, $P_{11}$ are specific to some instances of concept $C_0$; while $P_2$, $P_6$, $P_7$, $P_8$, and $P_{10}$ are excluded from all instances of Concept $C_0$.

Moving to the top left pane, which is the citation level for terms, we see that to each concept constituted by a unique combination of features, there corresponds a normative or ideal term. Thus, $C_0$ is termed $D_0$, $C_1$ termed $D_1$, and so on. In the bottom left pane, which accounts for the operational context or text-level realizations, we encounter the infelicitous 'contamination' of system-level assignments of term and concept. There will of course be times when the ideal relation of term to concept as specified citationally will be maintained.

Gerzymisch-Arbogast's theory of system-text term variation gives rise to several categories of 'contamination'. From the perspective of the term, contamination can manifest when:

a)    A term other than the one specified at the system level is used interchangeably to represent the same exact concept. This is referred to as contamination of similarity, and is illustrated by example (A) in the lower left pane of Figure 1;

b)    A hyperonym (superordinate term) and a hyponym (subordinate term) are used interchangeably so as to represent the other concept. This is referred to as contamination of inclusion, and is illustrated by example (B) in the lower left pane of Figure 1;

c)    Two terms are used interchangeably so as to represent concepts which intersect at the system level. This is referred to as contamination of intersection, and is depicted as example (C) in the lower left pane of Figure 1.

From the perspective of the concept, contamination may also manifest in several ways, including:

d)    The activation at text level of only a part of the system level concept. This is referred to as partial activation;

e)    The use of a term at text level in such a way that the concept which is activated differs from the concept at system level. This is referred to as author-specific usage.

Concept contamination (d and e) above are not shown in Figure 1. As with other accounts which define term variants in relation to an original, a challenge of applying this model in some cases may lie in determining what the system level specification is and what the text level realization or contamination is. However, what might have been a more important shortcoming of the model (the claim of a predetermined core set of conceptual characteristics) may be addressed in two ways: first, by viewing the core (and perhaps

excluded) characteristics as determined by consensus, thus socially constructed; second, by the allowance made for a category of optional characteristics. The latter allow us to see how contextualization processes (as local, situated meaning-making) may lead to varying uses of terms at text levels. The model is thus useful for observing and accounting for variations in term usage. Specifically, it provides a simple metalanguage for describing forms of terminology variation.

In Halliday's Systemic Functional Linguistics (SFL), transitivity is the system for analyzing language in its function as representation (Halliday 1994; Eggins 1994; Ravelli 2000). At the core of transitivity analysis is the Process, that is, "some activity, or some way of being, a going-on" (Ravelli 2000, 35). The Process type determines the type of Participants. Thus, a material Process would have a Participant called Actor; a Participant that is the object of the action (called Goal); and the Participant that provides information on the time, cause, extent, place and manner of the action (called Circumstance). A relational Process, when it is of the identifying sub-type (as in a definition), would have Participants called the Token (i.e. the definiendum) and the Value (the definiens). A transitivity analysis of conceptually equivalent clauses enables us to see how the wording for specific clause functions differs from one clause to the other. Such an analysis may sometimes (but not always) offer an adequate framework for hypothesizing equivalents through the linking of a set of terms to a common function. Consider the following simple clauses as analysed in transitivity tables (see Tables 1 and 2).

Table 1. Transitivity analysis of clause 1

| Functions: | Actor | Material process: | Goal | Circumstance |
|---|---|---|---|---|
| | Rabies | potentiates | drooling | in dogs |

Table 2. Transitivity analysis of clause 2

| Functions: | Actor | Material process: | Goal | Circumstance |
|---|---|---|---|---|
| | Hydrophobia | causes | uncontrollable salivating | in dogs |

Where both clauses are already known to be conceptually equivalent, transitivity analysis would show how in each clause a particular function is linguistically realized (Actor as *rabies* and *hydrophobia*, Process as *potentiates* and *causes*, and so on). Where both clauses are not already known to be conceptually equivalent, the analysis sets up a focused framework for reflecting on possible term equivalents.

