Using Graphic Organizers as a Tool for the Development of Scientific Language[1]

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Abstract

This observational study examines the effectiveness of graphic organizers two elementary teachers in California, United States use to teach the content and the academic language of science. The study was done during the 2006-2007 school year. The data was collected through field-notes and the audio recording of instructional activities, and they were clarified through interviews with the teachers. The cross-case analysis (Borman, Clarke, Cotner, & Lee, 2006) of the two teachers' teaching practices makes clear the different ways in which the teachers' use of graphic organizers supported both the development of content knowledge and language development in science education.

Keywords: science education, academic language, graphic organizers, second language learners (SLLs), instructional activities (IAs), dual language

Resumen

Este estudio de observación examina la eficacia de los organizadores gráficos que dos maestras de escuela primaria en California, Estados Unidos utilizan para enseñar el contenido y el lenguaje académico de las ciencias. El estudio se llevó a cabo durante el año escolar 2006 a 2007. Los datos fueron recogidos a través de apuntes tomados durante las observaciones y de grabaciones audios de actividades de instrucción y fueron aclarados a través de entrevistas con las maestras. El análisis de casos cruzados (Borman, Clarke, Cotner, & Lee, 2006) de las prácticas pedagógicas de las dos maestras aclara las diferentes maneras en las cuales el uso de las maestras de los organizadores gráficos apoyó en ambos el desarrollo del conocimiento del contenido y el desarrollo del lenguaje de la educación en las ciencias.

Palabras claves: educación en las ciencias, lenguaje académico, organizadores gráficos, estudiantes de una segunda lengua, actividades de instrucción (IAs), lenguaje dual

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Since 2000, and more particularly under United States national policies such as the *No Child Left Behind Act*, there has been a move toward a standards-based curriculum and assessments in different areas of the elementary school curriculum, which has prompted adding science to the currently tested subjects of reading, writing, and mathematics (Lee & Avalos, 2002). In this context, the type of literacy that is required for school-related tasks involves not only the development of reading and writing skills, but also the development of more abstract and more demanding language (Scarcella & Merino, 2005). The academic language of science as defined by Snow (2010) uses technical words and complex grammatical structures with a high density of information. The inclusion of science in schools' accountability signals the need to examine the ways the teachers in bilingual classrooms help students learn the content knowledge and the academic language of science. The question guiding this study is: What strategies do teachers use for instruction to help students develop both content knowledge and academic language in science?

To address this question and to contribute to the literature on teachers' practices with bilingual learners in science education, this study examines the strategic practices two elementary teachers use to teach science and the way in which the use of graphic organizers helps the students to develop the academic language of science.

Literature Review

The theoretical framework of this research includes studies relevant to science education with second language learners (SLLs). It is focused mainly on the elementary level (K-5). The literature review is organized into three sections: Firstly, research on elementary science teaching and learning is discussed. Secondly, research on the development of academic language through content is presented and analyzed. Finally, strategic practices for the development of both academic language and content are also discussed.

Research on Elementary Science Teaching and Learning

The role of *constructivism* as it relates to science teaching and learning is of particular relevance to this study. According to Tobin (2000), constructivism is a way of thinking about how students can learn best, depending on the situational context of the learning event, how others can mediate learning for students, and how the activities or tasks provided by the teacher help students acquire the necessary knowledge shaped by their own experiences with the concepts to be learned. According to this perspective, the teaching and learning of science occurs in a *community of practice* in which certain discursive

styles of the participants such as talking, writing, representation, and cognition, are constantly changing.

Learning science concepts with more capable peers who use their own discourse as a springboard for learning, allows students to develop a science-like discourse acceptable to the scientific community. This is similar to the concept of the zone of proximal development (ZPD) developed by Vygotsky (1978), wherein students can arrive at a higher level of understanding by working with a more capable peer or with the teacher, as a mediator of learning. According to Vygotsky, the role of the teacher is to identify the resources available according to students' needs, and to explicitly demonstrate how and when to access those resources for learning purposes. In ZPD, teacher and students need to learn how to interact and communicate with each other, and to use their previous knowledge and experience to learn (Lee, 2008).

