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Examining the theory/practice relation in a high school science register: A functional linguistic perspective

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Abstract

Using a functional view of language and drawing on extensive classroom data, this article examines a high school science class to see how language was used to connect theory and practice in a science register. The article tracks the teaching/learning paths from the introduction to the science topic and teaching of the theory (e.g., technical terms) to problem-solving activities (the practice) that necessitate the use of the terms. Research implications include (1) the value of a functional perspective which looks at science learning as a social practice for both a sharper understanding of issues of science language and content integration and a greater ability to analyze the role of language in learning science and (2) the significance of the theory/practice contrast for student learning. Assessment implications include the research potential for greater understanding of the development of scientific discourse in science classes as well as richer conceptions of the linguistic connections between students' practical experience and theoretical understanding of science.

Key words: systemic functional linguistics; register; science discourse; language and content integration; English as a Second Language

1. Introduction

The study of scientific discourse in school, like any other area of English for academic purposes, is based on the functional analysis of discourse in the contexts of academic study and exchange. Our approach is situated within Systemic Functional Linguistic theory (SFL) and explores the nature of science as a socially constructed practice, a "linguistic/semiotic practice which has evolved functionally to do specialised kinds of theoretical work and practical work in social institutions" (Halliday & Martin, 1993, p. x).

We will examine the teaching and learning of the science register in a grade nine mainstream secondary science classroom that contains a mix of students who are native speakers of English and of students who are culturally and linguistically diverse. Our guiding questions are: How can we analyze and assess the teaching and learning of science language and content in this classroom? What are the roles of content, language-content integration, and social practice? How are science theory and practice related to each other, to the construction of knowledge, and to formative assessment in the classroom context?

2. Framing the study

Science teachers teach the register of science, or in other words, science language and science content. How teachers and learners bring together theory and learners' experiences is a well-known and vital problem for science education researchers, who have studied the topic in terms of the coordination of theory and evidence (Driver, Leach, Millar, & Scott, 1996; Novak & Gowin, 1984). Few studies have taken a linguistic perspective to this theory-practice issue. In this paper, we explore how a science teacher socializes his students into the science register—thereby teaching students science language and meaning—which links what they do and observe with the theory being taught. Our central aim is to analyze the theory-practice relation in a science class taught by an expert science teacher, and to use linguistic analysis to throw light on the processes of teaching and learning science language and content to inform the field of content-based language teaching (CBI). We will selectively review the literature on CBI and particularly on science in CBI for insights into this aim.

Our first concern is the role of content in conceptions of CBI. Is the objective of CBI to teach the subject matter while helping students understand the linguistic characteristics of the field? Or is it as Pica comments, "the use of subject-matter content as an aid to L2 learning" (Pica, 2002, p. 3), which puts the spotlight primarily on language learning alone? Pica proposed that CBI should include more opportunities to focus on intervention strategies that would assist in the noticing and correction of grammatical errors. Much of the recent literature on immersion education, particularly in the Canadian context, reflects Pica's position by stressing a need for more focus on form. But this position effectively rules out the issues we are pursuing in this article. In contrast to Pica's view, Grabe and Stoller (1997) claimed that CBI efforts in secondary schools "are an attempt to provide *both* relevant language skills and serious, relevant content instruction" (p. 15, emphasis in original), with explicit language instruction integrated with the subject matter. Huang (2004) closely follows this interpretation of CBI, insisting that the language of science must be acquired through engagement in discipline-specific activities, that learning science and learning the language of science cannot be separated, a view that reflects the ideas of Halliday and Martin (1993) and other systemic linguists.

A discussion of the differences between focus on form and focus on meaning appears in Mohan and Beckett (2001), an SFL analysis of an ESL teacher's recasts of her students' causal explanations during an oral presentation about the brain. The authors contrasted recasts which focus on form with those that focus on meaning and form, changing the statements grammatically into more literate semantic paraphrases. In the current paper, we will illustrate how a science teacher used functional recasts to connect theory and practice.

Gibbons (2003) described how teacher recasts helped young ESL learners studying magnetism move across a model continuum from talk accompanying action into more context-independent, specialist discourse. Mohan and Slater (2005) similarly investigated the teaching and learning of magnetism in a class of young ESL children, showing how a simple theory of magnetism in a scientific register was built up and linked it to practical experience in a back and forth, theory–practice dynamic. Their article raises the question: How do older ESL learners fare when the classroom provides fewer hands-on experiences? Huang (2004) showed secondary students learning to write classification texts while learning scientific taxonomies. She offered strategies for language-content integration, a popular topic in the CBI science literature (see, for example, Dong, 2002) and insights into classification and taxonomy, a component of science theory.

In our data, practice includes student decision-making. Leung and Mohan (2004) studied classroom-based formative teacher assessment of student performance in two multiethnic and multilingual elementary classrooms. They observed how teachers guided students to make decisions about answers and noted implications of this socially constructed assessment for more established forms of language assessment. Leung and

Mohan's work provides us with insights into how to assess how students relate practice to theory.

