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A functional perspective on the critical 'theory/practice' relation in teaching language and science

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Abstract

This article uses a functional view of language to frame and analyze issues of language and content in mainstream classrooms. Describing a Western Canadian grade one/two science class, it examines how a teacher and her class of young ESL students were able to build up a simple theory of magnetism in a scientific register, link its technical terms to their practical experience, and apply the theory to explain and extend their experience of magnets. She thus created a new blend of theory and practice in their activity of doing science. The study demonstrates the value of a functional perspective on social practice, leading to a sharper understanding of issues of language and content learning in mainstream classrooms and a greater ability to analyze relevant data. Educational implications include a richer understanding of the connections between students' practical experience and their theoretical understanding.

Introduction

In this paper, we examine a grade one/two (6/7 year old) science class in which hands-on experiments are used to study magnetism. The students who make up this class are mostly ESL students in a school heavily populated by students who do not speak English as a first language. This situation necessitates a sensitivity to issues of language and content development in the mainstream on the part of the teachers. Since, however, views of the nature of language and content development vary so widely, one important task in this paper will be to discuss some of the differences between these views. This discussion helps to locate the functional viewpoint that we have adopted.

Once we have reviewed some of the relevant research literature to provide a context for our work, we will set the scene for our analysis of the classroom data, and then look at that classroom data in detail.

Framing the study

Because specialist vocabulary tends to be the most noticeable feature of scientific English (O'Toole, 1996), language development in science classes has tended to focus primarily on the teaching of technical terms. It has become more recognized, however, that learning to talk science "runs rather deeper than 'simply' learning to articulate the words and phrases of a new speech genre" (Scott, 1998, p. 74). Research into the *literacy* aspect of science literacy has been expanded, illuminating the depth of connection between language and science learning. We review five studies that help frame the current research. (For a broader review of the last 25 years of language arts and science research, see Yore, Bisanz, & Hand, 2003.)

Lemke (1990) examined the discursive practices of science classrooms. Using transcripts of oral interactions and descriptions of the context in which these interactions occurred, he revealed various activity structure patterns—patterns of dialogue that regularly occur in classrooms, such as triadic dialogue or bids to question—focusing on the thematic patterns which comprise science discourse. He argued that these thematic patterns are constructed from semantic relations, and it is the patterning of these semantic relationships which characterizes science discourse. Lemke states that difficulties in understanding the content frequently stem from differences in the semantic relationships that various individuals in the class hold, rather than from problems with the words themselves. The role of science educators, Lemke argues, is to apprentice students into the use of new thematic patterns, or new ways of meaning. This combination of thematic patterns and language was brought up again more recently by Roth (1998), who noted that concepts can be viewed "as the patterns in the language employed by students to describe and explain their science-related experiences, and conceptual change is the change in these descriptions and explanations" (p. 1020).

We have found Lemke's work to be particularly valuable in that it highlights how science teachers apprentice students into ways of meaning built from the semantic relations that characterize science discourse. It is, therefore, important that investigations of discourse in science classrooms examine the teaching and learning of those meanings that identify scientific registers. Lemke's emphasis on the meanings that belong to the language of science is consistent with Halliday's concept of register (see, for example, Halliday and Hasan, 1985). Halliday identifies the mathematics register, for example, in terms of meanings:

> We can refer to a 'mathematics register', in the sense of the meanings that belong to the language of mathematics… and that language must express if it is used for mathematical purposes… we should not think of a mathematical register as consisting solely of terminology, or of the development of a register as simply a process of adding new words. (Halliday, 1975, p. 65)

Although Ogborn, Kress, Martins, and McGillicuddy (1996) did not specifically examine how language and knowledge has been taught in the classroom, their work is also important here because of their development of a useful theoretical framework for examining explanations in science classes. These authors considered the construction of explanations to be synonymous with the construction of scientific knowledge. Their framework contains three main propositions: Explanations in science are analogous to stories with protagonists and actions (no matter how abstract and unfamiliar the entities might be); meaning-making in explanations consists of creating differences, constructing entities, transforming knowledge, and putting meaning into matter; and there are variations and styles of explanations to choose from. Ogborn et al. highlight the importance of describing, labeling, and defining by saying that these processes are necessary to build the entities that can then be used to construct explanations.

The work by Ogborn et al. ties in closely with Halliday's (1998) suggestion that learning science involves two types of patterning: constructing new taxonomies of concepts through description and definition; and constructing logical sequences of reasoning. We can therefore infer that scientific meanings will include the semantics of taxonomies and logical sequences. Yet Ogborn et al. did not illustrate in detail how explanations are related to experiments or actual cases.

Haneda (2000) examined meaning-making in an experiment by exploring the interactions between a teacher and two grade three (8 year old) Chinese-Canadian students as they conducted and discussed an experiment on refraction. The author was particularly interested in how the students participated in the interactions, and in the connections between the talk and the students' subsequent writing task. Haneda noticed differences between the two students with regards to their involvement with the topic in both the interaction and writing tasks. The girl—Jasmin—used different types of talk, from a recount to an explanation attempt, as the interactions progressed. The author further noted that talk that was concerned with procedure saw the children taking the lead, but when the task shifted to explanation, the teacher scaffolded the students' understanding and Jasmin began to reason logically about the topic. Alex, the boy in the study, remained at the level of doing and observing, with the author inferring that the interactions were beyond his "zone of proximal development" (Vygotsky, 1978). Haneda concluded that although it was evident that interactions between teachers and students can help students learn, more research should be undertaken, particularly into how these interactions can promote deeper thinking.

Haneda's research strongly suggests that the moves from recounting scientific experiments to giving scientific explanations is a challenging one which needs to be more closely examined. Recounting science procedures, Haneda claimed, seemed to be a relatively simple task for the students. When recounting an experiment, the students are talking about their own experiences (or practice) of the experiment. In trying to create explanations, however, the students are constructing theory, which is more abstract. In this paper, we respond to Haneda's call for more exploration into the teaching of science by examining, from a linguistic perspective, the relationship between experience and theory in the teaching and learning of science.

