A functional approach to evaluating content knowledge and language development in ESL students’ science classification texts

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This article investigates the use of a functional approach to discourse analysis – knowledge structure analysis, which focuses on meaning, form, and function simultaneously – to evaluate both writing development and content learning. The study examined written texts in science, produced by 35 ESL students in Canada in grades 8 to 10 with limited to intermediate English language proficiency, in which they constructed scientific classifications. By examining and comparing two pieces of writing produced by the same students on the same topic at different learning stages, the study reveals the progress they made in integrating language and content at the discourse level. It also raises new questions about the integration of language and content teaching in all subject areas.

Introduction

This article examines the use of a functional approach to discourse analysis, applied to students’ classification texts dealing with science content, to investigate how it can aid in the evaluation of both writing development and science content learning. These texts were produced by ESL secondary school students in Canada as they constructed scientific classifications in writing over a period of instructional time. By drawing upon ideas from Systemic Functional Linguistics (SFL) for discourse analysis and work like that of Novak on concept maps as learning and evaluation tools for knowledge construction (Novak and Gowin 1984; Novak 1990; Mintzes, Wandersee and Novak 1998), we hope to show a
connection between the understanding of science content in terms of knowledge structures and the language difficulties or linguistic tasks that L2 learners may face.

Recognizing “the central role of language in education, not only as a subject in the curriculum, but also as the medium in which the learning and teaching of all subjects is actually carried out” (Wells 1997), studies in language education have advocated the integration of language and content learning. Rationales behind the advocacy of such integration have been well articulated in the literature on content-based language learning (Snow and Brinton 1997; Stryker and Leaver 1997), as well as by researchers arguing for increased attention to language across the curriculum (Acherman 1993; Applebee 1981; Emig 1977; Gere 1985; N. Martin et al. 1976; N. Martin 1992; Wells 1999). Outside the field of language education, advocates for focusing on language across the curriculum have turned to constructivism to build an argument for the role of language in the learning of academic content (Newell 1998). From this angle, learning is viewed as organizing and reorganizing one’s experience and also reflecting on that experience (Britton 1970). Knowledge is viewed as “systems for interpreting the world” – systems that are transformed even as they are being used for understanding (Barnes 1976). Learning about the world or the acquisition of knowledge or skills thus cannot be separated from language development.

Research reveals that relationships between language and content or meaning in educational discourse can be problematic rather than transparent and that there is need for theory-based discourse analysis research which can illuminate these relationships. In the last two decades, “the development of content-based language curricula [has been] gaining prominence in a wide range of contexts” (Grabe and Stoller 1997: 5), and the adoption of a content-based curriculum often has been favored on the assumption that “through content teaching, second language learning will be enhanced . . . because content teaching is considered communicative teaching par-excellence” (Swain 1988: 68). Nevertheless, Swain’s studies of French immersion programs have suggested that content teaching is not necessarily good second language teaching due to its lack of attention to functionally appropriate form–meaning connections:

the language the teacher uses may be functionally restricted in certain ways, correction of content takes precedence over correction of form in order to preserve the communicative flow, the correction of form that does occur is inconsistent in its message, and students’ opportunities to engage in extended discourse are limited. (Swain 1988: 76)

The issue of functionally appropriate form–meaning relationships also presents a challenge to teachers who wish to link language and content when it comes to evaluation. Except for work in the tradition of functional linguistics, we know of little research that shows how to approach integrative assessment drawing upon a conscious and theory-based articulation of the relationships between wording and meaning. On the other hand, recent studies by Low (1999;
Mohan and Low (1995) of teachers working in a content-based program which was specifically aimed at a closer relationship between learning a language and learning subject matter have revealed that the teachers found it extremely challenging and problematic to attend to the interrelatedness of language and content in their evaluations of student writing. Though the teachers taught language and content in an integrated way, they did not mark in an integrated way. The widely held assumptions that support the separation of content and language in evaluation are that they should be marked separately (“5 points for language, 5 points for content”) and that meaning or content is to flow through discourse but not be intrinsic to or situated within it. Low’s studies show that teachers’ beliefs about the functional relationship between language and meaning are in conflict with the assumptions embedded in their everyday evaluative practices. This indicates that even teachers who applaud and practice integration in teaching need to develop an understanding of the functional relationships between meaning and wording, and need to be able to make their evaluative practices consistent with this understanding.

Systemic Functional Linguistics is based upon the premise that language is a resource for making meaning and thus provides a principled account of how forms and meanings (i.e. language and content) are related in discourse. Discourse is defined from a functional perspective as a system, i.e. “a socially and culturally organized way of speaking or writing, through which particular functions are realized” (Schiffrin 1994: 32). In other words, it is “connected stretches of language that make sense” in the context of a particular social practice (Gee 1989: 6). The focus of a functional analysis of discourse “is on how people use language to make meanings... They do this through their selections from the sets of choices that are available in the language systems” (Christie and Unsworth 2000: 3).

Three situational or register variables influence the way that people use language to form the context of situation: field, tenor, and mode. Field is concerned with the social activity, its content or topic; tenor is the nature of the relationships among the people involved; and mode is the medium and role of language in the situation. A description of the values for each of the variables at a given time of use is a register description of a text (Eggins 1994: 52). Each of these variables is related to a component of the language system: field relates to the ideational meaning, which deals with the representation of experience; tenor relates to the interpersonal meaning through which our social interactions are established; and mode relates to the textual meaning, which provides messages as text in context and creates coherence in text.

For example, a conversation between a diner and a waitress at a restaurant may go like this:

Waitress: What would you like to have for today?
Diner: Could you make some suggestions?
Waitress: Well, our roast beef is very good. A lot of people like it.
Diner: Then I will have a try.
The selection of language use in this interaction (such as lexical items for food, the modal auxiliary to present a polite or courteous manner, and features of oral language in a conversation) is influenced by (1) the ideational meaning, here the social activity of ordering food in a restaurant, (2) the interpersonal meaning, here the relationship between a diner and a waitress, and (3) the textual meaning, which is oral conversation in a friendly restaurant atmosphere. Halliday (1994) provides an analysis of the grammatical resources for realizing each of these meanings. A functional approach to discourse analysis can thereby link language and meaning in discourse by identifying the grammatical resources that realize these three kinds of meanings.