Is the theory-practice relation seen in the same way by science teachers and language teachers? Arkoudis (2003) argued that there needs to be more dialog between ESL and science teachers regarding the needs of their ESL students. She suggested that whereas science teachers claim to teach science concepts, ESL teachers consider their focus to be on language (see also Huang, 2004). This implies that content teachers and language teachers may not view science as a register and recognize the importance of the theory-practice relation as a language/content issue in the science classroom. Science teachers may overlook the language aspect, and language teachers may see the theory–practice relation as the sole concern of the science teacher.

3. Theoretical framework

An SFL view of language sees language and content *totally* differently than a traditional view. A traditional view (Derewianka, 2001) is primarily concerned with sentence-level form and gives minimal significance to content. This view sees language as a set of rules that allow us to make judgments about correctness, and language learning as the acquisition of these rules. Consistent with this view, a focus-on-form perspective (Long & Robinson, 1998) would ask whether the grade nine science teacher corrected his students' specific "problematic" features of grammar. The traditional view does not engage with the relationship between language and content, or offer a way to theorize content (i.e., meaning) in text. It does not support a functional and semantic view of academic discourse.

In contrast, an SFL view offers a way to theorize language and content in text and provides tools to investigate the integration of language and content. As Derewianka (2001) notes, SFL examines the purposes that language serves within our lives. It emphasizes the text or discourse as a whole in relation to the context and recognizes how science lexis and grammar correlate with science texts and contexts. It provides tools to investigate and critique how language is involved in the construction of meaning and sees language *as a resource for making meaning*. How is the teacher constructing science meanings? How is the students' science register learning extending their power to make meaning in science contexts?

SFL provides us with a way of characterizing the 'register' of the science classes in our study, describing how science meaning relates to science wording or, in other words, how science content relates to science language. Registers are the semantic configurations that are typically associated with particular social contexts and are described in terms of three main variables that influence the way we use language: *field, tenor,* and *mode*. Field is concerned with the activity being pursued or the subject matter the activity revolves around. Tenor refers to the social roles and relationships between the people involved, and mode is the medium and role of language in the situation. These three variables relate to three key areas of meaning in language: *ideational* meaning, the resources for representing our experience of the world; *interpersonal* meaning, our resources for enabling interaction; and *textual* meaning, our resources for constructing coherent, connected texts. Halliday (1994) considers ideational meaning to be the closest to the everyday sense of content, but it must be kept in mind that all three areas of meaning are always present in a text. Our science class register, then, is the configuration of meanings that are typically associated with this social context of science.

Of particular importance to this paper is Halliday's observation that learning science involves two types of patterning: creating taxonomies of new technical terms that differ from everyday understandings, and creating logical sequences of reasoning, such as cause-effect relations (Halliday, 1998). Because specialist vocabulary tends to be the most noticeable feature of scientific English (O'Toole, 1996) and everyday language is not adequate for explaining scientific concepts (Ebenezer & Erickson, 1996), views of language in science have tended to highlight the teaching of technical terms, overlooking the network of semantic relations they participate in. Our study will therefore describe how technical terms are linked to a taxonomy and to causal relations. Moreover, as learning science involves learning how scientists explain and use concepts (Leach & Scott, 2000), we will explore the linguistic progression from the introduction of technical terms to problem-solving activities which necessitate their use. We will also suggest that these problem-solving activities play a critical role in successfully relating theory to practice.

In our study we will use *social practice* as our largest unit of analysis. A social practice is a unit of culture that involves cultural knowledge and cultural action (Spradley, 1980) in a theory/practice, or reflection/action relation. It is thus a conceptual model of theory/practice relations that we can apply to real world cases. In our view, all registers of academic discourse include theory–practice relations. A theory and its practice match, rather like a question its answer match. Genre analysis does not address such "local" matching relations (See Fries, n.d.).

Examples of social practices include occupations, games, and academic disciplines. Learning in the high school science units we are analyzing is learning a social practice and involves acquiring knowledge (e.g., the properties of matter) and learning to do things (e.g., to separate mixtures of substances). Within a social practice there are knowledge structures (KSs) that are the semantic patterns of the discourse, knowledge, actions, artifacts, and environment of the social practice (Spradley, 1980). Our heuristic model uses a set of basic KSs: The knowledge or theory level of a typical social practice includes the KSs of classification, principles, and values, and the action or practice level includes the corresponding KSs of description, sequence, and choice. Each three-way contrast matches the three main process types of Halliday (1994): being, doing, and sensing (consciousness). Taken together these KSs form a *knowledge framework* or gestalt for the social practice, which allows a knowledgeable participant to make sense of the social practice (see Mohan, 1986; 2001).