Gibbons (1998, 2003) studied young ESL students in a mainstream classroom in Australia as they learned about magnetism using both experiments and discussion. She drew upon the constructs of *mediation* from sociocultural theory and *mode continuum* (from spoken "language as action" to written "language as reflection") from systemic functional linguistics (SFL) to investigate how teacher–student talk in a content-based science classroom contributed to learner's language development. Gibbons identified three “stages” which were repeated cyclically during the unit on magnetism that she investigated: a first stage, in which students were engaged in hands-on experiments; a second stage of “teacher-guided reporting,” during which the teacher helped the students reconstruct their personal experiences; and the third stage in which students completed related writing tasks in their journals. Following up on Gibbon’s work and applying it to a younger range of students, Gardner (2004) found teacher-guided reporting (TGR) in Infant Science and Literacy contexts in England.

In both her articles, Gibbons focused on the second stage, describing how teachers helped students as they attempted to report to their classmates on what they experienced in the magnet experiments. They mediated between students’ current linguistic levels in English and their commonsense understandings of science on the one hand, and the educational discourse and specialist understandings of the subject on the other. For example, Gibbons discussed how the teacher recast students’ statements that magnets “stick” into statements that magnets “attract.” Through this process of teacher-guided reporting, students’ contributions to the discourse were progressively transformed across a mode continuum from talk accompanying action into the more context-independent, specialist discourse of the school curriculum.

In sum, addressing the problem of moving beyond talk accompanying action described by Haneda, Gibbons gives a particularly insightful and valuable account of teacher scaffolding in terms of the mode continuum. However, unlike Lemke and Ogborn et al., she does not talk in terms of the semantic relations of the register of science discourse, and so she does not show in her analysis the teaching and learning of relevant semantic relations such as taxonomies and their relation to experience.

Our model of the theory and practice of a social practice frames the teaching and learning process in a very different though complementary way. We investigate how teacher and learner *relate* theory and practice, how they relate the taxonomies of magnetism to the experiments they do. Rather than asking how teacher and students move from a more practical type of discourse to a more theoretical type of discourse, we ask how teacher and learners *connect* practical discourse and theoretical discourse together in a back-and-forth, theory–practice dynamic where the meanings of the theory and practice are reshaped dialectically. Beyond recasting “stick” as “attract,” how does the teacher build up the meaning of a technical term like “attract” and relate it to the students’ experience? For our model, it is not enough to have a *taxonomy of text types*; we need to consider the *ecology of semantic relationships* within the field of magnetism. In discourse terms, how does the teacher work to help learners connect their theories with their experiments in a theory–practice dynamic? For example, how does a teacher discuss magnet experiments with a child who believes that magnets attract all metals, not just ferrous metals?

Like Gibbons, we will concentrate on classroom interaction when the students are not working hands-on, but are away from the materials with the teacher guiding the discussion. As we show, the teacher not only asked the students to report on what happened, but also asked them why it happened, and worked to help them make sense of what they saw. She worked to help the students connect concrete experience with general principles of magnetism by moving between specific reflection and general reflection. Somehow, the teacher was guiding a complex iterative process where students could develop the meanings of principles and their interpretations of experience in tandem.

When examining our data, then, we need to consider the following questions: (1) How does the teacher help ESL students develop a simple theoretical model of magnetism and the meanings of the science register appropriate for this model? (2) How does the teacher help the students link this model to practical experience? For example, how does the teacher link the meanings of individual technical terms to actual cases, bringing together discourse and students' experience in experiments? (3) How does the teacher help students apply this model of magnetism to their experiences to arrive at new ways of thinking about these experiences? The issue underlying these questions is well known in science education research, where it has been described in terms of the coordination of theory and evidence (Driver, Leach, Millar, & Scott, 1996, p. 49) and where it is recognized that children may have their own "theories" which are an important element in the learning process: "Children have ways of construing events and phenomena which … may differ substantially from the scientific view" (Driver, Squires, Rushworth, and Wood-Robinson, 1994, p. 2). In the experiments, the children concretely experience magnetic attraction as an invisible force which involves "action at a distance" (see Driver et al., 1994, p. 127) rather than direct physical contact, and they are therefore challenged to think in a new way about magnetism and indeed about causal relations.

Theoretical framework

What is content? A traditional view of language does not offer a way to theorize content or meaning in text or to engage with the relations of language and content. A *traditional* view of language, as Derewianka (2001) described, is concerned with the form and structure of language. It operates at the level of the sentence and below and does not recognize context as significant. It sees language as a set of rules that allow us to make judgments of correctness, and it sees language learning as the acquisition of correct forms. Consistent with this view, a focus-on-form perspective would look at a content classroom and ask whether the students are engaged in tasks and topics that highlight certain features of the grammar which may be considered problematic for students (Long & Robinson, 1998) and offer opportunities for students to practice these difficult constructions. Similarly, Pica (2002) proposed that content-based language teaching should include more opportunities to focus on intervention strategies which would assist in the noticing and correction of grammatical errors.

Derewianka noted that, in contrast to the traditional view of language, a *functional* view is based on the functions that language serves within our lives. It emphasizes the text or discourse as a whole in relation to its context, and recognizes that lexis and grammar vary with text and context. It sees language as a resource for making meaning and provides tools to investigate and critique how language is involved in the construction of meaning. It sees learning language as extending one's potential to make meaning in a broadening range of contexts, including academic discourse in schooling. Consistent with this view, we will examine how a teacher helps young ESL learners to understand and talk about a simple theory or model of magnetism in an appropriate scientific register and to apply the theory to reinterpret their practical contexts of experience. In particular, we use a functional perspective to examine the role of scientific theory and practice in teaching and learning language and science.

A functional view of language offers a way to characterize content and language. Broadly speaking, content is the meaning of a discourse and language is the wording of a discourse. Consider the following text, an ESL child's explanation of magnetism: "North and north doesn't go together because it's the same. If north and south go together, because it's not the same, they will attract" (Slater, 2004, p. 169). Reading this explanation for content, a science teacher might see this as a causal explanation of magnetism. Reading it for language, a language teacher might note the "if" and "because," and the technical terms "north," "south," "attract." Bringing the two together, a functional view of language could say that the meaning of this discourse is a causal explanation of a science topic, and this meaning is expressed in the wording (e.g., causality is expressed by "if" and "because," and technical terms of magnetism are used). If we look beyond the text or discourse to a larger unit of meaning, the social practice of doing science, the relation between content and language can again be seen as a link between meaning and wording.