We will concentrate on field and ideational meaning in this study. As Halliday (1994: 106) points out, it is ideational meaning that is closest to the everyday sense of “meaning in the sense of content”. Ideational meanings reflect, or rather construct, subject matter or content (field); therefore, to examine how ideational meanings are realized or constructed linguistically is to see how language is integrated with content. For instance, in a content area such as science, the learner’s written discourse in science reflects the learner’s scientific knowledge. The learner needs to select from the sets of grammatical resources to construct, e.g., scientific classifications which are drawn from and used in the discourse of learning science in the classroom (Halliday and Martin 1993; Lemke 1990). We look at classification in this study as a discourse structure of ideational meaning, which we term a knowledge structure following Mohan (1986). Note that a knowledge structure is different from a genre as defined in SFL. Classification is a discourse structure of ideational meaning. Genres, which refer to purposeful, staged uses of language that are accomplished in particular cultural contexts (Christie 1985), involve all three types of meaning: ideational, interpersonal and textual.

There are several reasons to focus on science and classification discourse. As argued by Halliday and Martin (1993), the language of science reflects the evolution of scientific knowledge. To understand scientific discourse, one needs to look closely at the language scientists use (Halliday and Martin 1993; Martin and Veel 1998). Consider a sentence from a school science textbook analyzed by Martin (1990: 93): “The production of rock waste by mechanical processes and chemical changes is called weathering.” A whole bevy of grammatical features mark this sentence as part of scientific discourse. “Some of the features are heavy subject; processes and actions named by nouns or nominalizations rather than verbs; passive main verbs and passive inside nominalization” (Gee 2001: 718). This kind of scientific language is inherently different from that of narratives and other text types. Students need to gain mastery of specific language structures which will help them access science discourse (Veel 1997). Discourse that constructs classification is centrally important in science. One of the semantic potentials of scientific language is “for transforming the flux of experience into configurations of semiotic categories” (Halliday 1998: 197). Halliday noted that nominalizations assist thematic progression in scientific texts. His studies on the register of scientific English show how nominalization helps create new
classifications and technical taxonomies: the verb *move* becomes the nominalization *motion*, and that allows the classification of linear motion, orbital motion, parabolic motion (Halliday 1998: 200).

Previous work within an SFL perspective has indicated directions for the analysis of student writing in science. Schleppegrell’s (1998) functional analysis of middle-school students’ science writing has demonstrated how a systemic functional approach works to connect form and meaning. Schleppegrell used functional grammar to identify the grammatical features, such as relational verbs and clause themes, that are useful for the task of describing and showed how those grammatical structures create particular kinds of meanings. The study calls for more research on the grammatical and discourse features of particular kinds of school writing so that classroom teachers may gain a better understanding of the intrinsic relationships between meaning and wording in academic writing tasks and thus be better able to help students use the grammatical resources available to them for expressing meaning in writing. Our study hopes to do just that.

The study

Knowledge structure analysis is utilized in this study to analyze students’ classification discourse, with special attention given to the ideational meaning or content. One of the benefits of a focus on ideational meaning is that it illuminates the relationship between classification discourse and the graphic representation of classification. This suggests connections with a body of work in science education which makes use of graphic representations of scientific understanding. The science education researcher J.D. Novak has argued for the importance of seeing learning as a change in the meaning of experience rather than as a change in behavior. He and his colleagues have developed a number of strategies for helping learners construct new and more powerful meanings. One of these strategies is concept mapping. “Concept maps are intended to represent meaningful relationships between concepts in the form of propositions” (Novak and Gowin 1984: 15). They are tools for organizing and representing knowledge which consist of concepts, usually enclosed in circles or boxes of some type, and relationships between concepts or propositions that are indicated by a connecting line between two concepts. Novak’s work has demonstrated that concept maps may be used for analyses of science content in terms of structures of knowledge and understanding. Concept maps have been used in science classrooms not only as learning tools but also as evaluation tools (Novak and Gowin 1984; Novak 1990; Mintzes et al. 1998). However, we are not aware of any work that connects the understanding of science content in terms of knowledge structures to the language difficulties that L2 learners may face.

We use graphic representations of classification in this study to illustrate development in the understanding of classification. We then show how the represented classifications are constructed in written discourse. By comparing
and analyzing written discourses produced at different learning stages, we can show a connection between the SFL analysis of discourse meaning and work such as Novak’s on the development of classification discourse by ESL learners. The specific questions that guide the analysis are:

i) How does knowledge structure analysis as a tool for discourse analysis capture both knowledge construction expressed in written discourse and the development of linguistic skills in science writing?

ii) What are the intrinsic relationships between the construction of scientific knowledge and development in science writing?

Methodology

Setting
The study was conducted in two ESL classes in a public secondary school in the Greater Vancouver area, British Colombia, Canada. More than 50% of the student population was ESL. The school is located in a rapidly expanding city where the population of new immigrants, especially from Hong Kong, keeps growing. The education of ESL students has become one of the most important issues for administrators, educators, parents, and the community. The major task of the educational programs in the system has been to assist ESL students linguistically, cognitively and academically.

According to the ESL policy of the school district, all ESL students were to be evaluated every year for their English proficiency levels to determine how much ESL support each student needed in the following year. The assessment tool used for evaluation was designed locally by teachers in the school district. Following the evaluation, each student was assigned to one of five levels, ranging from level 1 (the lowest English proficiency) to level 5 (abilities approximating to native speakers of English). During the year this study was carried out, ESL classes with different content focuses – science, social studies, literature, and community and culture – were offered to students at different ESL levels. The program was designed to facilitate the ESL students’ language and content learning so as to help them integrate into the regular academic programs more effectively.

Participants
Two classes were involved in the study: 23 level 2 students and 12 level 3 students from grades 8 to 10 (aged 14 to 17). Both classes were mixed gender: all together there were 18 male and 17 female students. Of the 35 students, 25 were from Hong Kong (all but one Cantonese mother-tongue speakers, the other Mandarin), 4 from Taiwan (Mandarin), 2 from Mexico (Spanish), 2 from India (Punjabi), 1 from Israel (Hebrew), and 1 from South Korea (Korean). Cantonese was the first language of the majority in both classes.