Above all, teacher and students should *co-participate* in the classroom community to *co-construct* their knowledge of science. Tobin (2000) explains that students should use what they both know and are able to do as a foundation for the scientific knowledge they are trying to learn in the classroom context. His framework takes into consideration how students can negotiate meaning as they interact with others and with artifacts, how students can demonstrate their knowledge about the subject, and properly express their need for feedback to confirm accuracy. This is similar to what teachers of SLLs need to consider as they work with students on the development of language proficiency.

Research on the Development of Academic Language through Content

Research on language acquisition has shown that language is best learned when it is organized and taught around the content areas (Richard-Amato, 1996; Snow & Brinton, 1997). Disciplinary literacy research and theory shows that students need academic language to be able to perform tasks related to school science (i.e., reading science texts, writing about scientific explorations, and discussing science concepts or activities orally). When teachers work with students who are learning in a second language (L2), they become both content and language teachers. Because of the nature of teaching, the teacher's content knowledge should be coupled with the pedagogical practice of transmitting the strategies and knowledge needed to learn an L2 (Moje, 2007).

Scarcella and Merino (2005) looked at the low performance levels in science (of students of a similar demographic profile to those of our present study) and reviewed effective practices for teaching science to this population. They concluded that "in order to learn science, students

must master the academic literacy that the subject requires" (p. 2). Academic literacy, as presented by Scarcella and Merino, encompasses subject matter knowledge, strategies, and skills which include vocabulary as an essential component. This has several implications for teachers: a) it includes the use of multiple *scaffolds* to help SLLs develop both the language and the content of science, b) it integrates standard-based instruction of language and science content, and c) it incorporates structured and meaningful inquiry-based activities that will help students build their language skills and knowledge of science, among other academic areas.

Strategic Practices for Academic Language and Content Development

Other researchers have also discussed the relationship between science learning and academic language. According to Lee and Fradd (1998), SLLs are at risk of performing poorly in science because they usually lack the linguistic, cognitive, and social behaviors that science learning requires. When teachers plan science units with an *embedded* language arts curriculum, students engage in authentic communicative interaction which both enhances the development of academic language (Lee & Fradd, 1998) as well as their understanding of science concepts. The embedded language arts curriculum also serves to engage students in critical thinking activities (Rosebery, Warren, & Conant, 1992).

Research shows that teachers should use a myriad of strategies to enhance SLLs' understanding of advanced academic concepts across disciplines and they should also facilitate the learning of those concepts (Bentley, 1998). Fradd and Lee (1999) similarly reinforce the idea that appropriate instruction for SLLs, one in which these have the opportunity to construct knowledge through concrete experiences, enhances their proficiency and literacy levels. One of the strategies teachers use are *graphic organizers.*

The use of graphic organizers has at least four purposes in the development of both academic language and content. First, graphic organizers are powerful, easy to implement tools that allow teachers to examine their students' thinking and learning on a particular topic of study (Struble, 2007). Second, a graphic organizer is a visual representation of a concept or topic that helps students sort, summarize, show relationships among ideas, and make meaning from texts (Gallavan & Kottler, 2007). Third, graphic organizers also reveal students' prior knowledge and promote their oral and written participation, all of which facilitate comprehension (Kirylo & Millet, 2000). Fourth, teachers can use graphic organizers to assess ongoing learning and also to design and modify instruction to meet students' needs. Graphic organizers

are particularly helpful for assessing students who are developing L2 skills.

Strategies such as graphic organizers are part of a supportive classroom environment in which thematic integrated instruction is the conduit for the comprehension of science knowledge and for the acquisition of academic discourse in science.

Research Design

This study is designed as a cross-case analysis (Borman, Clarke, Cotner, & Lee, 2006) of two classroom teachers working in a dual-language school. Through an in-depth study of each case, the researcher examines key *instructional activities* (IAs) occurring in these two teachers' classrooms, focusing on students' academic language development during science instruction. The examination of these two teachers' pedagogical practices makes what teachers do to support both the development of content knowledge and language development in science education visible.

Time Frame of the Study

The research was conducted during the 2 semesters of the 2006-2007 school year and was carried out in two phases. Phase one lasted 3 months; during which I collected detailed field notes of both the teachers' instruction and their interactions with students. A second round of observations and interviews lasted approximately 3 months. During that phase, I audio-recorded different classroom instruction events and reflections on practice. The recorded lessons were transcribed for analysis. Analysis was done using all categories from the literature review.