In our research, we draw on the ideas of systemic functional linguistics (SFL). In SFL, the immediate context of a text is described in terms of three main variables that influence the way language is used: *field* is concerned with the activity being pursued, or the subject matter the activity is concerned with; *tenor* is concerned with the social roles and relationships between the people involved; and *mode* is the medium and role of language in the situation. These three variables are related to three main areas of meaning in language: *ideational* meaning, the resources for representing our experience of the world; *interpersonal* meaning, the resources for enabling interaction; and *textual* meaning, the resources for constructing coherent and connected texts. As Halliday (1994) pointed out, it is ideational meaning in text that is closest to the everyday sense of content. In our data analysis, we will focus mainly on field and ideational meaning. It must be kept in mind, however, that all three areas of meaning are present in a text.

Our analysis will explore young learners engaging with the register of science at a very basic level. Researchers and educators working from an SFL perspective have provided work on the language of science that has offered an excellent starting point for examining the linguistic aspects of science instruction. Halliday's (1998) statement about science learning involving two types of patterning, described briefly in the last section, is particularly important. By focusing on how these two patterns evolve in the discourse of the teacher and learners over the whole unit on magnetism, we can see how science discourse and knowledge develop through the oral interactions and activities that occur in the classroom.

Our analysis examines how these young students learn the technical terms of the science topic they are studying. Martin and Rose (2003) stated that everyday and technical terms differ in that everyday terms can be learned ostensively:

> …by pointing to them and using them. By contrast, the meanings of technical terms in professional occupations, such as economics, linguistics or biology (e.g. inflation, malfunction, gene), refer not to concrete objects, but to abstract concepts, and can only be learned through a long series of explanations in secondary and tertiary education. Although technical entities like genes, atoms or galaxies can potentially be pointed to and named through instruments, the only way to fully understand them is by getting fully involved in scientific explanations, typically in writing. (p. 107)

In a similar vein, Martin (1992), writing with respect to the humanities, social science, and science disciplines, stated that:

> most of the specialized lexis associated with these literacy dependent fields cannot be ostensively defined. It has to be learned through language, via Token Value structures defining technical terms, and these definitions are stored in writing (in textbooks). (p. 543)

It follows that learning technical terms is central to success in much of academic discourse and schooling. If so, there are questions about how easy it is for young ESL learners with rudimentary literacy skills to learn technical terms in their second language.

Given this understanding of the problem, it is ironic that over the years, the use of hands-on discovery learning in science has been heralded by educators and researchers in the field of English language teaching and learning as an excellent way to provide a context in which language and content development can occur (e.g., Cantoni-Harvey, 1987; Chamot & O'Malley, 1992; O'Malley & Chamot, 1990; Rupp, 1992). O'Malley and Chamot, for example, argued that, by "providing additional contextual support in the form of demonstrations, visuals, and hands-on experiences" (1990, p. 194), subject matter is made more comprehensible for English language learners. Along a similar line, Echevarria, Vogt, and Short (2000, 2004) advocated the use of hands-on experimentation.

The use of hands-on discovery learning in science can be problematic even for students who are native speakers of English. Experiments typically offer carefully designed experiences to children, but how does the teacher capitalize on the possibilities of the experiments? What guidance does the teacher give to involve learners in scientific explanations? The science educator Rosalind Driver stated that "theoretical models…will not be 'discovered' by children through their practical work…guidance is needed to help children assimilate their practical experiences into what is possibly a new way of thinking about them" (1994, p. 49).

In our study, we use *social practice* (also known as "activity") as our unit of analysis. A social practice is a unit of culture which involves cultural knowledge and cultural action (Spradley, 1980) in a theory–practice, reflection–action relation. Some educational theorists regard education as the initiation of learners into activities (or modes of thought and conduct) that are worthwhile (Peters, 1966 p. 55), and so, in this view, all educational content areas can be regarded as social practices. Examples of social practices include academic disciplines, occupations, games, sports, arts, and music. Social practices can also contain sub-practices; for example, learning science can include learning magnetism. Knowledge structures (KSs) are semantic patterns of the discourse, knowledge, actions, artifacts, and environment of a social practice (Spradley, 1980, p. 93). In our heuristic model, core KSs of typical social practices include at a general level, classification, principles, and values, and at a specific level, description, sequence, and choice. Taken together they form a *knowledge framework* or gestalt for the activity or social practice (See Mohan, 1986; 2001). We will use “classification” as a broad non-technical term and “taxonomy” as a corresponding technical term.

In the teaching unit on magnetism that we examined, the teacher knows the theory of magnetism (knowledge) and guides the students to do experiments (action). The teacher interprets the experiments using the theory of magnetism. Many students initially interpret the experiments in commonsense terms and only later become aware of the scientific theory. In successful cases, the students build a semiotic whole, which includes both a knowledge of theory and a reinterpretation of their practical experience. From our data, it appears that teacher and students build this semiotic whole in a back-and-forth, theory–practice dynamic over a period of weeks.

From a systemic functional discourse point of view, an activity or social practice is a semiotic unit of “field” (see Martin, 1992, p. 292). In our view, it is a unit that combines discourse of reflection and discourse 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; Hasan, 1999; Martin 1999). In the teaching unit on magnetism, for example, the teacher discusses the theory of magnetism with the learners (discourse of reflection), and the learners talk themselves through the experiments (discourse of action). Discourse of reflection can be divided further into specific reflection (e.g., where teacher and students talk about what happened in a specific experiment) and general reflection (e.g., where teacher and students talk in general terms about the theory of magnetism). All the data discussed in this paper are reflection discourse, so our analysis examines specific and general reflection only. This discourse contrast, which can be tracked by the contrast of specific versus generalized entities and single-occasion versus habitual events (Cloran, 2000, pp. 170-1) is helpful for illuminating theory–practice relationships in the data.

In our approach, theory–practice and reflection–action relations are modelled as links between general knowledge structures and specific knowledge structures. Classifications are related to descriptions of specific things, principles are related to sequences of happenings, and values are related to choices. In the experiments, learners are expected to relate specific magnets to classifications/taxonomies of magnets, to explain sequences of magnetic attraction and repulsion in terms of cause-effect principles, and to appreciate the values that guide the interpretation of evidence.

These three main theory–practice relations are constructed using Halliday's three main types of processes[1] of transitivity. Descriptions and classifications are constructed using processes of being (the world of abstract relations), sequences and principles are

1. "Processes is an SFL term that corresponds roughly to what are conventionally called verbs.

constructed using processes of doing (the physical world) and choice and values are constructed using processes of sensing (the world of consciousness). We will highlight relevant processes in our data as a basic way of tracing the construction of these meanings.