At levels 2 and 3, most of the students had the ability to communicate orally and in writing in English using Basic Interpersonal Communicative Skills (BICS)³
(Cummins 1980, 1981, 1984; Cummins and Mackay in press), with some variability in fluency and accuracy. However, in terms of Cognitive Academic Language Proficiency (CALP) necessary for academic success (Cummins 1980, 1981, 1984; Cummins and Mackay in press), the students still struggled tremendously, both orally and in writing. One focus of the program therefore was to help the students improve their academic language proficiency.

DATA COLLECTION
This research is part of a larger study which attempts to integrate science content and academic writing skills for ESL students. The data were gathered from the teaching of the entire content unit “The Composition of Matter” from an ESL science textbook *English for Science* (Zimmerman 1989). Twelve lessons were conducted in each of the two ESL science classes taught by the teacher/researcher. A series of lessons focused on both academic content learning and writing skills development, organized around the classification knowledge structure (Mohan 1986). These designed tasks were intended to engage students in both knowledge construction and academic writing, using graphic representations to mediate between language and content. Data included lesson plans, a field journal, and discourse data from student–teacher interactions and student written work.

Copies of lesson plans produced by the teacher/researcher were collected as “artifacts” (McMillan and Schumacher 1989: 411) to reveal the intention of the teacher and to help provide information on the instructional context in which student discourse was produced. Field notes were taken at the end of each instructional day to record the content of lessons and help investigate how plans were actually implemented to facilitate the integration of writing and content learning. They also aided the recording of relevant information that otherwise could not have been gathered, such as the dynamics of group work and the teacher’s reflections on instructional actions taken. Finally, student–teacher interactions and student written work produced during the instructional period were collected as discourse data for the analysis of the students’ understanding of academic content and their writing skills development. An audio tape recorder was used for five lessons during which oral interactions in the form of whole group instruction and class discussion took up larger chunks of class time. Written work from all 35 participants was collected for text analysis. Discourse data used for the analysis in this article is mainly from the lessons in which written drafts were produced.

INSTRUCTIONAL CONTEXT
Since the focus of this article is on discourse analysis, the following description of the instructional process will be succinct. See Huang (2000, 2002) for a more detailed analysis of the instructional process and the role played by instruction in making changes in students’ writing and knowledge development.

The teacher/researcher was very aware from the beginning of the study of the dual goals in the program of learning science content and developing academic language proficiency. The instruction and assessment had to embrace
both students’ content knowledge and linguistic abilities. The teaching approach had a language and content emphasis based on Mohan’s (1986) ‘knowledge framework’. It was carefully chosen to serve the purpose of facilitating the students’ language acquisition, content learning, and cognitive development.

Mohan’s knowledge framework (KF) views language as discourse in the context of social practices or activities. It “provides a theoretical basis for aspects of language as a medium of learning” (Mohan 2001: 107). Within the KF perspective, social activity involving any content topic is a combination of knowledge (theory) and action (practice). The theory aspect of an activity typically includes knowledge structures (KSs) like classification, principles, and evaluation. The practice aspect of an activity typically includes KSs like description, sequence, and choice. For example, there are consumer reports on different kinds of cars (classifications), on running conditions for potential uses of these cars (principles and if–then relationships), and on rankings of cars (evaluation). When buying a car in practice, consumers have a specific idea of what they need (description), follow certain procedures when selecting a car (sequence), and make a decision on the car they want (choice). Taken together, these knowledge structures form a knowledge framework which provides a general analysis of a social activity (such as buying a car).

Knowledge structures are identified semantically (Mohan 1986: 40). Classification is recognized through the semantic relationships of taxonomy or part–whole. From an SFL perspective, each KS can be constructed or realized through specific linguistic features in a variety of ways, depending on the context (see Mohan 1986, 2001; Mohan and Huang 2002). When one is engaged in constructing a certain KS (e.g. classification) under a content topic (e.g. matter), the particular language features associated with that KS are required. In addition, according to Mohan, each KS can be represented by a key graphic which makes its content visible.

The use of KF as a teaching approach attends to at least four aspects of learning:

i) construction of content knowledge
ii) knowledge organization, which serves as a kind of template to help structure knowledge so that learning capability may be enhanced (Novak 1990; Novak and Wandersee 1991)
iii) development of language, which plays an important role in mediating learning (Mohan 2001)
iv) visual representation of knowledge in an organized fashion (see Ausubel 1963, 1968; Ausubel, Novak and Hanesian 1978).

A content topic is always the starting point for instruction. The topic then may be analyzed into at least the six kinds of KS mentioned above: classification, description, principles, sequence, evaluation, and choice. Particular content is presented and/or constructed in any one KS depending on the focus of the lesson. The teaching unit employed in this study focuses on only classification:
how matter (the content topic) may be classified in science and which grammatical resources are used to construct and represent this classification.

Following the organization of the textbook, the teacher began by introducing a short reading passage as a model text about the classification of matter according to its properties (see Appendix), which clearly entails the KS of classification. After a discussion of the three states of matter, the teacher conducted a classroom discussion, using examples from the passage on how the KS of classification could be expressed in English. Several classification trees interpreting the KS of classification in the passage were utilized to mediate between language and content and to visualize the classification relationships in the text. A summary of one kind of linguistic device used for classifying in science was also provided (see Figure 1). Then the class was asked to write a

Figure 1. A summary of one kind of linguistic device used for classifying in science given to students (from Zimmerman 1989)

Classifying from general to specific

Matter \{ classified grouped divided arranged categorized \} into \{ divisions groups types classes categories classifications \}

<table>
<thead>
<tr>
<th>is/are</th>
<th>may be</th>
<th>can be</th>
<th>could be</th>
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<th>classified categorized classed grouped</th>
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as \{ solid, liquid, or gas. \}

There are three \{ types kinds classes categories \} of matter.