From a discourse viewpoint, a social practice is a context for discourses of reflection and discourses of action. Discourse of reflection talks *about* the social practice; discourse of action enacts what is going on *in* the social practice (see Cloran, 2000; Halliday & Matthiessen, 1999). In the teaching unit on matter, for example, the teacher discusses the theory of matter with the learners (discourse of reflection) and at times uses experiments which the teacher and learners talk themselves through (discourse of action). Discourse of reflection can be divided further into specific reference (e.g., where the teacher and students talk about what happens in a specific situation) and general reflection (e.g., where the teacher and students talk in general terms about the theory of matter). This discourse contrast, which can be tracked by the contrast of specific versus generalized entities and single-occasion versus habitual events (see Cloran, 2000), is helpful for noting the *difference* between theory and practice in our data, but it does not describe the *relation* between theory and practice.

Exploring the linguistic progression from the introduction to the science topic to the problem-solving activities raises the problem of "intertextuality":

> …part of the environment for any text is a set of previous texts, texts that are taken for granted as shared among those taking part. Again, the school provides very clear examples. Every lesson is built on the assumption of earlier lessons in which topics have been explored, concepts agreed upon and defined. (Halliday & Hasan, 1985, p. 47-9)

How is the theory developed in the introductory lessons matched with the practice of the later problem-solving activities? We will use three levels of description to explore how theory is matched with practice in our data. At the highest level we will examine knowledge structures, at a middle level we will examine question-answer relations, and at a micro-level we will examine lexical cohesion. Halliday explains lexical cohesion in the following terms:

> Continuity may be established in a text by the choice of words. This may take the form of word repetition; or the choice of a word that is related in some way to a previous one—either semantically, such that the two are in the broadest sense synonymous, or collocationally, such that the two have a more than ordinary tendency to co-occur. Lexical cohesion may be maintained over long passages by the presence of keywords, words having special significance for the meaning of a particular text. (Halliday, 1994, p. 310)

Within this theoretical framework, we now examine the teaching/learning paths of the science class.

4. The current study

The current study examines the teaching and learning of science content and language in a mainstream grade nine science class following provincial curricular goals for the development of science content, language, and thinking skills. The class, consisting of 30 students (14 boys and 16 girls), fourteen to fifteen years old, was taught every other day in a large science lab by Mr. Peterson, who was the head of the science department and the only teacher of grade nine science. The class reflected the general diversity of the school, with native-English-speaking students and speakers of Cantonese, Korean, and Hebrew who had varying abilities in English but were deemed proficient enough to participate and succeed in the mainstream class. Classroom interactions were audiotaped and supplemented by field notes and interviews with participants.

Although there were many topics addressed, we will focus on the discourse data that leads up to and includes a problem-solving activity about the science topic of matter.

5. Tracking the teaching/learning paths

With Mr. Peterson, both the teaching of theory and the guidance of problem-solving activities of practice play a critical role in successfully relating theory to practice. We will analyze how theory is related to practice across his unit at three levels. At the highest level, we will explore the linguistic progression from the introduction and teaching of science theory to problem-solving activities of practice, which necessitate the application of theory.

With Halliday's two types of patterning at the forefront, we can see how Mr. Peterson builds a taxonomy of physical properties and describes the effects of these properties, associating the properties in the taxonomy with cause-effect relations, so that students can test properties to tell different substances apart. In terms of our framework of knowledge structures, taxonomy is included in classification and cause-effect relations are included in principles. Within his lessons, Mr. Peterson continuously cycles between theory and practice: He illustrates generic properties by describing specific things and illustrates generic cause-effect relations by sequences of events. In knowledge structure terms he is illustrating classifications with descriptions and principles with sequences. In other words, he is linking knowledge structures together in a knowledge framework. In the theory texts we will italicize some of the lexicogrammar associated with different KSs.

At the middle level, we will see how Mr. Peterson binds theory together in question-answer relations, thus socializing the students "to develop an appreciation for both the kinds of questions, and the types of answers, that scientists value" with respect to physical properties (Newton, Driver, & Osborne, 1999, p. 556). Underlying his classroom work is a general theory question: "What are the physical properties that distinguish one substance from another?" This question is answered by the whole taxonomy of physical properties. In his lessons on individual properties, he uses various, more limited forms of this question to guide the lesson in a theory question-answer dialogue. It is beyond the scope of this paper to examine this process in detail so we will restrict ourselves to pointing out how Mr. Peterson typically opens the discussion of a physical property by posing a form of this theory question. We will later see how he similarly coherently binds practice together in question-answer relations. The problem-solving exercise poses the general practical question: "How do you separate one substance from another?" and limited forms of this question direct student work towards deciding upon an answer. In the theory texts we will underline some of his initial questions.