## 3. Materials and Methods

Passages related to three topics, namely, nitrogen cycle, cell environment (osmosis, diffusion) and the nervous system, were excerpted from three biology textbooks used in the second tier of high school (final three years) in Nigeria. These passages were selected either because

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within each there was variation in the terminology used for a given topic, or because variation could be observed across the different textbook excerpts on a given topic. For some of the topics, there were graphic illustrations in addition to the narrative or running texts. The first objective of this article was addressed as follows: variant terminology was identified in the corpus, then simultaneously presented and analyzed within the clause structures in which it occurs in order to determine variation according to clause functions. For this purpose, we used transitivity analysis. We drew on the metalanguage of LCT (Maton 2013b) and the context-specific term model (Gerzymisch-Arbogast 1996) to address the second objective on providing a typological description of variant terminology. For reasons of space, only the data on nitrogen cycle are presented in respect of the first two objectives, but we drew on data from the other topics in addressing other objectives.

For the third objective on the effects of variant terminology, a task to be performed by study participants was set up as follows. A passage (using a specific set of terms) was chosen for each topic to serve as reading material. Questions were then formulated, using the wording or terminology employed in the other passages or sections of a passage, thus setting up a situation in which one or more of the terms employed in a question differed from the terms used in the excerpts read by the participants. Participants had to answer six questions, two each from nitrogen cycle, cell environment (osmosis, diffusion) and the nervous system (see samples in textboxes 1, 2 and 3 in Section 5). The participants (15 in number) were in the final year of secondary schooling in an elite high school in Maiduguri, north east Nigeria. They were assigned to groups of three and interviewed by one of the researchers, so that the reasoning behind whatever written down answers could be verbalized (as think-aloud protocols) and audio-recorded. As in other schools in Nigeria, English is the medium of instruction in the school from which participants were recruited, even though the participants were themselves L1 speakers of a number of Nigerian languages. At the time of participating in the study, students had been exposed to all topics, but in different grades or classes.

In addressing the fourth objective on overcoming any observed barriers posed by variant terminology, we offer the outlines of a pedagogy for developing terminology literacy, drawing in part on the theoretical frameworks presented earlier.

## 4.   A picture of variation in the use of terms: objectives 1 and 2
In attempting to provide a composite picture of variation in the use of terms, we combine the analysis of data for the first and second objectives. For reasons of space, we are only able to provide the data for nitrogen fixation (see Table 3).

Table 3 uses the metalanguage of transitivity analysis to present a picture of variant terminology related to the subject of nitrogen fixation as documented in the running text and graphical illustration of passages in the three textbooks. Apart from the doublets — *nitrogen fixing bacteria* and *azotobacter* (in brackets) — which are themselves consistently used whenever they occur, there is reasonable consistency of terms for the Actor function. The Material Process function is realized by four different forms: *converts*, *fixes*, a directed

arrow and *synthesises*. The Goal is realized by three forms: *atmospheric nitrogen, nitrogen in the air, atmospheric nitrogen gas*.

Table 3. Terminology variation in select passages on nitrogen fixation (with terms coded according to LCT semantics categories)

| Function: | Actor | Process: Material | Goal | Circumstance: Place | |
|---|---|---|---|---|---|
| Class: | Nominal group | Verb | Nominal group | Preposition | Nominal Group |
| Data sources | | | | | |
| Essential Biology Text | Nitrogen fixing bacteria SD- (azotobacter)SD+ | converts SD- | atmospheric nitrogen SD+ | to SD- | nitrogenous compounds SD+ (proteins in the soil) SD- |
| Essential Biology Graphics | Nitrogen fixing bacteria SD- (azotobacter)SD+ | directional arrow SD+ | nitrogen in the air SD- | directional arrow SD+ | Nitrates SD+ |
| Exam Focus Text | Azotobacter SD+ and Clostridium SD+ | fix SD+ | atmospheric nitrogen SD+ | Ellipted | Ellipted |
| Exam Focus Graphics | Nitrogen fixing bacteria SD- (azotobacter) SD+ | directional arrow SD+ | nitrogen in the air SD- | directional arrow SD+ | Nitrate SD+ |
| New Biology Text | Nitrogen fixing bacteria SD- | synthesises SD+ | *organic substances SD+ (proteins) SD- | from SD- | *atmospheric nitrogen SD+ |
| New Biology Graphics | Nitrogen fixing bacteria SD- | directional arrow SD+ | atmospheric nitrogen gas SD+ | directional arrow SD+ | Nitrates SD+ |

*Indicates swapped positions as a result of the verb, 'synthesises' which places the Circumstance before the Goal.