Classifying from specific to general

Oxygen | may be | can be | could be |
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<tbody>
<tr>
<td>is/are</td>
<td>classified</td>
<td>classed</td>
<td>categorized</td>
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<tr>
<th>as a gas.</th>
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Oxygen is \{ an example of a | a type of | a kind of \}
| a | gas. |

Note: These sentence patterns are only samples, not a comprehensive list of all possible patterns.
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Figure 2. Classification tree for the writing task

The students produced three drafts of this text during seven lessons. They were asked to start working on a first draft following the model text. As will be shown later, their first drafts demonstrate weaknesses in both content knowledge expressed and the degree of sophistication in language use. A classroom discussion of the concepts in the classification tree and an analysis of samples of their first drafts were conducted to help the students improve. Criteria in terms of both content and language were agreed for the second draft. The students engaged in a variety of classroom activities, including small group and whole class discussions, as well as cooperative learning through information searching from various sources. Using the linguistic and scientific knowledge gained through these activities, students produced a second draft. Unlike the first draft, which was the result of individual effort, the second, though still produced by individual students, represented a collective effort, especially in terms of content construction.

The students engaged in peer editing for the final stage. Peer editing is a technique that many researchers recommend should be avoided with non-native writers when the focus is on the form of language. Therefore, the teacher directed the students to focus mainly on the content aspect, such as providing definitions or explanations of terms, using examples, and showing relationships between the terms. Depending on the language level of the students, attention to certain linguistic aspects was also demanded or encouraged, including the use of the passive voice, noun–verb agreement, and sentence structures typically used – e.g. expressing classification relationships in science as shown in Figure 1. A
third draft was then produced which was the result of peer editing, often accompanied by requests for assistance from the teacher.

**Data analysis and discussion**

Knowledge structure analysis (KSA), based on Mohan’s knowledge framework, was employed to examine the integration of language and content by investigating form–function relationships in these students’ written classification discourses. This approach draws upon ethnographic research (Werner and Schoepfle 1987) and the work of SFL (see Halliday 1994; Eggins 1994; J. Martin 1985, 1992). The analysis of the students’ written discourse focused on explicitly examining (1) their knowledge of how matter can be classified, (2) whether the semantic relationship of classification is successfully expressed via linguistic devices, and (3) their sophistication (i.e. the ability of successfully using more types and tokens of linguistic features) in the use of the English language to demonstrate knowledge construction. The analysis centered on the students’ first and third drafts. As in Schleppegrell’s analysis of students’ descriptive discourse, this approach “views students’ error within a broader textual context and recognizes the strength that learners bring to particular assignments, rather than focusing on discrete errors in isolation” (1998: 183).

Though texts were collected from all 35 participants, 6 students failed to hand in either the first or third draft. Therefore, only the data from the 29 students who produced both drafts were included in the analysis. For each draft, the following four steps were taken:

i) identify the KS that the text represents
ii) present a graphic representation of the KS expressed in the text
iii) specify the main semantic relationship(s) that serve to construct the KS in the text
iv) identify the key linguistic features that express the KS in the text, with particular attention to generic reference, transitivity processes, conjunction and lexis (discussed further below).

In the following, we provide a detailed discourse analysis of two texts produced by one student in order to show a change or development. We then present a summary of the findings from the analysis of all the discourse data to provide a general picture of the change made by the whole class.

**DETAILED DISCOURSE ANALYSIS OF ONE STUDENT’S DRAFTS**

The following two pieces of writing from student 17 are typical of the students’ first and third drafts.

**Draft 1**

All the things in the world are made up of matter. Anything has weight and take up space is matter.
Matter can be classified as organic and inorganic. Organic can be divided into two classes: plants and animals. Inorganic never has life.

Plants are a kind of organic, plants can be classified as bacteria, algae, and seed plants.

There are two categories of animals: vertebrates and invertebrates. Amphibians, birds, reptiles, bony fish and mammals are all classified as vertebrates. Insects are a kind of invertebrates.

Everything we know is made up of matter in organic and inorganic form.

Draft 3

All the things in the world are made up of matter. Anything has weight and takes up space is matter.

Matter can be divided into organic and inorganic. Organic is the thing that has life. Bacteria, birds, insects, mammals are all classified as organic. Inorganic never has life.

Organic can be grouped into two classes: plants and animals. Plant is that any living thing has cell that has cell wall. Trees, shrubs, fungi, algae are plant. Animal is that any living thing has cell that do not has cell wall.

Bacteria, algae, seed plants are classed as plants. Bacteria is diverse group of one-celled micro-organisms found when there is life. Algae is a large group of mainly asexual, one-celled or multi-celled organisms traditionally are classified as plants. Any plant that bears seeds are seed plants. Animals can divided into two classes: vertebrates and invertebrates. Any animal that has a segmented spiral column is vertebrate. Any animal lacking a backbone is invertebrates.

Amphibians, birds, reptiles, bony fish and mammals are grouped as vertebrates. Amphibians is an animal that can live either on land or in water. A frog is an amphibian. Feathered creatures with two legs and two wings are birds. A cold-blooded animal that creeps or crawls is reptile for example snake. Bony fish is a fish that has many bones, it has bones to prop up their body. Mammals is an female animal feeds the young with its own milk. Pigs and cows are mammals. Insects are a kind of invertebrates. Insects is a very small animal usually with three pairs of legs and two pairs of wings. Bee and butterfly are insects.

Everything in the world is made up of matter in organic form and inorganic form.

Let us start with the KS that the two texts represent. Graphic representations of the texts in Fig. 3 and Fig. 4 reveal both the KS represented and the elaboration of the message content (e.g. definitions and examples). In the graphics, all the basic concepts that appeared in the texts are boxed, with relevant content types which were provided given under each box. A comparison between Figs. 3 and 4 shows that while the KS entailed by the two texts is the same – classification (taxonomic and part–whole) – draft 1 contains five layers of classification and draft 3 contains six. The extra layer added to draft 3 provides specific examples illustrating different groups of animals. Both drafts introduced 16 different scientific concepts, but while only two concepts have definitions in draft 1, every concept is accompanied by a definition in draft 3. Using definitions or explanations of terms and providing specific examples illustrating those terms has helped make draft 3 more elaborated in terms of message content.