At the micro-level, we will examine lexical cohesion. Mr. Peterson's theory lessons build lexical items; the problem-solving activities then make bridges to theory through lexically cohesive links back to these lexical items. These technical lexical items appear to be ”keywords, words having special significance for the meaning of a particular text" (Halliday, 1994, p. 310). We judge that important lexical items associated with the theory of physical properties include items referring to properties (e.g., 'density'), effects of properties (e.g., 'attracted to a magnet'), elements (e.g., 'iron') and substances (e.g., 'cork'). Also included is the metalanguage for discussing taxonomy, for example, 'property', 'characteristic'. In the theory text examples we have bolded a number of important lexical items.

With these three levels clarified, we will now examine the discourse and show how Mr. Peterson led the students through the unit. First, Mr. Peterson carefully introduced a number of technical terms to build a taxonomy of physical properties. Three that are central to the problem-solving exercise are Density, Magnetism, and Solubility. Because space prevents us from including all three, we will illustrate only density here. In the following data, we can see the three levels of analysis. At the highest level of analysis, the technical term 'density' is discussed as one property in the taxonomy of properties. The knowledge structure being built is taxonomy, which is included in classification. Note the processes of being. A taxonomy typically includes definition of its elements, and we see the teacher asking for a definition of density: "What's **density** *mean* anyway? *By definition*?" where the words in italics are items of the lexicogrammar of meaning associated with the knowledge structure of classification. This is followed by Mr. Peterson's related discussion of how density is measured and a call for examples of dense metals. At the middle level of analysis, we have underlined the third sentence as a more limited form of the general theory question: "What are the physical properties that distinguish one substance from another?" A later example is the question: "What's the difference between lead and aluminum?"

At the micro-level, we have bolded a number of lexical items, beginning with 'density'.

5.1. Classification/description: Building up a taxonomy of physical properties

Mr. Peterson: Say I had two pieces of metal, and I ask you do you think they're the same metal or different metals? A lot of metallic elements look silvery. <u>How would you tell if they're the same metal or different metal?</u>

Mike: **Density**…

Mr. Peterson: What's **density** *mean* anyway? *By definition*? Let me say this substance is more **dense** than that substance.

Mike: How compact it is.

Mr. Peterson: Okay you've got the idea. What kind of units does **density** use to measure? **Quantitative properties.** So if you just ask what is the **density** of a substance and I were to tell you, what kind of units might I use?

Jamie: Grams.

Mr. Peterson: Grams would be a **mass** unit. You've got the right start. Grams per amount? Isn't it? Per **volume** or per area or what? What do you think?

Sandy: **Volume**.

Mr. Peterson: So grams per **volume** then. Your **volume** unit comes in cubic right? Cubic centimeters is one. .**Grams per cubic centimeter**. How about if I asked you this. <u>What's the difference between lead and aluminum?</u>

Irene: Lead is heavier.

Note how Mr. Peterson's discussion of Irene's answer shows him moving her from everyday meaning ("Lead is heavier") towards technical meaning ("Lead is denser") in this register.

Mr. Peterson: Lead is heavier. There you go. Now if somebody says that I go "oh yeah?" I go in the back and I rummage around to find a huge piece of aluminum. A big chunk of aluminum and a tiny lead thing and I'll bring them out and I'll go okay lift them. I can make the aluminum so big and the lead so small that the aluminum is actually heavier. Couldn't I? Think about it.

Irene: You have to compare equal **volumes.**

Mr. Peterson: Oh I'd have to compare equal **volumes** to be fair. In other words we're comparing **density**. So if you're asked what's one of the differences between lead and aluminum. Don't go "weight" because a guy like me is going to prove you wrong. Okay? It's **density**.

Mr. Peterson continued by creating a list of elements and their densities and writing them on the board.

5.2. Principles/Sequence: Explaining the effects of the properties

Mr. Peterson associated the properties in the taxonomy with cause–effect sequences that students could use tests to tell different substances apart. Thus the discourse in his classroom included not only the building of taxonomies but also logical sequences of cause-effect (included in the knowledge structure of Principles). Note the processes of doing. The words in italics (‘determines’, ‘dependent on’) are items of the lexicogrammar of causality. At the middle level of analysis, we note that his opening question links to a sub-question of the general theory question: “What are the effects of the physical properties that distinguish one substance from another?” At the micro-level, the most prominent lexical items are ‘floating’ and ‘sinking’.

Mr. Peterson: What *determines* if something **floats**?

Todd: **Density.**

Mr. Peterson: In **water**. **Density**. Exactly. So if something **sinks** in **water** would you guess it’s more or less **dense**? Uh ice **floats** just below well… **floats** low in the **water**. Correct?

Mr. Peterson then performed a small demonstration to visually reinforce for the students the effects of density, showing how he cycles between theory and practice, and how he illustrates generic properties by describing specific things (‘a rubber stopper’, ‘a cork’) and generic cause-effect relations (“why things sink or float in water is dependent on density”) by sequences of events (“here’s a cork in water. It floats quite high”). In knowledge structure terms he is illustrating classifications with descriptions and principles with sequences of events.