Note that *organic substances* (further specified by *protein*) only appears in the Goal position as a result of the peculiar process (*synthesise*) used which requires a swapping of positions, but

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it belongs to the Circumstance. The Nominal Group in the Circumstance is realized by four different forms: *nitrogenous compounds* (specified further by *protein in the soil*), *nitrates* and *nitrate*.

Using Gerzymisch-Arbogast's analytical categories to comment, it is evident that, for the Actor, there is largely an ideal relation (involving tokens of *nitrogen fixing bacteria*) across all the source materials but for one, that is, *Essential Biology* Text, where *Azotobacter* and *Clostridium* are used, and exemplify a relation of inclusion vis-à-vis a generic *nitrogen fixing bacteria*. The foregoing relates to intertextual relations. Intra-textually, that is, within a given running text or between the running text and the associated graphic, we observe a relation: of inclusion involving *nitrogen fixing bacteria* and *azotobacter* in *Exam Focus* text, *Exam Focus* graphic, and *Essential Biology* graphic.

With respect to the Process, terms used across the running texts of the three sources illustrate Gerzymisch-Arbogast's relation of similarity (*converts*, *fixes* and *synthesises*). The latter affects sequence of Goal and Circumstance, as seen earlier. Across the graphics of the three source materials, an ideal relation is observed (with the directed arrows). Between graphics and running texts, there is contamination of similarity (arrows and verbs).

As for the Goal, with *atmospheric nitrogen*, we find an ideal relation across the running text of all three sources. Between two of the graphics (*Exam Focus* and *Essential Biology*), we also find an ideal relation involving the tokens of *nitrogen in the air*, which then stand in a relation of similarity to the running text tokens of *atmospheric nitrogen* and the *New Biology* graphic of *atmospheric nitrogen gas*. For the Circumstance, the preposition is realised by *to* and directional arrows, which exemplify a relation of similarity. But in the *Essential Biology* text, the preposition is not at all stated, and in the *New Biology* text we have an opposite preposition *from* which is the consequence of the Process employed (*synthesise*). For the Nominal Group class of the Circumstance, we find the three tokens of *Nitrate* used across all three graphics exemplifying the ideal relation. Within each of the *Exam Focus* text and the *New Biology* text, we find in the term doublets relations of inclusion: in the case of *Exam Focus*, *proteins in the soil* are an instance of, or included in, *Nitrogenous compounds*; with the *New Biology* text, *proteins* are included in, or are an instance of, *organic substances*.