This is significant in that it shows how this approach can address the issue of content construction. It is not difficult to argue that an understanding of
Figure 3. Graphic representation of draft 1 for student 17

Figure 4. Graphic representation of draft 3 for student 17
certain kinds of message content is inseparable from an understanding of certain concepts. In school science, as in any subject area, concepts are fundamental to the learning of principles and are usually introduced in classification discourse. Classification serves two functions (see Veel 1994): (1) to establish basic knowledge in a topic area and to show how things within the topic area are classified, and (2) to introduce important technical terms and show how they relate to one another. Thus, to analyze a classification discourse, the tool for analysis has to be able to indicate if the discourse serves its functions. In both texts, as revealed by the graphic representations of the texts, some basic knowledge about matter is demonstrated, and terms related to matter are classified. Furthermore, technical terms (e.g., vertebrates and invertebrates) are introduced and the relationship between terms (amphibians are a kind of vertebrate) is illustrated.

We need to look into not only the question of “if” but also of “how well” in order to address the issue of development in knowledge construction and language use. Put another way, it is not only the understanding of the classification of matter that is relevant but the level of that understanding as well. In effect, we need to look into students’ conceptual knowledge of terms related to matter. It has been argued that concepts are synonymous with the formation of categories. Human beings “organize background knowledge and experiences into conceptual hierarchies according to class, example, and attribute relationships” (Vacca, Vacca and Gove 1995: 232). The capability to explain a concept in terms of class, critical attributes, and examples (or negative examples: x is not a kind of y) thereby shows the level of understanding of the concepts. Learning to classify basically involves the development of conceptual knowledge related to different forms. The more accurately a student can express class–example relationships, elaborately describe critical attributes, and provide specific examples, the better conceptual knowledge we can argue the student has.

Extending the argument to this study, a comparison of Figs. 3 and 4 reveals how the student has progressed in the construction of conceptual knowledge from draft 1 to draft 3. The graphics used in this study to reveal content construction are, in essence, a type of concept mapping. They have some general features that are often evaluated highly by Novak, like hierarchical structure within which concepts and propositions are illustrated and explained. Although terms are classified in both drafts, only in draft 3 are extensive definitions or descriptions and specific examples provided. One can argue that at the draft 3 stage the student has demonstrated a better understanding of at least 14 more concepts among the 16 covered in both texts, even though the text still carries some inaccurate content information.

The analysis of classroom discussion that took place between draft 1 and draft 3 indicated students’ lack of understanding of content knowledge at the stage of the first writing. Classroom instruction appears to have played a very significant role in gradually leading the students to the stage of draft 3 (see Huang 2000, 2002). While the graphics show the KS expressed in the student discourse and the degree of elaboration in terms of content, a discourse analysis is needed to
examine the linguistic sophistication of the two drafts. Thus KSA goes beyond examining content knowledge by connecting the construction of conceptual knowledge and knowledge structures to the language demands that L2 learners may face when being required to express their understanding linguistically.

If the analysis tried to evaluate the use of the language in the two texts in a more traditional way – i.e. examining them only at the sentence level using traditional grammar to identify discrete errors in isolation – it would be difficult to see the fundamental difference between the two texts: both contain numerous grammatical mistakes. Interestingly, draft 3 may contain more mistakes, especially with the increased use of relative clauses in the discourse. However, those with knowledge of classification discourse in science may well agree that draft 3 is linguistically more sophisticated. How do we accountably and explicitly evaluate levels of sophistication in academic writing? KSA seems to offer a way to address the issue. Accuracy and perfection at the sentence level are not the main focus of KSA. Learning is a process where there is always room for improvement. The aim of KSA is to examine in a specific textual context the level of linguistic sophistication, which may represent a crucial aspect of a learner’s writing skills.

In genre analysis, language subsystems such as reference, conjunction, and transitivity processes are analyzed to identify the features of a genre. These are analyzed in KSA to identify the way in which they convey the semantic macro-organization of a text. The analysis tool (1) looks into the specific semantic relationships that serve to construct the KS in the discourse sample, and (2) identifies the key linguistic features in terms of how they combine to express the KS in the discourse.

J. Martin (1992: 294–309) uses ‘taxonomic relationship’ as a broad term to cover superordination and composition relationships. This is similar to what Werner and Schoepfle (1987) call taxonomic and part–whole relationships. KF uses ‘classification’ as a broad term to cover these. The classification relationships in the discourse samples presented here are represented through both subclassification or taxonomic (“is a”) relationships, and compositional or part–whole (“has a”) relationships. Table 1 is a summary of the linguistic devices

<table>
<thead>
<tr>
<th>Linguistic Device</th>
<th>Draft 1</th>
<th>Draft 3</th>
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</thead>
<tbody>
<tr>
<td>Reference (generic)</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>Transitivity (relational)</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Conjunctions (additive)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Lexis (a) single word signifying</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>classification relationships</td>
<td></td>
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</tr>
<tr>
<td>Lexis (b) two or more words that</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>are taxonomically related</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Nominal groups: expansion of head nouns   | 4       | 17      | through modification

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employed in the two drafts to help realize these semantic relationships. The figures in the table provide a sense of the difference in language use between the two drafts rather than claiming a causal relationship between editing and the changes. This demonstrates how the development of knowledge construction is intrinsically related to sophistication in the use of language.

The following is a detailed analysis of the discourse sample of student 17, paying special attention to the linguistic categories such as reference, transitivity, conjunction, lexis, and nominalization.

**The use of generic reference**

Generic reference is identified by both Martin and Christie as a linguistic feature that goes with classification.

Generic reference is selected when the whole of some experiential class of participants is at stake rather than a specific manifestation of that class. (J. Martin 1992: 103)

[The] term ‘generic’ used here is the adjective of the noun ‘genus’ . . . The term ‘genus’ refers to a class of phenomena, be they animals or plants. We build a great deal of our knowledge, . . . by identifying living things as having characteristics in common, so that we can group them as a genus. (Christie 1989: 20).

In both texts, generic reference is used to help build classification, e.g.:

1) *Anything* [that] has weight and takes up space is *matter*. (draft 3)
2) *Amphibians, birds, reptiles, bony fish* and *mammals* are all classified as *vertebrates*. (draft 1)

While *anything* is used as a generic reference to a set, *matter, amphibians, birds, reptiles, bony fish* and *mammals* are used as generic references to a subset of matter, i.e. *vertebrates*. The difference between the two texts is that draft 3 used 15 more different generic references than draft 1.