The current study

The current study is part of a larger research project that examined the development of causal explanations in primary and high school science classes (see Slater, 2004). In this article, we focus on Mrs. Montgomery's grade one/two (6-7 year old) class that was learning about magnetism using ten hands-on experiments. Mrs. Montgomery, in her twenty-second year of teaching, taught this class in an inner-city school in a large Western Canadian city. Only three of the twenty-one students in this class were native speakers of English; most of the others came from Asian or East Asian countries, and one came from Russia. There were twelve boys (five in grade one and seven in grade two) and nine girls (five in grade one and four in grade two). The class met twice a week for these science lessons in the school's lunchroom, where identical stations were set up for groups of two or three students to carry out their magnet experiments in front of audiotape recorders. At one end of the lunchroom, chart paper was taped to the wall for Mrs. Montgomery to use when needed, and at the beginning and end of each class, she gathered the students in front of this paper to give them instructions and to ask what they had discovered from their experiments. All interactions between the teacher and students and among students in their experiment groups were audio-recorded and subsequently transcribed; field notes taken by the researcher during and immediately after each experiment supplemented the transcriptions. All written work by the students was collected, and interviews with a selection of students were carried out at the end of the unit to reveal what these students had learned about magnets.

In our interaction data, we highlight only those processes central to constructing and applying the model of magnetism. Processes of being are in **bold**, processes of doing are in *italics*, and processes of sensing (including saying) are <u>underlined</u>. We also enclose examples of general reflection within square brackets, introduced by the label GEN. Since all of our data under discussion are examples of reflection discourse, unmarked data are to be understood as specific reflection.

Constructing the model: attract, north and south poles, repel

In this section we will concentrate on the learning of four central terms: "attract," "north pole," "south pole," and "repel." Mrs. Montgomery began constructing a path which would link experience to science knowledge by telling the students on the first day of the magnet unit that they were going to use a wand[2] magnet to "<u>figure out</u> which things the magnet… will *attract*." She then elicited a definition of "attract" from the students:

Teacher:	Do we <u>know</u> what that word attract **means**?
Students:	No.
Teacher:	[GEN What does that word attract **mean**?
Angela:	I <u>think</u> um… if the thing **is made** out of metal and you can… the there'**s** a force that will *pull* it so it *stays*.
Teacher:	Good. It *stays* there. Angela said an energy force… will *pull* it.]
Student:	And you can *stick* it on the refrigerator and it will *stay* because it'**s** cold.

2. A wand magnet is a long flat magnet with its poles on its broad top and borrom surfaces, whereas a bar magnet has its poles on its ends.

Teacher: You think these magnets can *stick* on our refrigerator because it **is** cold?… Well we’re going to discover that. We’re going to discover if it**’s** because it’**s** cold or if it’**s** something else.
Student: But we don’t **have** a refrigerator.
Teacher: Not here we don’t. But we’ve **got** the magnet wand and this **is** all our experiment. So we’re going to *put* our wand next to each one of these things.

It can be seen that Angela already had a beginning definition of “attract” while the student who thought a magnet sticks because of the cold would have to learn the difference between “attract” and “stick.”

Mrs. Montgomery then introduced the items that the students would test in the first experiment, eliciting the labels for each item and printing those labels, with hand-drawn representations of them, on chart paper on the wall. Once all the items were labeled, Mrs. Montgomery told the students what they were going to do with them, using both the target term “attract” and the everyday term, “pull toward,” which Angela had introduced:

Teacher: This is your job… You want to find all the things that are *attracted* to the magnet.
Students: Oh.
Teacher: All the items that are *pulled* towards the magnet. So there’**s**
Student: Energy?
Teacher: There’**s** an energy. That’s right. Some things *won’t* and some of the things *will.*

By choosing to repeat the sentence but with a translation of the technical term into everyday words, and by choosing the everyday “pull towards” rather than “stay” or “stick,” which had also been mentioned earlier, Mrs. Montgomery was able to introduce the idea that the concept of “attract” goes beyond two items being in a state of togetherness, that it more closely involves a process of coming together.

After using “are pulled towards” to gloss the meaning of “are attracted to,” the teacher shifted back to a consistent use of the technical term as she directed the students to sort out the items according to which were and were not attracted. She also told them to think about why:

> Teacher: I want you <u>thinking</u> about what things are *attracted* to the magnets… and why. What **is** similar about all these things?

This experiment allowed the students to experience the phenomenon of attraction and non-attraction as well as required them to classify items based on their experiences. It also implied a contrast between the magnet attracting and the magnet sticking. Some of the items challenged the students' everyday taxonomies, causing them to question what they considered to be metal, and whether all metals are attracted to magnets:

> Abby: Hey it *doesn't.*
> Teacher: It *doesn't*. Why *doesn't* the key… what do you <u>think</u> Janie?
> Janie: It *doesn't*. That key'**s** small.
> Teacher: It's because it'**s** too small? Why do you <u>think</u> Abby? Why do you <u>think</u> it doesn't… why do you <u>think</u> it isn't *attracted*?
> Abby: Mm… it doesn't *attract.* I don't <u>know</u>. Maybe it'**s** not metal.
> Teacher: Maybe it'**s** not metal.
> Abby: It doesn't *stick.*
> Teacher: **Is** that not metal?
> Abby: No… maybe? I <u>think</u>? Yeah. I just <u>think</u> that not metal. It **looks** like metal.

The experience of doing the experiment forced students to question their judgment of what metal is, as Abby is does in the excerpt above. Furthermore, it also helped build up the concept of "attract," a process which students began to realize only occurs with certain types of metal for reasons that they were unsure of, as the above excerpt shows. By the end of this experiment, however, the teacher had led them to the consensus that *some* metals were attracted to the magnet, but not all.

There is an important background issue to note about choice or decision-making in experiments as a dynamic link between theory and practice. When the learners are engaged in the process of experimenting by testing the materials with the magnet, they have to decide how to interpret the results of the experiment and whether to revise their theoretical hypotheses. In the example above, Abby has gone through a decision-making process ("No…maybe? I think? Yeah. I just think that not metal") which eliminates the evidence which would challenge her hypothesis that the magnet attracts all metals. Experiments and similar forms of research are standardly regarded as decision-making procedures that link hypotheses to data, theory to practice: "Having stated a specific hypothesis which seems important to a certain theory, we collect data which should enable us to make a decision concerning the hypothesis. Our decision may lead us to retain, revise, or reject the hypothesis and the theory that was its source" (Siegel & Castellan, 1988, p. 6). Looked at in broader perspective, the learners are being apprenticed into an approach which values knowledge based on experiment as well as on authority or conjecture.