An LCT view allows for a dynamic perspective that reveals how sets of variant terms interact, for instance, within a text. Adopting such a perspective for the clauses from the running text and the graphics of *Essential Biology* text in Table 3, we obtain a picture such as Figure 2. We assume that a directed arrow ( — >) may be semantically more dense than its linguistic realization (converts, to, etc.).
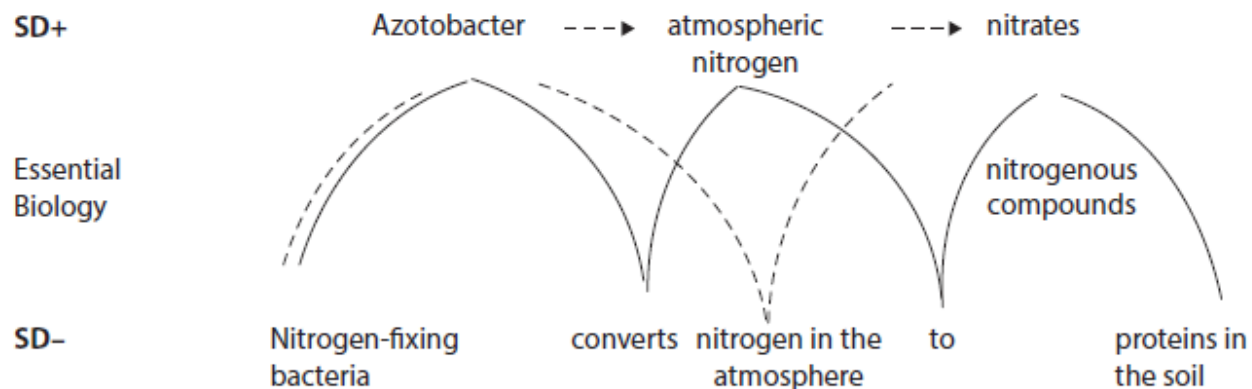
**Figure 2.** A dynamic LCT view of textual and graphic realizations of a clause in *Essential Biology*. Legend: broken lines identify terms realizing clause functions in the graphic mode, and track the density path of these terms in text time. Solid lines do the same thing for the textual mode.

In Figure 2, the designations realizing the clause functions in the graphic mode (broken lines) of *Essential Biology* form the shape of a wave (that looks like one full dome and half a dome), illustrating the undulation of semantic densities in text time or progression. The designations associated with the textual mode (solid lines) form three complete waves. Figure 2 shows that, when both the running text and graphic are considered, each clause function (Actor, Process, Goal, Circumstance) is realized by more than one designation. The nominal group in the Circumstance in fact has three designations (*nitrates*, *nitrogenous compounds* and *proteins in the soil*). Interestingly, for each clause constituent there is a relatively more dense/complex designation (*SD+*) and a relatively unpacked/simpler designation (*SD−*).

What this means is that for every simple designation intended to ease understanding, there is a more technical/specialized one whose use may be considered indexical of in-depth disciplinary knowledge. It is also instructive in this specific example that in neither mode do the designations build a semantic flatline (high or low). Rather, we have clause functions realized by terms with relatively high and low densities building waves for each mode. These waves do not run in a parallel fashion, but intersect or criss-cross.

To sum up how the data in Table 3 address the first two objectives, it is evident that virtually each clause function is realized by three or more designations, with the Actor position being relatively more stable than other functions. Hypernymic/ hyponymic shifts, or relations of inclusion, are a major feature of the designations for the Actor function, while relations of similarity typify the Process function. The differences in semantic densities, which have the function of simplifying and complexifying, are frequently a consequence of hypernymic/hyponymic shifts in textual progression. Although for reasons of space we do not comment here on the other datasets, fairly similar patterns to the data on Table 3 can be observed.

## 5. Exploring possible effects of terminology variation: objective 3

Table 4 presents an overview of the performance of participants on the 6- item test.

Table 4 (last row) shows that the majority (nine or 60%) of test participants scored less than 60% on the test. The Table also shows that while the performance was between 80%–100% on three of the questions, the performance on the other three questions was extremely low, ranging between 13%–20%. For a group that had been exposed to all the topics prior to the test, this task would appear to suggest (going by the lower scores) that variant terminology could have been a specific type of challenge for which the students were not particularly prepared. But however suggestive these test scores are, the number of participants is much too small to draw anything but the most tentative inferences concerning the impact of variant terminology. This is even more so because no pattern of correlation could be discerned between performance and the type of variation involved. As a result, we focus on the qualitative, talk-aloud protocol data, in order to obtain deeper insight into the effects of variant terminology on students' reasoning or processing of tasks.

A striking example of a student recognizing and verbalizing a problem of variant terminology, then resolving it with what Pym (2003) refers to as "justified confidence", is seen in protocol data 1 related to question 4. The question required participants to react by answering [Yes] or [No] to a statement (see textbox 1).

Textbox 1: Question 4

**Question 4:** The movement of molecules of gas, solid and liquid from a region of higher concentration of that substance to a region of lower concentration of that substance is diffusion. True or False?
**Reference text which participants were to read:** Diffusion is the movement of ions or molecules of a substance from a region of higher concentration to region of lower concentration. Source: *Exam Focus*, p. 6.