**Transitivity: relational processes**

Christie (1989: 29) states that the “use of transitivity processes, relational ones in particular, . . . help build . . . classification”. Relational processes are identified by Halliday (1994: 119) as “those of being . . . The central meaning of clauses of this type is that something is.” There are two relational process modes, attributive and identifying. For the identifying mode, two of the three ways of being (intensive, circumstantial, and possessive) can be linked to linguistic features that realize classification:

a) intensive: *x is a*, which can realize the taxonomic relationship
b) possessive: *x has a*, which can realize the part–whole relationship.

In both texts, the identifying mode for both intensive and possessive ways of being were used, manifested through *is/are, has*, and *made up of*:
**Taxonomic relationship realized through intensive ways of being**
3) Anything . . . is matter. (drafts 1 and 3)
4) Plants are a kind of organic [thing]. (draft 1)
5) Plant is . . . any living thing that . . . (draft 3)

**Part–whole relationship realized through possessive ways of being**
6) [An] inorganic [thing] never has life. (drafts 1 and 3)
7) All the things are made up of matter. (drafts 1 and 3)
8) it has bones . . . (draft 3)

J. Martin (1992: 303–7) cites three major types of composition relationships: constitution (the relationship between part and whole), collective (treating collections of individual participants as aggregates), and consistency (relating the material to the object it constitutes). Both consistency and constitution relationships occur in the discourse samples, as demonstrated in examples 7 and 8, respectively. No collective relationships were identified in this discourse sample.

In addition to the use of intensive and possessive ways of being, certain classification verbs were also employed in the passive voice as relational transitivity processes:

9) Plants *can be classified as* bacteria, algae, and seed plants. (draft 1)
10) Organic [things] *can be grouped into* two classes: plants and animals. (draft 3)
11) Bacteria, algae, seed plants *are classed as* plants. (draft 3)
12) Organic [things] *can be divided into* two classes: plants and animals. (draft 3)

But while draft 1 contains 6 different types of relational transitivity, draft 3 contains 7.

The use of material transitivity process was also identified in texts of other students as a device to help establish classification relationships. When material process is used, the verb is always a lexical item that specifies a sense of classification and is used in the active voice:

13) Human beings *can classify* matter in many ways according to different qualities they have. (student 23, level 2)
14) One way is *to classify* it as if it is organic or inorganic matter. (student 27, level 3)
15) Human being *can classify* matter into many groups. (student 12, level 2)

Since such examples are rare in the collected samples and thus may not be significant, we have made no attempt to conduct a detailed analysis of them.

**Conjunction**
Both texts contain one kind of conjunction, *and*, which is additive. But draft 3 has more tokens of this conjunction.
Lexis

Another means of encoding classification is through word choice. In both drafts, two kinds of lexical realization of classification are obvious. One is through the use of a single noun that explicitly entails classification relationships, such as kind, class, group, category, etc.:

16) Plants are a kind of organic [thing]. (draft 1)
17) Algae is a large group of . . . (draft 3)

Both drafts contain three different examples of this kind of lexis.

The second way is through the use of two or more words that are taxonomically related:

18) Plants can be classified as bacteria, algae and seed plants. (draft 1)
19) Pigs and cows are mammals. (draft 3)

In draft 3, there are six more instances of such classification lexis than in draft 1, and all of them are used in conjunction with specific examples of terms.

Nominal groups

In Halliday’s (1994) discussion of the logical structure of the “nominal group”, modification is described or analyzed in terms of taxonomy (subcategorization). The nominal group is considered a major linguistic feature that realizes the semantic relationship of “subcategorization: ‘a is a subset of x’”. This has usually been referred to in the grammar of the nominal group as MODIFICATION” (Halliday 1994: 191). For elaborated taxonomies (or classification), the noun is expanded into a nominal group by pre-modification. For complex nominalization, English uses post-modification. In Werner and Schoepfle’s analysis (1987: 106–10) of folk classification, modification is perceived as an important aspect of the MT (Modification and Taxonomy) schema used to analyze taxonomic relationships.

In both drafts, there is frequent use of nominal groups which help realize classification relationships. But draft 3 makes much heavier use of nominal groups (17 vs. 4), usually when a definition or explanation of a term or concept is given, and expansion of a noun into a nominal group through pre- or post-modification is the main device employed. For example:

20) Everything is made up of matter in organic and inorganic form. (draft 1)
21) Amphibians is an animal that can live either on land or in water. (draft 3)
22) Feathered creatures with two legs and two wings are birds. (draft 3)

This improvement in draft 3 is significant since, in a typical classification text in science, technical terms are not only introduced but also elaborated through definition or description (see Halliday and Martin 1993). It is the elaboration of terms that helps make the student texts much richer in content.
When examining the utilization of nominalization in the data, we can see that the students had problems using relative clauses for post-modification. The errors in the following samples are typical in the writing collected from all students at the draft 3 stage:

23) Anything has weight and take up space is matter. (student 17, level 2)
24) Mammals are things use lungs to breathe. (student 19, level 2)
25) Reptiles are animals have dry skins, have scales and they lay eggs. (student 22, level 2)
26) Mammals which are worm-blooded animals that have backbones and nurses its young. (student 2, level 2)
27) Organic is something has life or used to have life before. (student 33, level 3)
28) Reptiles are that animals can both live in the sea or on the land. (student 28, level 3)

This information obtained through discourse analysis enabled the researchers to identify students’ weakness in a specific textual context and hence makes the task of addressing form–function connections easier in planning future lessons.

Even with identification of many grammatical errors, the above analysis shows that draft 3 is linguistically more sophisticated in that more types and tokens of the same linguistic devices were used. It is worth noting that draft 3 is both linguistically more sophisticated as well as expressing a more elaborated message content.

ANALYSIS OF THE WHOLE CLASS
To obtain a general picture of differences between the 1st and 3rd drafts for the whole class, paired-sample t tests were conducted for 9 variables in the texts produced by the 29 students who submitted both drafts. The differences between the 1st and 3rd drafts taken as a whole were statistically significant (see Table 2).