Mr. Peterson: Here’s— here’s a **rubber** stopper in **water**. (Drops it in.)

Students: Whoa!

Mr. Peterson: Rubber's more **dense** than water. Here's a **cork** in **water**. (Takes out the rubber stopper and drops the cork in.)

Todd: Less…

Mr. Peterson: It **floats** quite high. Right?

Students: Yes.

Irene: It's so cool.

Mr. Peterson: Okay. **Ice** would **float** lower. Right? **Cork**'s is around point two five. About a quarter as **dense** as **water**. Now why things **sink** or **float** in water is *dependent* on **density**.

5.3. Addressing a problem-solving activity (Evaluation/Choice)

Once Mr. Peterson had introduced physical properties and discussed them in some detail, he asked the students to consider how they could separate a mixture of salt, sand, gold, and iron. This is a practical and specific activity, doing something to a mixture of specific things: "Now your job is to separate *them* into four piles. How would you *do* that?"

Once again looking at our three levels of analysis, we will show how the practical and specific problem-solving activity can be analyzed as a decision-making process (i.e., as an example of the knowledge structure of choice). Note 'think', a process of sensing. Mr. Peterson guides students to tackle this problem by valued methods of reasoning rather than physical action, and this introduces the knowledge structure of evaluation or values. Within this section of text we will see how decisions and values are both talked about and enacted. Thus the knowledge structures of choice and evaluation appear both in the topic of dialogue and in the action of dialogue. We will then examine how this practical decision-making is related to the theory of physical properties. At the middle level, we will note how the problem-solving exercise poses the general practical question: “How do you separate one substance from another?” and how variants of this question direct student work towards deciding upon answers. We will also see how Mr. Peterson makes links between the general practical question and the general theory question about physical properties. At the micro-level, we will see how lexical cohesion in answers to the practical question plays a role in linking back to the theory texts. We offer here the full text of this activity before presenting a detailed analysis of what Mr. Peterson is attempting to do. Three student decisions are bolded:

Mr. Peterson: Now your job is to separate them into four piles. How would you do that? There’s the thinking science nine students’ way and then there’s the extremely tedious well you could get a microscope or a magnifying glass and a pair of tweezers and you pick out all the things—it’d take you forever! Especially if there’s a big pile of them. So. It’s important that you do it in the right order actually I think. You gotta think which one do I do first. Hint? Physical properties. That’s how you do it. Think physical properties. What’s the physical property this stuff has that the others don’t. That’s how you do it. **(1)Stan?**

Stan: Use a magnet to separate the iron?

Mr. Peterson: …Right. There’s one. Iron’s attracted. None of the others are. What’s next? **(2)What would you do next? Yeah?**

Todd: Dissolve the salt in water.

Mr. Peterson: Add water. The salt will dissolve. The sand and the gold won't…

Okay what's next. You've got sand and gold.

Irene: And there's some water too.

Jamie: Add more water.

Keith: Pan for gold.

Mr. Peterson: Think of a physical property that separates the two. Like you can go crystal shape? No not going to help. Solubility? No neither of them dissolve. No viscosity? No that's for liquid. Magnetism? Neither are magnetic. Color? Well that's good if you want to do the tweezers method okay? **…(3) How does panning work? You got this kind of like big dinner plate right?**

Mike: Add water to it. And shake it around and the gold is more dense so it'll sink to the bottom and the sand will—

Mr. Peterson: But the sand would sink too wouldn't it?

Mike: No. It would sink but if you keep spinning it wouldn't.

Decisions appear in two main stages in the above text, and questions are a central element in the analysis of both stages. In the first stage Mr. Peterson talked about how students could decide how to deal with the separation problem, mentioning questions they should ask themselves to guide their decision processes, as in: "You gotta think "Which one do I do first?" In the second stage he moved to getting students to actually make decisions about what to do by asking them questions, such as "What would you do next?"

Our view that questions call for decisions about responses draws on the analysis of speech functions and their responses by Halliday (1994, pp. 68-71), where the respondent decides between alternative choices of responses. Our analysis of the first stage follows in

Table 1. We have selected only those parts of the text that are central to our purposes. We have used italicized labels for the parts of the discourse and a letter and numbering system to show the relationship between the parts. Brackets are used for interpolations and comments.

Table 1: The teacher talks about decisions

A.1.	The teacher talks about decisions
A.1.1.	*STATEMENT of the decision situation or problem.* T: Now your job is to separate them into four piles.
A.1.2	*QUESTION of alternative ways of doing the job.* T: How would you do that?
A.1.2.1.	There's the extremely tedious [way] [N.B. This clause has been reordered.]
A.1.2.2.	There's the thinking science nine students' way
A.1.2.2.1	*QUESTION of order of actions (1,2,3) in the thinking way.* T: You gotta think "Which one do I do first?"
A.1.2.2.2.	*QUESTION of physical properties and uniqueness.* T: Think physical properties: "What's the physical property this stuff has that the others don't?"