The answer expected was [True]. Notice that, whereas the text to be read used *ions or molecules* for the Goal, the question used *solid, liquid or gas*. Let us see how participant Benny (fictitious name) processes this challenge.

Protocol data 1: Verbalisation by Benny on the process of diffusion
1. The answer is true because it is stated here (*Referring to the reference text)* that diffusion is
2. the movement of <u>ions or molecules,</u> while in the question, it is said to be the movement of
3. <u>gas or liquid</u>. <u>Gas or liquid</u> may be in form of ions in the human body and they are in
4. molecules.

Benny states the correct answer (she says 'true'). She recognizes and verbalizes the intended challenge by contrasting what is said in the reference text and in the question, then goes on to state in the final sentence (lines 3–4) that *gas* or *liquid* are generic to *ions* and *molecules*. She

demonstrates one kind of knowledge required to correctly answer the question, that is, knowledge that *ions* and *molecules* are hyponymic forms of the hypernyms *gas* and *liquid*.

Let us consider another example of a correct answer, even if less felicitously arrived at. Question 1 on the nitrogen cycle similarly required participants to answer [True] or [False]. See textbox 2.

Table 4. Performance of participants on 6-item test (√ = correct answer; X = incorrect answer)

| Question | Participants | | | | | | | | | | | | | | | Average percentage pass per question |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
| 1. Nitrogen cycle | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | 100% |
| 2. Nitrogen cycle | X | X | √ | √ | X | X | X | X | X | X | X | X | X | X | X | 13% |
| 3. Cell environment | √ | √ | √ | √ | √ | √ | √ | √ | √ | X | √ | X | √ | √ | √ | 87% |
| 4. Cell environment | √ | √ | √ | X | √ | √ | X | √ | √ | √ | √ | X | √ | √ | √ | 80% |
| 5. Nervous coordination | X | X | X | X | X | X | X | √ | X | √ | X | X | X | X | X | 13% |
| 6. Nervous coordination | X | X | √ | X | X | X | X | √ | X | X | X | √ | X | X | X | 20% |
| Average percentage pass per participant | 50% | 67% | 83% | 50% | 50% | 67% | 33% | 83% | 67% | 50% | 50% | 33% | 33% | 33% | 60% | |

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## Textbox 2: Question 1

Question 1: Azotobacter converts atmospheric nitrogen to compound nitrogen . True or False?
Reference text: A few species of bacteria called the nitrogen fixing bacteria can synthesise organic substances like proteins, from atmospheric nitrogen and carbohydrates. Some of these bacteria are free living in the soil. Others, like Rhizobium, live in root nodules. Source: *New Biology*, p. 30.

The answer expected was [True]. In textbox 2 there are differences in the terms used across question and reference text for several clause functions: Actor function: *azotobacter* vs. *nitrogen fixing bacteria*; Goal: *atmospheric nitrogen* vs. *nitrogen in the atmosphere*; etc. Let us see how participant Izuoma (fictitious name) processed the challenge.

Protocol data 2: Verbalisation by Izuoma on the process of nitrification in the Nitrogen Cycle
1. I choose true because from the definition of nitrogen fixing bacteria, it says nitrogen fixing
2. bacteria is the process of converting atmospheric nitrogen in to what? compound nitrogen,
3. by *a* bacteria called *eeheeh* bacteria for example called azobacter*, and from here
4. *(referring to the Reference Text)* nitrogen fixing bacteria converts nitrogen in the
5. atmosphere to form nitrogenous compounds. And that is the correct definition of nitrogen
6. fixing bacteria and I choose true for that.