Table 2 shows that the average number of technical terms introduced in both drafts is similar, but significant differences exist for all other variables. There also are variations between the two levels of students. Content-wise (variables 8 and 9), greater change is indicated for level 2 students. In terms of linguistic differences, level 2 students demonstrate greater improvement in the use of generic references, relational transitivity process, and additive conjunctions, while level 3 students show greater improvement in the use of single lexical items that explicitly entail classification relationships.

Regardless of the differences between the two levels of students, the KS analysis seems to indicate a strong correlation between content elaboration (represented by variables 7 and 8) and sophistication in language use (variables 1–6). When improvement in the use of linguistic devices is significant, so is the improvement in content construction. We will compare the texts by two students to further illustrate this relationship. Table 3 provides a language and content comparison of the two drafts from student 17 and student 33.
### Table 2. Means and significance for paired differences of variables for drafts 1 and 3 for the whole class

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L2</td>
<td>L3</td>
<td>Mixed</td>
<td>L2</td>
</tr>
<tr>
<td>1) Reference (generic)</td>
<td>−23.26</td>
<td>−22.10</td>
<td>−22.86</td>
<td>10.94</td>
</tr>
<tr>
<td>2) Transitivity (relational)</td>
<td>−1.26</td>
<td>−2.10</td>
<td>−1.55</td>
<td>1.45</td>
</tr>
<tr>
<td>3) Conjunction (additive)</td>
<td>−0.74</td>
<td>−1.00</td>
<td>−0.83</td>
<td>0.73</td>
</tr>
<tr>
<td>4) Lexis (single word)</td>
<td>−1.00</td>
<td>−1.00</td>
<td>−1.00</td>
<td>1.45</td>
</tr>
<tr>
<td>5) Lexis (2 or more words)</td>
<td>−16.53</td>
<td>−21.30</td>
<td>−18.17</td>
<td>9.98</td>
</tr>
<tr>
<td>6) Nominal groups</td>
<td>−7.11</td>
<td>−7.30</td>
<td>−7.17</td>
<td>6.53</td>
</tr>
<tr>
<td>7) Terms introduced</td>
<td>−0.42</td>
<td>−1.70</td>
<td>−0.86</td>
<td>2.36</td>
</tr>
<tr>
<td>8) Terms defined</td>
<td>−8.74</td>
<td>−8.80</td>
<td>−8.76</td>
<td>3.28</td>
</tr>
<tr>
<td>9) Terms exemplified</td>
<td>−3.74</td>
<td>−5.10</td>
<td>−4.21</td>
<td>2.58</td>
</tr>
</tbody>
</table>

df: L2 = 18, L3 = 9, Mixed = 28

significance (2-tailed): ** = p ≤ .001, * = p ≤ .01
<table>
<thead>
<tr>
<th>Variables</th>
<th>Student 17</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Draft 1</td>
</tr>
<tr>
<td>Linguistic devices</td>
<td></td>
</tr>
<tr>
<td>1) Reference (generic)</td>
<td>20</td>
</tr>
<tr>
<td>2) Transitivity (relational)</td>
<td>6</td>
</tr>
<tr>
<td>3) Conjunctions (additive)</td>
<td>1</td>
</tr>
<tr>
<td>Lexis 4) Single word signifying classification relationships</td>
<td>3</td>
</tr>
<tr>
<td>5) Two or more words that are taxonomically related</td>
<td>16</td>
</tr>
<tr>
<td>6) Nominal groups: expansion of head nouns through modification</td>
<td>4</td>
</tr>
<tr>
<td>Content information</td>
<td></td>
</tr>
<tr>
<td>7) Terms included</td>
<td>16</td>
</tr>
<tr>
<td>8) Terms defined</td>
<td>2</td>
</tr>
<tr>
<td>9) Terms exemplified</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3. Language and content comparison for drafts 1 and 3 by student 17 and student 33
Content-wise, student 17 made much greater progress in draft 3, dramatically increasing the number of conceptual terms that were defined and exemplified, while for student 33 the increase in defined terms was small and there was even a decrease in exemplified terms. In terms of language improvement, the table shows that student 17 increased the number of different uses of three linguistic devices more significantly than student 33 (variables 1, 5 and 6).

This comparison strongly indicates that content construction in science and development in language use are interrelated and interdependent in science writing. On the one hand, the science knowledge a student constructs very often determines his or her selection of the grammatical resources used to express it. For instance, when students do not realize that classification in science is usually constructed through definitions and examples or are not equipped with the conceptual knowledge necessary for being able to define and exemplify, the use of generic references, nominal groups and taxonomically related lexical items is limited. On the other hand, the linguistic capability of the students has a great impact on the way that the students construct their knowledge. For example, when students feel uncomfortable using relative clauses as a form of nominalization, a device widely used when terms are defined in science, definitions may not be provided properly or at all, which is likely to result in a lack of elaboration in content knowledge construction.

Conclusion

The study shows that knowledge structure analysis as a theoretically motivated approach is useful as an evaluation tool for young ESL teenagers. What was learned by the participants in the study comprises both language learning (mainly in the form of discourse features of scientific writing) and content learning (in the form of scientific concepts). From this double perspective on the nature of learning in the context of school science for ESL students, drawing upon a conscious and theory-based articulation of the relationship between wording and meaning, we have successfully used knowledge structure analysis to address the challenge of linking language and content in evaluation. By illuminating the relationship between classification discourse and the graphic representation of classification, we made the connection between understanding of science content in terms of knowledge structures and the language difficulties that L2 learners may face.

There are limitations of the study which may point to directions for further research. The analysis focused on only one type of knowledge structure in student written discourse – classification – while there are many other important knowledge structures encountered in a school setting. How this kind of approach works for other types of knowledge structure remains a question. In addition, the analysis was conducted in the context of school science and may provide limited understanding of students’ classification discourse in other subject areas. Finally, while the study revealed a difference in writing and knowledge
development between students at different language proficiency levels, it did not investigate why such variation exists. Findings from further research are very likely to provide useful diagnostic and instructional tools for classroom teachers.