This analysis shows how the teacher outlined a structured process of reasoned decision-making based on physical properties and the theory of matter. Mr. Peterson's emphasis on reasoning is consistent with but much more elaborate than the teachers in Leung and Mohan (2004) study who placed considerable importance on reasoned answers rather than guesses. Mr. Peterson modeled the process as a series of questions. After he stated the decision situation, the question "How would you do that?" set up the general decision the student had to make. Mr. Peterson then identified two alternative answers, clearly favoring the *"thinking* science nine students' way," rather than "the extremely tedious well you could get a microscope or a magnifying glass and a pair of tweezers and you pick out all the things—it'd take you forever!" Note the explicit appraisal in 'extremely tedious' and 'forever'. Mr. Peterson is recommending that students address this scientific problem by valued methods of reasoning (ultimately based on the theory of physical properties) rather than brute physical action. We will see later how his words about the value of thinking and reasoning about physical properties are followed by his actions in guiding students to relate their answers to the theory of physical properties.

The thinking way involves two further questions. Each of these is a *wh*-question that clearly points to alternatives and each is embedded under 'think', a verbal process of 'sensing.' 'Think' emphasizes that the resulting student decision should be a reasoned one.

In each of the three student decisions bolded in the text, Mr. Peterson posed a question, and a student made a decision by answering it. In each case the teacher approved the choice the student made. Additionally, in the first two cases, the teacher was careful to model a reason that justified the choice made. In this decision-solving situation, the teacher was not asking the student for rote knowledge but for a reasoned decision. As noted above, our analysis draws on Halliday's view that the respondent decides between alternative choices of responses. It also recognizes Mr. Peterson's explicit concern for student decision-making and reasoning based on what they have learned about physical properties.

How does the teacher apply the taxonomy of physical properties and the effects related to properties that have been discussed previously with these students to this decision-making exercise? Is there an interaction between theory and practice, general ideas and particular cases? Are links being made between the theory of physical properties and the specific case of this exercise? What is the discourse evidence?

Mr. Peterson invoked physical properties of the theory of matter initially when he said: "What's the physical property this stuff has that the others don't"? Later in the text, aiming to coach an actual decision, he made the link to actual properties: "Think of a physical property that separates the two [sand and gold]. Like you can go crystal shape? No, not going to help. Solubility? No, neither of them dissolve. No viscosity? No that's for liquid. Magnetism? Neither are magnetic. Color?" He again modeled this more detailed decision-making process as a series of questions and answers about physical properties, and gave a sense of the alternatives that are rejected. Both of these quotations come before actual decisions, and are "top-down," from general theory to a particular case, so to speak.

Mr. Peterson responded to student decisions about a specific case in a "bottom-up" way by offering a reason that contrasted how one substance behaves by comparison with another. He thus implied that the student decision used a physical property that "this stuff has that the others don't." In other words, Mr. Peterson highlighted that the choice can be justified with a reason that links back to physical properties.

Table 2: Mr. Peterson. Semantic/lexicogrammatic recasts of student answers ("What's the physical property this stuff has that the others don't?")

Speaker	Substance	Has physical property	Effect of property	Other substances	Effect of lack of property
Stan	The **iron**		[use a magnet to separate **the iron**]		
Mr. P.	**Iron**		**Iron**'s **attracted**	Other's (salt, gold, sand)	None are (**attracted**)
Todd	The salt		[**Dissolve** the salt in water]		
Mr. P.	The salt		The salt will **dissolve**	The sand and gold	Won't (**dissolve**)
Mike (uptake)	The **gold**	The **gold** **is** more **dense**	So it'll **sink** to the bottom (of water).	And the sand	Wouldn't (**sink**)

It is revealing to look at the detail of how Mr. Peterson responds to student answers to appreciate the fine linguistic quality of his work with students. Table 2 shows how Mr. Peterson *functionally* recasts the first two student answers from a form that answers the practical question ("How do you separate these substances") to a form that answers the theory question ("What's the physical property this stuff has that the others don't?"). The columns in the table indicate how his recasts are answers that match the theory question. In these functional recasts, he makes semantic and lexicogrammatical changes consistent with the SFL view of language as a resource for meaning and grammar as meaning-based, but he does not make changes which correct grammatical errors in form, which is the function of formal recasts (see Mohan & Beckett, 2003). In more detail, Mr. Peterson changes answers from "do this" to "this is the case" as in "dissolve the salt" becomes "the salt will dissolve." He also matches the negative element in his question about the physical property "this stuff has *that the others don't"* by adding a negative contrast to answers, as in adding "The sand and gold won't (dissolve)." Finally he changes a word to a key lexical item: "*separate* the iron" becomes "iron's **attracted**." Note the splendid example of learner uptake in the third answer where Mike notices Mr. Peterson's recasting of other student answers and independently produces his own answer in the theory form. He even improves on Mr. Peterson's recasts by adding an explicit reference to the relevant physical property: "the gold is more dense."