Selection of Site and Teacher Participants

The site. The school selected for the study was Doyle Elementary School (pseudonym). It was selected because of its fulfillment of the following criteria:

- The school was one of the few in the district that had purposefully arranged the schedule to provide time for science.
- It earned standardized exam scores that were similar or slightly higher than other schools in the district that were likewise serving largely low-income students.
- The school administration performed school and district presentations based on analyzed students' data using multiple measures (standardized assessments, portfolios, and district benchmarks). These presentations made it clear that the students who were in different programs performed differently (i.e., students in the dual language strand performed better in all measures by 4th grade).

The school is an inner-city elementary school in a medium-sized city (population of approximately 500,000 inhabitants) in the Central Valley of California. Doyle Elementary School serves low socioeconomic level students from the surrounding community. According to the school website,[3] the student population is 70% Hispanic, 18% Asian, 6% African-American, and 6% White, non-Hispanic. Of the total school enrollment, 53% are considered English language learners (ELLs).

The school has two different program models to serve the needs of the students: English-only classes and *dual language* classes. Of the total school enrollment, one quarter of the students was enrolled in the dual language strand. My study focused on this strand which includes programs that have both native English speakers and speakers of another language. Together these two groups are learning language through content in both English and their native language (Lindholm-Leary, 2003). Doyle Elementary School uses the 90/10 dual immersion program model.[4]

The participants. In this qualitative study, the sampling strategy used is what Gall, Gall, and Borg (1999) refer to as the *criterion* strategy, reflecting a conceptual rationale. Of a total of 32 teachers that work at the selected site, only 9 are teachers in the dual language strand. From the dual language pool of 9 teachers, one teacher in grade 3 and one in grade 5 were selected. The selection of the third grade classroom was based on the consideration that third grade provides the foundation for the transition to a more rigorous fourth grade curriculum where content is more language-demanding. The selection of the fifth grade classroom was motivated by recent state policy mandating that students in fifth grade pass a standardized science test in conjunction with the California Standards Test that focuses only on language arts and math.

Both teachers involved in this project are Latinas who self-identified as having good literacy skills in both English and Spanish. They have very different educational backgrounds and experiences which have shaped their understanding of teaching and learning. Each teacher was considered as a separate case. Both cases provide key information on the importance of the development of academic

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[3] This web-site is not included in bibliography due to the anonymity of the school being researched. If there is any issue that needs to be resolved, personal communication with the author is recommended.

[4] The 90/10 model refers to the amount of time devoted for instruction in each language at the beginning of the program. Students from both language groups are taught in both languages moving from more Spanish instruction at the early grades toward more English in the upper grades. By grade 6, students are receiving half of the instruction in each language.

language in science and on students' possibility for success in Doyle Elementary School.

Data Collection

Multiple sources of data were collected, including: classroom observations, audio-recordings of classroom interactions, teacher interviews, and student work samples, including pictures. A database was created for each teacher. During science class time, my field observations focused on the unit of study and the different elements of the IA to be analyzed. These included introduction to the topic, academic language used in the classroom, materials used to support academic literacy development, strategies such as graphic organizers used for instruction and academic discussions, writing assignments, and hands-on projects. These elements provided a framework for content knowledge and academic language development.

For this study, I focus on two definitions of IA. The more general definition from Merriam-Webster's Dictionary (1998) defines an IA as an organizational unit for teaching. It can take the form of whole-group lecture, small-group dialogue, independent-group work, one-on-one interaction, or individual tasks. I also used Freeman and Johnson's (2005) operational definition of an IA as an "interplay among the actions of participants that creates a meta-level of activity that is a language class in itself" (p. 75). These writers consider that the use of tools (overhead projectors, texts, visual aids, etc.) is necessary to accomplish or to organize activities depending on its purposes.

I performed follow-up informal interviews in order to probe and clarify the data. All the observation notes and the transcribed interviews were coded into themes by data source and then compiled by categories. I used the research question and sub-question to organize the database of each teacher. The research question: What strategies do teachers use for instruction to help students develop both content knowledge and academic language in science? allows for the exploration of a specific sub-question: How do teachers use graphic organizers to develop scientific content-specific and general academic vocabulary as well as higher-order thinking skills?

Table 1 shows the different types of data collected and the data analysis approach used to address the research question.