While not focusing on discrete errors in isolation, the present analysis tool does allow researchers to identify students’ weaknesses in specific textual contexts and thus provides helpful guidance to diagnostic assessment and instructional intervention. One of the weak areas identified in the students’ written language is the use of relative clauses. Since the relative clause, often used as post-modification in nominalization, is an important linguistic feature in classification discourse, this could be a focus for future instructional planning. It is worth pointing out that what is suggested here is not a focus on grammar in decontextualized examples, but rather an emphasis on using “grammar as resource” (Schleppegrell 1998) to help students strengthen their language capability to produce more successful classification discourse.

There are several related issues which are beyond the scope of this article. While we believe that the ultimate purpose of assessment is to facilitate learning, we need to look into how improvements in linguistic sophistication and the learning of content knowledge took place at the same time in a content-based language program. The issue of the role played by classroom instruction requires an examination of the process of integrative instruction. This is a major aspect of the original study, which is discussed in separate papers (Huang 2000, 2002).

A second issue is related to teacher training. This article has demonstrated that an educator wishing to undertake integrative assessment needs knowledge of both content and language. However, it would not be an exaggeration to state that most content area teachers, while being familiar with the content knowledge they teach, are not equipped with sufficient linguistic knowledge to conduct any language analysis in subject area discourse. As Christie (1999) revealed, many of today’s English teachers are also not equipped with sufficient linguistic knowledge to teach the use of the English language, despite our tendency to believe that English teachers are the people best equipped with the knowledge of how language works. The question is where and how our teachers are to gain this knowledge and these skills. With functional linguistics being embraced more and more by educational researchers and scholars, practitioners in places such as Australia, Canada, the United Kingdom, and a number of European countries are making an effort to use functional linguistics to guide their teaching. It would be helpful to develop relevant materials for teachers in different teacher preparation programs that provide an analysis of language features associated with different academic disciplines and offer training with a focus on evaluating both content knowledge and discipline-specific language development. Established work such as that by Mohan (2001), Martin (1990), Martin and Veel (1993), Lemke (1990), and Schleppegrell (1998) may offer a good starting point.

Even though this study is based on an ESL situation, where educators are more ready to embrace both content and language goals, are there implications for other subject areas in non-ESL situations? A brief examination of an
education document of core curriculum content standards produced by the New Jersey State Department of Education (1996) indicates a demand for more attention to language abilities (including both oral and written language) in different subject areas (see Huang 2001). From a socio-cultural point of view, the language used in a particular subject area has to be acquired through engaging in activities in that discipline. With more and more findings from research studies revealing how language and knowledge interact, and with increasing demand for students’ language capabilities in subject areas, educators are confronted with the challenge of integrating language and content in all subject areas. However, the reality is that a science teacher may not be able to clearly articulate how language is used in a unique way in the scientific community to construct and disseminate scientific knowledge. The feasibility of this large-scale integration is daunting, especially at the secondary school level, where subject-area teachers traditionally see language development as lying beyond their responsibility. This is an example of an educational issue that involves the integrating of tradition, philosophy, pedagogy, politics, and reality.

Notes

1. “Traditionally, the term genre has referred to categories of literary texts . . . Recently, however, the term has been employed to refer to much more: to varieties of expository prose, to types of films, and to musical categories” (Johns 1997: 21). In SFL, genres are employed to refer to varieties of texts. For genres used in different subject areas, see Martin and Veel (1998), Lemke (1990), and Halliday and Martin (1993).

2. A term that is also often used to refer to visual representation and organization of information is ‘cognitive mapping’ (see McTighe and Lyman 1988; Armbuster and Anderson 1980; Dansereau et al. 1979; Davidson 1982; Vaughn 1982). In Novak and Gowin (1984: 138), cognitive mapping refers to “a representation of what we believe to be the organization of concepts and proposition in a given student’s cognitive structure. Cognitive maps are idiosyncratic, whereas concepts maps should represent an area of knowledge in a way that experts in that field agree is valid.”

3. The distinction that Cummins (1980) makes between Basic Interpersonal Communication Skills (BICS), which relate to language use in day-to-day familiar contexts with an orientation to social interaction, and Cognitive Academic Language Proficiency (CALP), which are language skills related to language used in formal situations and academic study, has been very influential in the field of TESOL (see Mohan et al. 2001). While it usually takes two to three years for an ESL learner to acquire BICS, research studies suggest that depending on a number of factors, it can take between five and ten years for students to match their English-speaking peers in achievement in subject-matter learning that requires CALP (Collier 1987, 1989, 1995; Cummins 1996).

References


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Appendix

A short reading passage (from Zimmerman 1989) with sample classification language highlighted as a model for students (sentence patterns underlined, lexis italicized)

All matter may be classified as either solid, liquid, or gas. Solids are firm and have a definite form. Rubber, wood, glass, iron, cotton, and sand are all classified as solids. A considerable force would be needed to change the shape or volume of an iron bar, for example, because the atoms or molecules of a solid are densely packed and have very little freedom of movement.

Solids may be further divided into two classes: crystalline and amorphous. Rocks, wood, paper, and cotton are crystalline solids. Crystalline solids are made up of atoms arranged in a definite pattern. When these solids are heated,
the change to a liquid, known as melting, is sharp and clear. *Amorphous substances* include *rubber*, *glass*, and *sulfur*. In these substances, the pattern of the atoms is not orderly, and when heated, they gradually soften.

*Liquids*, on the other hand, are not rigid. If *water*, *milk*, or *oil* is poured on a table, it will flow all over the surface. The atoms or molecules of liquid attract each other and thereby enable liquids to flow. But these atoms are loosely structured and do not keep their shape. Therefore a liquid will take the shape of any container in which it is poured. However, liquids have a definite volume; a quart of milk cannot fit in a pint container.

*Gases*, such as *air*, *oxygen*, and *carbon dioxide*, have no fixed shape or volume of their own. They diffuse or spread out to fill any container. If water is put into a tire, it will run to the bottom; if air is put into a tire, it fills the whole space inside the tire. The atoms or molecules of gases are widely spaced and move very rapidly. They either compress or expand to adapt to any area.

Everything we know is made of matter in solid, liquid or gaseous form. Later in this chapter, we will discuss other ways matter may be classified.