The recast answers and Mike's uptake are each contrastive causal statements of the effects of the relevant physical property. How are these statements lexically related to their physical properties? The three general physical properties that were introduced in the theory lessons are 'magnetic attraction', 'solubility', and 'density', all of which are nominalizations. Each statement has a lexical item that is lexically cohesive as a more congruent form of its nominalization: "Iron's *attracted* [to the *magnet*]" is lexically cohesive with 'magnetism'; "The salt will *dissolve*" is lexically cohesive with 'solubility';

and “gold being so much more *dense”* is lexically cohesive with ‘density’. In other words, these lexical items are related through grammatical metaphor (Halliday 1998). To the best of our knowledge, this is a different kind of lexical relation than the two main kinds of lexical relation, taxonomic and expectancy, presently recognized in lexical cohesion (Eggins, 1994, p. 101).

To sum up, decisions are central to the discourse constructing this exercise. Decisions are both discussed and made. Mr. Peterson appeared to be very careful to discuss how students might make decisions about the exercise and draw upon prior classroom discussion of properties. Through a close examination of the discourse, we can see that he took pains to encourage students to link the abstract and general taxonomy of physical properties he had initially worked to build up—and the effects of those properties—to the specific, practical actions they were proposing to take, thereby linking theory to practice.

6. Conclusions

Our study of how theory and practice are constructed linguistically in the science classroom indicates how SFL provides theory and analysis to enable research assessment of science discourse to go beyond language form to include content (i.e., meaning), language–content integration (i.e., relating meaning to wording), texts in the context of social practice, and intertextuality in education. Unlike the studies we reviewed, we examined the teaching/learning paths that can occur as a science teacher constructs the target theory and the classroom practices surrounding that theory.

We have analyzed how theory is coherently related to practice at three levels. At the highest level, theory is related to practice by coherently linking KSs of theory to KSs of practice. In this way the whole teaching unit forms a coherent framework of KSs. The initial lessons construct theory (which is generic) while the later problem-solving activity engages the students in practice (which is specific). In terms of knowledge structures, the lessons construct a *taxonomy* of physical properties which are testable through their *cause-effect relations.* The problem-solving activity requires *choice or decision-making* about a specific case by the students, and illustrates classroom-based formative teacher assessment. Mr. Peterson guides students to connect the specific case to the generic theory. We have briefly indicated how some of these knowledge structures are realized in text. Much more can be said using SFL analysis.

At the middle level, theory is related to practice through question-answer relations by coherently linking the general theory question to the general practical question. Theory: the general theory question is answered, in effect, by the whole taxonomy of physical properties. In the lessons, various forms of this question guide question-answer dialogues. Practice: the general practical question sets up the problem solving exercise and students work towards an answer. Mr. Peterson connects this answer to an answer to the theory question when he advises students on how to answer this question and when he recasts student answers.

At the micro-level, theory is related to practice through lexical cohesion when lexical items in the practical exercise answers link back to lexical items developed in the theory lessons and are lexically coherent with them. Mr. Peterson uses lessons to build up knowledge of scientific lexical items in the lessons, and guides students' use of lexical items in the problem-solving activity answers.

Implications for the observation of teachers' work call for a greater understanding of the development of the science register in science classes. Mr. Peterson was creative, artistic, systematic, and thoughtful in his work with students to construct theory-practice relations in science. Our central analysis question was: How did he use language as a resource for meaning to construct theory and relate it to practice? Mr. Peterson worked consciously at the word level on the morphology of scientific terms, but as we have shown, his theory-practice work over a period of weeks dealt with extended linguistic and semiotic relations, which he was not necessarily conscious of. There is thus a vital role for language specialists to recognize, valorize, and discuss these linguistic and semiotic aspects of the theory-practice work of science teachers like Mr. Peterson. This can take many forms. For instance, where science teachers and ESL teachers are working closely together, it can become part of a researcher's observation of a science teacher in the classroom. We recommend that the observer enact Eisner's critical connoisseurship of the art of education (Smith, 2005) so that that the observer would recognize and discuss theory–practice aspects of science discourse with the science specialist constructively in order to build shared awareness of them, and shared cooperation about them, in a community of practice. It is time to move beyond a negative and reductive examination of language errors alone.

Implications for the assessment of students start with the student problem-solving work with science theory and practice that we have analyzed. Problem-solving work is central to classroom-based formative teacher assessment of student performance (Leung & Mohan, 2004), assessment that is capable of promoting learning. For science, our central question was: How did the students use language as a resource for meaning to decide upon an answer and justify it in terms of theory and the scientific questions that inform theory?