Over the next few experiments, Mrs. Montgomery continued to reinforce the meaning of "attract" by having the students do various experiments to help them discover, for example, which parts of the magnet (middle, ends) were responsible for attraction, how attraction was a force that could be transferred from a magnet to other ferrous metals, and how this force could attract ferrous materials through items such as glass, paper, wood, and even children's hands. These experiments and the discourse around them helped move students towards an understanding of "attract" as a technical term that contrasted with "stick," the commonsense understanding that they had brought to the unit. Through reflection discourse, the teacher elicited definitions of "attract" and encouraged the use of the term, while pointing out that "stick" was not appropriate.

Through experiments, the teacher helped students discover features of the meaning of magnetic “attraction” which were quite different from a process of “sticking.”

In the second experiment, Mrs. Montgomery introduced the concepts of “north pole” and “south pole.” This was in an experiment which expanded on students’ understandings of “attract” by helping them discover which parts of a bar magnet were responsible for attraction. She brought the students’ attention to the “N” and the “S” printed on the bar magnets:

Teacher:	Now on your bar magnet there **are** two letters.
Student:	S N.
Teacher:	An S… and an N. I wonder what they **stand for.**
Student:	North.

Mrs. Montgomery then made a connection between the “S” and the “N” on the magnets and directions, which she assumed some of the students may have studied earlier:

Teacher:	Have you <u>studied</u> directions at all? North south east west? How many of you have <u>heard</u> of those words north south east west?… (Very few raise their hands.) How many of you <u>know</u>… the word north?… (Few.) Right. How many of you have <u>heard</u> the word south?… (Few.) Okay now I want you to <u>listen</u> to the words. Nnnnnorth. What letter does it **belong** to?
Students:	N.
Teacher:	Could it **be**—
Student:	That’**s** north.
Student:	North and south.
Teacher:	You’re right. That’**s** north.
Student:	And then that’s the other one **is** south.
Teacher:	Oh very good. That’s very good.
Student:	[GEN So magnets **have** a north and a south.]
Teacher:	Right. It **has** an N for north… and S for sss
Students:	South.
Teacher:	Can you say that? North… south.
Students:	North… south.

Again the teacher helped students to understand and contrast “north pole” and “south pole” as technical terms through the experiments and the reflection discourse around them. Through reflection discourse the teacher pointed to the letters "N" and "S" on the magnet and asked what they stood for. She associated north and south with the compass direction meanings. Through experimentation, she had students find out that the north and south poles, rather than the middle, are the areas of the magnet that attract.

By the end of the third experiment, the students had been introduced to two more types of magnets ("horseshoe magnets" and "ring magnets") thereby building a small taxonomy of magnet types. Mrs. Montgomery directed the students' attention to the "N" and the "S" on the bar magnet and the horseshoe magnet and asked about the ring magnet, which did not have these letters, foreshadowing an issue which she had the students explore and reason about later. Building up this taxonomy of magnet types from the students' hands-on experience played a key role in promoting new ways of thinking about differences in the position of the poles.

At the beginning of the ninth experiment, Mrs. Montgomery told the students they were going to learn a new word, "repel." This new word was contrasted with "attract" from the outset:

Teacher:	You're going to *take* your two bar magnets… and you're going to <u>experiment</u> with them because your job is to <u>find out</u>… what two ends *attract*… and I'm going to <u>teach</u> you a new word today.
Students:	A new word.
Teacher:	A new word. You're going to <u>look</u> at attract. (She writes the word on chart paper.)
Students:	Attract.
Teacher:	[GEN That **means** come together]… And the new word today **is** repel.
Student:	Repel?
Teacher:	<u>Watch</u> my diagram for repel. (She starts to draw on the chart paper. See Figure 1.)
Student:	Repel.
Teacher:	And tell me if you <u>know</u> what it **means** by <u>looking</u> at my diagram.

Figure 1: The graphic representation of the two key processes

Attract → ←
Repel ← →

A number of students already had a good understanding of “attract” because they had been working with the concept over the past eight experiments. The drawing related the two processes as opposites, which elicited a few related responses:

Student 1: They’re no… *attracting*.
Student 2: Not *attract*.
Student 3: *Take* it out.
Student 4: Not *attracted*.
Student 5: *Taking* it out.

Mrs. Montgomery acknowledged all these efforts but pushed the idea beyond the negative of “attract” towards the idea that Students 3 and 5 were suggesting. She did this by having the students act out both “attract” and “repel” with their hands. Whereas with “attract” the students responded that they could not pull their hands apart, they showed that when their hands were repelling, they could not force them together. This physical acting out of the two processes aimed to demonstrate that the two processes were opposite, but not simply negatives of each other. The students did this physical acting out at the beginning of both the ninth and tenth experiments to reinforce the idea of “repel” as something different from “not attract.”

Once “repel” had been presented in a visual graphic format, defined linguistically by contrasting it with “attract” (as shown by the students’ responses above), and constructed further through physical action, the students began their experiment in which the force of repulsion could be experienced. They commented excitedly about how one north end would “chase” another north end on the table, and how one end would “push them out.”

The teacher then had the students systematically experiment with north and south poles and attraction and repulsion. They completed their experiment by writing the rule of magnetism in their magnet booklets.

During the experiments, the teachers prompted students to use the new word to talk about what they were experiencing:

Student: It *pushes* it away.
Vic: It *turns* right away.
Teacher: It *does*. It does not *attract*. We learned a new word for that Vic. Can you remember?
Vic: Attract?
Teacher: This *attracts*. (She puts the north pole and south pole together.)
Vic: *Repel*?
Teacher: Yes. You showed us what it **was**.

The hands-on activities combined with Mrs. Montgomery's careful linking of these experiences with technical discourse promoted the construction of the small taxonomy—"attract," "not attract," and "repel"—which the students would need if they were to understand the basics of magnetism. There was evidence that students had successfully built up this taxonomy. When asked, for example, what the difference was between "repel" and "not attract," Barbie replied, "the not attract one if… it doesn't push each other out and the repel one push each other out."

In the case of "repel," then, it was very clear how the teacher helped students understand and contrast "repel" and "attract" as technical terms. Through reflection discourse, she very carefully pointed out the related but distinct meanings of the terms. Through experiment, she engaged the students to work with repulsion and attraction.