Table 1
Data Collection Sources and Data Analysis Approach for Each Case

Research Question	Portfolio Data Sources	Data Analysis Approach
What strategies do teachers use for instruction to help students develop both content knowledge and academic language in science?	• observation notes • interviews • audio-recorded instruction	• coded examples of strategies used during instruction • tracked and analyzed teachers' use of strategies during instruction and feedback from observation notes and audio-recorded instruction • coded patterns of teachers' responses to interview questions to clarify classroom instruction

Data Analysis

Data in this study was analyzed in two stages: a *within-case* analysis and a *cross-case* analysis. In the within-case analysis, each classroom teacher was considered to be an individual case. Each case was analyzed using the steps of interpretational analysis presented by Gall, Gall, & Borg (1999). I began by preparing the database which contained all the information collected for each case study. Then, I divided the data into meaningful chunks of information such as student-teacher short dialogues, classroom scenarios of teacher-strategic instruction, students' inquiry discussions, and different artifacts such as teacher-made graphic organizers and pictures. Finally, I created categories from the data or they were developed based on the research described in the review of the literature. During the data analysis procedure, the researcher focused on the identification of the strategies each teacher had used to help students develop the academic language of science across multiple IAs. Both teachers selected graphic organizers as one of the strategies they used in the IAs that focused on the teaching and learning of general academic and content-specific vocabulary as well as critical thinking.

Categorical lenses were used to explain what teachers do to support students' academic language development in English and Spanish in the content area of science. Once findings were identified for each case, the two teachers were compared and contrasted in order to demonstrate how they helped students develop academic language. The two sub-questions that were derived from the research question guided the focus of the analysis.

Findings

It is clear from the analysis of the data that each teacher used a variety of instructional strategies that encompassed the four language learning skills (listening, speaking, reading, and writing) to support her students' development of academic language in the IAs in science. Based on the definitions of an IA by Mirriam-Webster's Dictionary (1998) and

Freeman and Johnson's (2005) described earlier, Table 2 illustrates the use of graphic organizers for the development of academic language in two selected instructional activities (IA1 and IA2) by both teacher-participants involved in the study; the initials T1 represent the third grade teacher, Mrs. Lee, while T2 is used for the fifth grade teacher, Mrs. Saldana. This table takes into consideration the above mentioned definitions, and reflects a total of 42 different lessons which were observed and/or audio-recorded during the course of a year.

Table 2

Cross-case Analysis of the Used of Graphic Organizers by Each Teacher during Two Different IAs

Instructional Activity		**IA1**		**IA2**	
Focus	*Strategies*	*T1*	*T2*	*T1*	*T2*
content-specific vocabulary	graphic organizer	**x**	x	x	x
general academic vocabulary	graphic organizer	x	x	x	x
higher-order thinking	graphic organizer	x		x	

The following discussion provides an analysis of the use of graphic organizers for the development of the academic language of science by each teacher in the selected IAs as presented in Table 2. Examples of classroom dialogues and excerpts from interviews are used to exemplify the analysis and justify the findings. First, Mrs. Lee's examples are presented and discussed. Second, Mrs. Saldana's excerpts from her IA are analyzed. The analysis of these teachers' strategic teaching practices is twofold in that it focuses on the use of graphic organizers that foster both vocabulary building and higher-order thinking.

Mrs. Lee's Focus on Vocabulary Building and Higher-Order Thinking

The IAs presented and analyzed here from Mrs. Lee's classroom are part of multiple lessons from a long-term unit on ecosystems. Throughout this theme, students learned about the different habitats; including the animals, plants, and climate types that exist in each one. The topic of the first IA was "characteristics of the tropical rainforest." The second IA contextualized the concept of tropical rainforests with a discussion about different types of forests, and a focus on the age of trees. Through these activities and by reading different types of texts, using and discussing graphic organizers with color-coded information, as well as using scaffolded questioning techniques during scientific explorations, Mrs. Lee provided students with multiple opportunities

to discuss, develop, and acquire content-specific and general academic vocabulary, as well as opportunities to think critically about scientific concepts and language. Table 3 exemplifies Mrs. Lee's uses of strategies with a focus on vocabulary building and higher-order thinking during IA1. (T = teacher, S = student)[5]

Table 3
Analysis of Mrs. Lee's IA1 (translation from the Spanish)