A first step could be that the researcher observes student group work around problems in the science classroom, analyzing how language is used in theory-practice discussion. Further possibilities include examining ways of enhancing the theory-practice quality of student problem-solving work in cooperative learning or peer teaching in ESL science classrooms.

References

Arkoudis, S. (2003). Teaching English as a second language in science classes: Incommensurate epistemologies? *Language and Education, 17* (3), 161-173.

Cloran, C. (2000). Socio-semantic variation: Different wordings, different meanings. In Unsworth, L. (Ed.), *Researching language in schools and communities: Functional linguistic perspectives* (pp. 152-183). London, UK: Cassell.

Derewianka, B. (2001). Pedagogical grammars: Their role in English language teaching. In A. Burns & C. Coffin (Eds.), *Analysing English in a global context: A reader* (pp. 240-269). London, UK: Routledge.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science.* Buckingham, UK: Open University Press.

Ebenezer, J.V., & Erickson, G.L. (1996). Chemistry students' conceptions of solubility: A phenomenography. *Science Education, 80* (2), 181-201.

Eggins, S. (1994). An introduction to systemic functional linguistics. London: Pinter.

Grabe, W., & Stoller, F.L. (1997). Content-based instruction: Research foundations. In M.A. Snow and D.M. Brinton (Eds.), *The content-based classroom: Perspectives* *on integrating language and content* (pp. 5-21). White Plains, NY: Addison Wesley Longman Publishing Company.

Halliday, M.A.K. (1994). *An introduction to functional grammar* (2nd Ed.). London, UK: Edward Arnold.

Halliday, M.A.K. (1998). Things and relations: Regrammaticising experience as technical knowledge. In J.R. Martin & R. Veel (Eds.), *Reading science: Critical and functional perspectives on discourses of science* (pp. 185-235). New York, NY: Routledge.

Halliday, M.A.K., & Hasan, R. (1985). Language, context, and text. Victoria, Australia: Deakon University.

Halliday, M.A.K., & Martin, J.R. (1993). *Writing science: Literacy and discursive power.* Pittsburgh, PA: The University of Pittsburgh Press.

Halliday, M.A.K., & Matthiessen C.M.I.M. (1999). *Construing experience through meaning.* London, UK: Cassell

Huang, J. (2004). Socialising ESL students into the discourse of school science through academic writing. *Language and Education, 18* (2), 97-123.

Huang, J., & Morgan, G. (2003). A functional approach to evaluating content knowledge and language development in ESL students' science classification texts. *International Journal of Applied Linguistics, 13* (2), 234-262.

Leach, J., & Scott, P. (2000). Children's thinking, learning, teaching, and constructivism. In M. Monk & J. Osborne (Eds.), *Good practice in science teaching: What research has to say* (pp. 41-56). Buckingham: Open University Press.

Leung, C., & Mohan, B. (2004). Teacher formative assessment and talk in classroom contexts: Assessment as discourse and assessment of discourse. *Language Testing, 21* (3), 335-359.

Long, M.H., & Robinson, P. (1998). Focus on form: Theory, research, and practice. In C. Doughty & J. Williams (Eds.), *Focus on form in classroom second language acquisition* (pp. 15-41). Cambridge, UK: Cambridge University Press.

Mohan, B.A. (1986). *Language and content.* Reading, MA: Addison-Wesley Publishing Company.

Mohan, B.A. (2001). The second language as a medium of learning. In B. Mohan, C. Leung, & C. Davison (Eds.), *English as a second language in the mainstream* (pp. 107-126). London, UK: Pearson Education Limited.

Mohan, B., & Beckett, G.H. (2003). A functional approach to research on content-based language learning: Recasts in causal explanations. *Modern Language Journal, 87* (iii), 421-432.

Mohan, B., & Slater, T. (in press). A functional perspective on the critical 'theory/practice' relation in teaching language and science. *Linguistics and Education.*

Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education, 21* (5), 553-576.

Nieswandt, M. (2001). Problems and possibilities for learning in an introductory chemistry course from a conceptual change perspective. *Science Education, 85* (2), 158-179.

Novak, J.D., & Gowin, D.B. (1984). *Learning how to learn.* New York: Cambridge University press.

O'Toole, M. (1996). Science, schools, children and books: Exploring the classroom interface between science and language. *Studies in Science Education, 28,* 113-43.

Pica, T. (2002). Subject-matter content: How does it assist the interactional and linguistic needs of classroom language learners? *The Modern Language Journal, 86* (1), 1-19.

Smith, M. K. (2005). Elliot W. Eisner, connoisseurship, criticism and the art of education, *The encyclopaedia of informal education*, retrieved July 1, 2006, from www.infed.org/thinkers/eisner.htm

Spradley, J.P. (1980). *Participant observation.* New York, NY: Holt, Rinehard and Winston.