Thus, through carefully guided experimentation, Mrs. Montgomery worked to help the students build up a simple model of magnetism which included several taxonomies: (1) "north pole" and "south pole"; (2) "attract," "not attract," and "repel";

and (3) various types of magnets. The model also constructed logical relations involving attraction and repulsion between the poles, which the class referred to as the "rule of magnetism" outlined in Figure 2. As mentioned above, the students' attention had been brought to the ring magnets, which did not have an "N" and an "S" on them. This situation helped Mrs. Montgomery guide the students towards new ways of thinking about their experiences by applying this technical model of magnetism.

Figure 2: The rule of magnetism

North + South ➔ Attract

South + North ➔ Attract

North + North ➔ Repel

South + South ➔ Repel

Applying The Model And New Ways Of Thinking

There were two activities that Mrs. Montgomery involved the students in to help them apply their model of magnetism to explain their experiences. She first showed them a broken bar magnet and had them speculate about which of the broken ends was the north pole and which was the south pole. As mentioned earlier, a whole bar magnet had an "N" and one end and an "S" and the other, so the broken pieces therefore had either an "N" or an "S" on them. The students were asked to manipulate the pieces and, based on the attraction or repulsion of the ends, reason whether the broken ends were north poles or south poles. To make an educated guess about this, the students needed to understand not only the concepts of "attract" and "repel," but also the poles and the rule of magnetism.

The students also needed this understanding for the final experiment. They were first to put one ring magnet on a pencil, then put a second ring magnet on top of the pencil to see what happens, and finally turn the second ring magnet over and once again place it on top of the first ring magnet. When they did this, they experienced one situation in which the second ring magnet appeared to float over the first, an event that led to great excitement. Mrs. Montgomery then used questions to guide the students to reason about what they saw, using the model which she had carefully built up with them over the past nine experiments. They responded finally to the question she had posed much earlier about whether the ring magnets, which did not have an "N" or an "S" on them, did in fact have a north pole and south pole, and where they might be. Students quickly applied their new, technical model of magnetism to the problem at hand:

Teacher:	So… what *happened* here?
Students:	It *repelled.*
Teacher:	They're *repelling*. Right. They were *repelling* and I'm going to *turn* this one over. What do we **call** this? North or south?
Students:	North.
Teacher:	North. It doesn't matter. I'm *turning* it over. What…
Student:	*Attract.*
Teacher:	So if it's *attracting* what **is** underneath here? North or south?
Students:	South.
Teacher:	South. Right. The bottom **is** probably north and this part **is** south. Does it matter? No it doesn't. This could **be** north. This could **be** south. This could **be** north or this could **be** south. Why? Because?
Student:	Because north and south.
Teacher:	Because north and south and [GEN what do north and south always *do*? What **is** the rule?
Students:	*Attracts.*
Teacher:	That's right. North and south always *attract*. What *repels*?
Student:	North and north or south and south.]

From the rule of magnetism, of which these students now had a working understanding, they were able to reason and explain that the second ring magnet appeared to float over the first because the two poles were repelling, and if they were repelling, the poles which are facing each other must be the same: "north and north or south and south."

When the students had reasoned through this issue, Mrs. Montgomery brought their attention back to the more general question of whether ring magnets had a north pole and a south pole like the other magnets. Once again, these students responded to this question using their newly acquired ways of thinking and talking about their experiences:

Teacher:	Okay. So tell me about these magnets? Do they **have** a north and south?
Students:	Yeah.
Teacher:	**Is** it on the same side?
Student:	No.
Teacher:	No? Who says they're different? (Show of hands.) If this side **is** north… if this side of the ring magnet **is** north what **is** the other side of it?
Student:	South.
Teacher:	So the ring magnet **has** a north and south?
Students:	Yes.
Teacher:	How do we know?
Jack:	Because we tried it out.
Teacher:	And? What did we discover?
Student:	[GEN Magnets *attract*.]
Teacher:	Let Jack finish.
Jack:	Because if you *turn* it around it won't *attract* and if you *turn* it around it'll *attract*.
Teacher:	So it **has** a north and south? Yes it does. And **is** it all on the same side of the magnet?
Jack:	No.
Teacher:	No. One side of the magnet will **be**?
Jack:	North.
Teacher:	And the other side of the magnet will **be**?
Students:	South.
Teacher:	Right. [GEN And when we have two souths *coming* together they are going to?
Student:	Um *repel*.
Teacher:	*Repel*. If we have norths *coming* together they are going to?
Student:	*Repel*.
Teacher:	If we have a north and a south *coming* together they're going to?
Students:	*Attract*.
Teacher:	*Attract*. Just like the other magnets.]

Notice how Jack brings together his newly acquired technical knowledge and his hands-on experiences by responding that the ring magnet has a south pole and a north pole “because we tried it out.” Notice, too, how far this is from visual, ostensive, identification. Jack has not identified the poles by what they look like but by criteria established by reasoning from the general rules of the model to the particular case. His words in fact echo what Mrs. Montgomery has attempted to do: to link the students’ hands-on and real-life experiences with technical taxonomies and a scientific model of magnetism which they can then use to reconstrue their everyday experiences in a scientific manner.

At the end of the unit, several students were invited to talk about what they had learned from the magnet experiments they had done. As we can see in Barbie’s and Angela’s examples below, students were able to offer scientific explanations using appropriate terms from their taxonomies and using the terms to express the cause-and-effect relations they had experienced earlier in their hands-on experiments:

Barbie: [GEN North and north doesn’t *go together* because it’**s** the same but if north and south *go together* because it’**s** not the same they will *attract*].
Angela: [GEN If you *put* north with north… *repel*. If south and south again *repel*. North and south… *attracts*. South and north *attracts*.]

When Angela was asked to explain the mystery of the floating ring magnet, she applied her understanding of the rule to her earlier physical experience by talking about the force of magnetism and how this force acts in relation to the poles:

Angela: If it **was** south to south… it was like *flying*!
Researcher: It was like *flying* off the pencil. Mm-hmm?
Angela: And it mm when it was north and north like… when it **was** north and north it *did* the same thing. And poof!
Researcher: Why did it *do* that?
Angela: Because it was uh… because the magnetism is *pushing* away from each other.