Izuoma somehow anomalously re-processes the question as being about the definition of *nitrogen fixing bacteria* (in lines 5–6), and describes *nitrogen fixing bacteria* as being the "process of converting" (lines 1–2). Even with this confusion, in line 3 Izuoma usefully sets up a relationship of inclusion (not stated in the reference text) between *bacteria* and *azotobacter*: she speaks of *azobacter* [sic] as an example of *bacteria* that is the Actor responsible for (see preposition 'by' in line 3) her "nitrogen fixing bacteria is the process of". With the particular challenge of the hypernymic — hyponymic shift in the reference text and question apparently resolved, Izuoma does not appear to be concerned by the other variations: *atmospheric nitrogen/nitrogen in the atmosphere*; *compound nitrogen/nitrogenous compounds*. She goes on to conclude that the statement must be correct.

The next two protocols show even less felicitous processing of variant terminology, leading to incorrect answers. Question 3 on the process of osmosis required participants to choose either [True] or [False] as reaction to a statement (see textbox 3). The answer expected was True.

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## Textbox 3: Question 3

Question 3: Osmosis is the passage of solvent from a dilute solution to a more concentrated solution. True or False?

Reference text:

In osmosis, the stronger solution is called hypertonic solution while the weaker solution is called hypotonic solution. Thus water molecules move from the hypotonic solution to hypertonic solution. Source: Exam Focus, pages 6–7

Notice in textbox 3 that there are differences in the terms that are used across question stem and reference text, e.g.: *solvent* vs. *water molecules*; *dilute solution* vs. *hypotonic solution/ weaker solution*; *more concentrated solution* vs. hypertonic solution/ *stronger solution*. Consider protocol data 3 presenting the reasoning behind student Nokani's (wrong) answer.

Protocol data 3: Verbalisation by Nokani on Osmosis
1. The answer is false because in the passage osmosis is said to be the movement of
2. molecules from hypotonic to hypertonic solution. That makes the answer to the question
3. wrong... I mean false.

Presumably, as Nokani is unable to map *hypotonic solution* and *hypertonic solution* to their equivalents in the question, she concludes that the answer to the question must be false. She clearly fails to leverage the bridging function of the semantically less dense (SD⁻) *weaker solution* and *stronger solution* to map *hypotonic solution* and *hypertonic solution* to their equivalents in the question.

In sum, we have seen in this section that, in the quantitative results, the performance on three questions was extremely low, ranging between 13%–20%. Such low levels of performance were said to be striking, considering that the group had been exposed to all the topics prior to the test. In the qualitative (protocol) data presented, we saw one student getting the answer correct with justifiable confidence, on the basis of an identification of a hypernymic-hyponymic shift involving ions/molecules and gas/liquid. Her processing underscored the kind of competence required to respond to the challenge. Such awareness of variant terminology was largely absent in the other three protocols presented, including one in which the participant got the answer correct by fluke.

### 6. Responding to terminology variation: prologemonon to a pedagogy of literacy in variant terminology

What these data would appear to suggest is that variant terminology could have been a specific type of challenge for which the students were not particularly prepared. Recall that the students had been exposed to all three topics prior to their participation in the test. How might these students have been better equipped to deal with variant terminology? In ongoing

work, we are developing and hoping to test an approach to terminology literacy within content learning. For now, we can draw attention to how two of the theoretical frameworks employed in this article might provide some of the bases for (a teacher's guide to) developing students' literacy of variant terminology. While of course extensive further reading can only be helpful, the guide as developed here presupposes little more than a good understanding of this article.

To illustrate aspects of this terminology literacy, we will use the text in textbox 4, which is a combination of the text of question 3 and the corresponding reference text in textbox 3. A text with an accompanying and labeled graphic might also have been of interest in light of text-graphic variations in term use.

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**Textbox 4: Illustrative text for a pedagogy of literacy in variant terminology**

Osmosis is the passage of solvent from a dilute solution to a more concentrated solution. In osmosis, the stronger solution is called hypertonic solution while the weaker solution is called hypotonic solution. Thus water molecules move from the hypotonic solution to hypertonic solution.

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The guide outlined here has three parts; it is presented in a pedagogical style; and it can be taught to students once at the beginning of a term or at intervals within the term; the idea, however, is for students to integrate the awareness gained into their own independent learning processes.