Thus not only did students adopt the appropriate register for talking about magnetism through this unit, the way they explained their experiences in and after the unit offered evidence that they understood the technical terms that were part of the taxonomies of magnetism, and could reason causally in this new form of discourse.

Discussion

This paper has examined how a teacher and a class of young ESL students were able to build up a simple theory of magnetism in a scientific register and link it to practical experience in a back-and-forth, theory–practice dynamic. They began by experimenting with what things a magnet attracts and later applied the theory to explain and extend their experience of ring magnets, creating a new blend of theory and practice in their social practice of doing science with magnetism.

Systemic functional views of language development in education look further than the acquisition of features of language form below the sentence level; they examine learner development of form and meaning in discourse in context. For example, SFL views emphasize learner development of the more abstract, less context-dependent academic discourse needed to address the demands of education. This type of discourse is illustrated at the end of the magnetism unit by Angela’s explanation of the rule of magnetism.

This paper addressed the question of how teacher and students worked to build up the meanings of the theory and practice of magnetism that are *assumed by* an explanation such as Angela’s. Rather than relying on a discourse types approach, it used an activity/social practice, theory–practice framework to trace the construction of meanings.

The *theory* at the core of the model of magnetism in our data is "the rule of magnetism"; the *practice* in our data is the group of experiments that the teacher and her students work through. Simple as it is, the model of magnetism illustrates Halliday's claim that science discourse constructs taxonomies and logical sequences of reasoning such as cause-effect principles. The model includes a taxonomy of attracting/not attracting/repelling and a simple taxonomy of the north and south poles of a magnet, as when a student said: "So magnets have a north and south." In addition, there are simple logical sequences relating poles and attraction/repulsion. When Angela said "If you put north with north, repel. If south and south, again repel. North and south attracts. South and north attracts," she constructed a causal explanation that included four logical sequences of implication and drew on two simple taxonomies. Notice that the taxonomy statement uses a process of being, and the logical sequence statement uses processes of doing. Both the taxonomy statement and the logical sequence statement are generic or general discourse, as befits the discourse of theory.

In the first part of the unit, teacher and learners were constructing the model of magnetism; towards the end of the unit, they were applying the model. At the broadest level, the link of theory to practice is seen most simply towards the end of the unit when the teacher guides the learners to apply the model to the two ring magnets. The learners have to relate taxonomies such as the general concepts of "north pole" and "south pole" to an actual place on some real magnet, describing it as a north pole or south pole:

Teacher:	Okay. So tell me about these magnets. Do they have a north and south?
Students:	Yeah.

Similarly, the learners have to relate the general implication sequences involving attraction and repulsion to actual sequences of doings and happenings occurring in real time:

Teacher:	So…what happened here?
Students:	It repelled.

Thus in applying theory to practice, the knowledgeable learner links abstract taxonomies to descriptions of actual things and events, and links logical sequences of reasoning to sequences of actual doings and happenings. Notice again that the taxonomy question uses a process of being, and the logical sequence question and answer use processes of doing. Both the description statement and the sequence statement are specific discourse, as befits the discourse of practice.

In the first part of the unit on magnetism, where teacher and learners were constructing the model, working with "attract," "repel," "north pole," and "south pole," the link of theory and practice was much more complex because the learners did not have the necessary understanding of theory or interpretation of practice. We particularly concentrated on the development of "attract" and showed how this was not a process where the teacher simply substituted the word "attract" for the students' term "stick." Instead, over a period of weeks she built up the meanings of magnetic attraction as an invisible force that could act on ferrous materials at a distance, and was transferable to another ferrous object. Beyond this, she connected attract with "repel" and "north pole" and "south pole" in a semantic network of related categories (see Halliday & Matthiessen, 1999, p. 81) which extended further than the terms we have studied.

In her work with the students, the teacher demonstrated her clear understanding of the social practice under investigation as a *theory–practice dynamic*. Building from the students' current knowledge and experience, she worked very skillfully and systematically to help them reconstruct their theory and practice of magnetism, weaving together theoretical guidance with practical experience in a process where practice changed theory and theory changed practice cumulatively. We are not aware of any study that has traced the construction of meaning in linguistic terms by ESL learners in science with respect to a theory–practice dynamic, despite its central importance, and so this construction process remains an intriguing area of future investigation. We will now consider in more detail the teacher's build-up of taxonomies and logical sequences of reasoning, and her work in guiding student decisions or choices.

With respect to taxonomies, consider how the teacher built the taxonomy of "attract" and "repel." She began with "attract" and was quick to coordinate the *verbal with the experiential.* For example, in the first lesson on magnetic attraction, she asked the general question of the meaning of "attract" and then quickly engaged the learners in a specific practical hands-on experiment using magnets to attract. By choosing to start with "attract" rather than "repel," she built on *students' familiar knowledge*, though she still had to help the students distinguish "attract" from "stick." Then she had to establish an understanding of the poles so that learners could understand the basis of the contrast between "attract" and "repel." Finally she helped the learners build up a taxonomy of "attract" and "repel" by both discussing the general meanings of these words *contrastively* and engaging the students in *contrasted* experiences of magnets attracting and repelling.

Some of the moves the teacher made, when taken in isolation, such as work with definitions or pointing to instances, are quite familiar to language teachers. What appears to be different here is the way the teacher combined a variety of strategies to develop the taxonomies of the model as part of a holistic *theory–practice understanding*. This suggests more generally that an important factor in the learning of technical terms for these learners, and possibly for many other learners, is the *coordination* of verbal meaning contrasts with experiential meaning contrasts.

In the case of the buildup of logical sequences of reasoning and particularly cause-effect relations, the teacher asked causal questions based on processes of doing. These questions are quite different from the questions she asked to construct taxonomies, which are based on processes of being, as we see in “Why do you think it isn’t attracted?” versus “What does that word attract mean?”

The first experiment was for the students to examine the fairly general theoretical causal question of “what things are attracted to the magnets…and why” by practical testing of various materials for attraction. For some students their assumption that all metals are attracted to magnets was challenged by the results, and they were faced with resolving the contradiction between assumption and results. The teacher took various opportunities to remind the learners of the question to be examined, asked learners for explanations of the results, and queried the explanations the learners offered. This pattern of cause-effect dialogue continued through the various experiments: discovering which parts of a bar magnet were responsible for attraction (i.e., north and south poles); given two bar magnets, discovering what two ends attract and what two ends repel; given two ring magnets, discovering whether they had a north and south pole, and where they might be, using repulsion as a guide. With each experiment, the teacher directed the causal reasoning process systematically to increase student understanding, and to ensure that the series of experiments built cumulatively on each other. Initially, the teacher mainly guided students to reason from the practical ("Why doesn't the key?" "Because it's too small?"), but in the final stages she mainly guided them to reason from the theoretical ("If we have norths coming together they are going to?" Student replies, "Repel"). More generally, she worked to ensure that student engagement with the experiments was not simply a *hands-on* matter of having something physical to do but was also a *minds-on* matter, an effort to reason causally, as when the teacher challenged the students to explain their results.