A) Sensitization to terms. The first point in this pedagogy is to sensitize students to terminology in knowledge and texts. This could proceed in the form of the following exercises:

1. Based on the definition of terms as one-word, multi-word or even non-verbal designations for the concepts of a special subject field, underline all term tokens in the passage in textbox 4.
2. Martin (2013) refers to terms as 'power words' by which he means the technical or specialized labels or designations of a subject field, but which we can also interpret in a near-literal sense. Now, efface/conceal all previously underlined term tokens from the text in textbox 4. Is what is left of the text still meaningful? If, on the other hand, you left the previously underlined terms

intact and effaced all other words, would you be able to make sense of the text (e.g. say what the text was all about)? Do you see the near literal sense in which terms are power words?

On sensitization to terms, see also the notes and exercises in Antia (2005).

5. Sensitization to variation. The second point of the pedagogy would be to draw attention to the reality and the functions of variant terminology specifically. This point may be developed as follows:

· LCT semantics suggests that pedagogical discourses tend to function as oscillations between more technical and less technical registers, with the consequence that items in the latter registers stand in synonymic relations to the former which they simplify. In the text provided (textbox 4), without prejudice to your answers in the exercises in section A, match a relatively more difficult term with its simpler equivalent. Having done this, do you agree with the claim that oscillation between registers functions, in part, to support understanding?

· (With a text involving several distinct 'contamination' types (cf. Gerzymisch-Arbogast's or other typologies of variation), a question on variation types seen in the paired terms of B1 above might also have been appropriate.

6. Confirmatory procedures. The final core point of the pedagogy would be on the diagnostic potentials of transitivity analysis. Although operating at the level of grammar rather than meaning, transitivity analyses of different clauses (e.g. in question and reference text) may on occasion facilitate identification or confirmation of conceptual equivalence among terms. This point may be operationalized as follows:

1. Use the table (Table 5) provided to do a transitivity analysis of the two clauses below, the second of which has been slightly modified to also read like a definition with an identifying relational Process:

Table 5. Clause analysis as aid for detecting variation in terminology

| Token | Process: Relational (identifying) | | Value | |
| --- | --- | --- | --- | --- |
| Noun | Verbal Group | Nominal group | Place (alpha) | Place (beta) |
| osmosis | is | the passage … | from … | to … |
| Osmosis | is | the movement … | from … | to … |

7. Osmosis is the passage of solvent from a dilute solution to a more concentrated solution.

8. Osmosis is the movement of water molecules from the hypotonic solution to hypertonic solution.

2. Are you able to confirm and/or expand on your analysis in B2?

Although as yet empirically untested and subject to further development, this pedagogy has thrusts that are coherent with the tasks reported in this article and the manner in which these tasks were processed.

## 7.    Conclusion

In this article we have attempted to bring insights from work on variant terminology or 'indeterminacy in terminology' (Antia 2007) to bear on science education. We have done this as a means of drawing attention to what is perhaps a promising pathway for addressing an aspect of the crisis of science literacy in high schools. While worldwide concerns about the performance of students in the sciences have continued to be addressed from a range of standpoints, including language proficiency, relatively little attention has been devoted to variant terminology which, as the data presented in this article show, is quite pervasive and does on occasion impede literacy. As the performance data showed, 9 of the 15 study participants scored less than 60% on the 6 test items, with the performance on 3 of the items being extremely low (between 13%–20%).

It would seem perfectly logical that the problem of variant terminology be addressed by controlled language mechanisms that enforce specific forms of usage, as Evans (1976) appears to suggest. It has also been suggested that the terminological load of school science textbooks, which is only made worse by variant terminology, is itself unnecessary as quite a bit of this abstruse terminology can be expressed in simple ordinary words (Groves 1995). Whatever the merits of these approaches are, we have elected to take a different tack. Our approach acknowledges that:

·    Terminology (consistent or variant) simultaneously has a high nuisance value and a high functional value;
·    Much as we would like to think of terms as the building blocks of specialized knowledge, these blocks require the glue of grammar;
·    Much is to be gained from systematic reflection on how to develop terminology literacy in a manner that is integral to content teaching and learning;

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