We now turn to the teacher's work in guiding student decisions or choices, moving from our earlier focus on what was learned in the magnetism unit to a focus on how the participants learned it, and how the teacher and students co-constructed the learning process. We traced the co-construction process in a basic way by noting relevant verbs of sensing, such as "think" and "know" and "discover." In this process, the dynamic between general theory and specific practice appears clearly.

Typically, the teacher guided the students to make decisions or choices about general theory questions by means of specific experiments, for example:

> Teacher: I want you *thinking* about what things are attracted to magnets and why."

Using "think," she thus positioned the learners as thinkers and projected what was to be thought about. Later she guided them to decide how to explain their results:

> Teacher: Why do you *think* it isn't attracted.
> Abby: It doesn't attract. I don't *know*. Maybe it's not metal.
> Teacher: …Is that not metal?
> Abby: No…maybe? I *think*?

Later still she reviewed their decisions with them, raising questions of the basis of their knowledge claims:

> Teacher: So the ring magnet has a north and a south?
> Students: Yes.
> Teacher: How do we *know*?
> Jack: Because we *tried* it *out* [i.e., proved it by experiment].

Jack seems to have little difficulty answering this epistemological question in practical terms.

Thus, the teacher positioned the learners as thinkers who could decide upon answers to theoretical questions by trying them out in practice (experimenting) and deciding what their results meant. In other words, the teacher positioned the learners as decision-making agents investigating their world in a theory–practice dynamic.

Conclusion

A vital requirement of the serious study of language and content learning is a linguistic definition and analysis of content. This study has illustrated a functional rather than a formal approach to the study of language and content learning. It has shown the role of language as a medium of learning. Broadly speaking, we have shown how content is meaning in text and context, and examined how participants used language to construct that meaning. More specifically and theoretically, we have shown how content can be analyzed through the contextual variable of field and its associated ideational meaning. In other words, from a research perspective, we demonstrated how systemic functional linguistics can provide a theoretically sophisticated and analytically accountable research approach to the study of language and content, form and meaning. A traditional approach to language cannot do this because of its limitation to form.

By using social practice as our unit of analysis, we have shown how the teacher and her students worked to construct a holistic unit of meaning. This unit covered ten experiments and was necessarily larger than the word, clause, or individual text. Rather than seeing teacher and learners as producing a type of text, we viewed the teacher and learners as constructing a theory of magnetism and constructing a practice of engaging in experiments with magnets, in a back-and-forth, dynamic process. We investigated how teacher and learners dynamically *related* theory and practice, how they related the concepts of magnetism to the experiments they did, and vice-versa. Our account of the teacher's detailed semantic work introducing "attract" and "repel" to the learners shows how much work was required. Using language indicators to note the flow of discourse, we traced the theory–practice dynamic of how teacher and students worked to construct meaning by developing the interplay between students' understanding of magnetism and their practical experience and experiments with magnets. While our indicators were intentionally basic and minimal (the processes of being, doing, and sensing; general and specific entities and events), they point to central distinctions of meaning and provide a foundation for more elaborate study.

In our analysis of the classroom interaction, we have shown connections with systemic functional studies of scientific discourse by showing how the teacher and learners constructed taxonomies and logical sequences of cause-effect reasoning. In addition, we have shown how the teacher helped the learners connect taxonomies to their descriptions of things, and causal relations to their accounts of event sequences. We would argue that these two connections are a requirement whenever taxonomies and causal relations are applied to actual cases. We have also highlighted ways in which the teacher guided the learners to make decisions or choices about theory questions by experimentation and to decide how to explain their results. The knowledge structures of classification/taxonomy and description, principles (e.g., causal relations) and sequence, and decision-making or choice, whose construction we have investigated in this study, are included in the Knowledge Framework heuristic mentioned earlier. Thus the Knowledge Framework heuristic gives a broad sense of the pattern of the holistic unit of meaning around which the classroom work on magnetism coheres, and the work on magnetism provides an analyzed sketch of the semantic structure of a social practice.

The theory–practice dynamic is a central process in research and in learning, but it has not been sufficiently recognized in applied linguistics research. It is widely believed that hands-on experience is significant in learning in the elementary school generally and in ESL classes in particular, but the challenge of relating hands-on experience to minds-on understanding and vice-versa is frequently overlooked. By contrast, the dynamic is clearly recognized in science education research. In this paper, we have traced how teacher and learners linked experience and understanding in a semiotic process mediated by discourse. A similar approach to tracing the theory–practice dynamic could be applied in the many fields of education where the coordination of theory and evidence is an issue.

The knowledge structures mentioned above are fundamental to the development of literacy in school science both for individual students and for the group as a whole. These structures are presupposed by some of the major genres that are required in school science education. Thus this teacher and these students were building a vital foundation for science literacy. Report genres include classification and description and can be further subdivided to include descriptive reports and taxonomic reports. Explanation genres include causal relations and sequences and may be further subdivided to include causal explanations and sequential explanations. Recount genres deal with sequences of events and actions, as in the record of events of a science experiment (see Unsworth, 2001, p. 125). Perhaps surprisingly, these structures, broadly understood, are also fundamental to the development of literacy in school history. School history genres include report genres such as descriptive report and taxonomic report, explanation genres include consequential explanation and historical account, which focuses on the sequence of events (see Unsworth, 2001, p. 124). Of course there are significant differences between a given genre (and underlying knowledge structures) in science and in history, and it has been the role of genre research to subclassify genres and identify such differences. But this should not blind us to the importance of identifying similarities of knowledge structures across disciplines both for research purposes and for educational purposes. There is a balance to be struck between looking for differences and looking for similarities. In our heuristic model, there is no requirement that classifications should be as clear-cut as taxonomies in science, and general implication relations need not involve cause-effect relations but can include rules and principles, as, for example, in mathematics. We believe our model can be applied more widely than science and history. How widely is a question for further research.

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