IA1 Topic: Describing the tropical rainforest	Strategies	Data which supports findings
Focus on content-specific and General academic vocabulary. It fosters higher-order thinking as the students discuss language embedded in science content.	reading	Uses informational texts (*Dentro de la Selva Tropical*) to provide a foundation for the language activity.
	graphic organizer	**1. Helps students develop higher-order thinking skills as they discuss and complete the graphic organizer.** T: Now I want you to think of a descriptive map. As a group we are going to complete a descriptive map using all the adjectives that describe the tropical rainforest. We need to remember that we can circle the words that describe the tropical rainforest in the text and then discuss the importance that those words have in relation to the theme of study. Who could think of a word that describes how the tropical rainforest is? (2007, L OBS 21) **2. Makes connections to students' first languages through the use of cognates. A discussion about different types of cognates provided students with tools to comprehend texts better.** T: Who could think of a word that describes what the tropical rainforest is like? S1: It is dense. T: What does *dense* mean? S2: That there are lots of trees and you cannot even walk. T: Okay . . . and in English . . . Is there any word, a cognate that has the same meaning? S3: Very dense. T: Dense is the cognate and it means very, very crowded . . . (2007, L OBS 21) T: I liked the word that María used. Please, María, could you repeat the word you just said? S11: Colossal. T: What would be a synonym for *colossal*? S12: Gigantic T: Very good, and a cognate? S11: It is the same . . . T: Yes, it is almost the same. It has one more *s*. As you can see, some cognates have almost all the same letters, some have parts of the word that are the same, and others are totally similar and they are only pronounced differently. Always remember that. Well, now we have enough adjectives to describe the rainforest. Let's read it together. T and Ss: The rainforest is hot, dense, humid, important . . . (2007, L OBS 21)

[5] Inserted in the transcription of the table is some information about how the data was collected. For example, (2007, L OBS 21) means that the dialogue was recorded in 2007 during observation #21 in Mrs. Lee's classroom (represented by an *L*).

Excerpts from the audio-recorded lessons and classroom observation notes provided the data for this analysis. The IA1, which describes the tropical rainforest, started with the teacher reading aloud the book *Dentro de la Selva Tropical* [Inside the Tropical Rainforest,Willow & Jackes, 1993]. Because each page of the book presented a selection of plants and animals that live in the tropical rainforest, an added opportunity for oral language development and content-specific knowledge was provided. After the teacher read the book to the class and they finished with the academic discussion, the students were asked to gather at the rug area to create a graphic organizer using the shared knowledge from the whole class.

As students focused on features of language and learned new vocabulary through this IA, cognitive development was also activated while they completed the descriptive graphic organizer. The informational text on the tropical rainforest provided a context for the academic language discussion. Dickinson and Tabors (2001) demonstrate that oral language practice through meaningful activities serves as the input for data that learners internalize and use to express their own meanings in their interactions with others. Mrs. Lee's communicative exchange with students supports this claim and shows her understanding of the interplay between language, and content teaching and learning. The same interplay is shown in the analysis of the second IA, which is discussed in the following paragraphs.

Mrs. Lee's second IA is part of the long-term unit on ecosystems. The focus of this activity is on the age of trees contextualized in different types of forests. Table 4 represents the analysis of the strategic teaching in Mrs. Lee's classroom. We observed findings which are similar to those of the analysis of the activity. I use examples and excerpts from observation notes and tape-recorded lessons to exemplify the categories used.

Table 4
Analysis of Mrs. Lee's IA2

IA2 Topic: The age of trees	Strategies used	Data which supports findings
Focus on content-specific and general academic vocabulary. It fosters higher-order thinking as the students discuss language embedded in science content.	reading	Science article to confirm and disconfirm predictions made during the scientific observation about age of trees
	graphic organizer	**Develops higher-order thinking skills through the completion of the circle map graphic organizer:** T: What is a circle map? S1: We use it to describe what we are studying. T: Ok . . . It helps us organize ideas about the topic being studied. Now we are going to complete this circle map about the age of trees. It is important that you remember what we read this morning. (2006, L OBS 9) (The teacher reviews the concepts learned on the topic of tree growth which involved the question: *How do we know the age of a tree?* She creates a graphic organizer using students' responses using color-coded information for the improvement of sentence structure, to better convey scientific understanding). T: Please, pay attention and participate in the discussion. I am going to use the color blue to write your ideas and the color red to add new ideas as well as the science vocabulary that you have learned . . . We need to practice the best way to write sentences that can express the meaning of the ideas that we have learned about the theme. Let's see . . . How do we know the age of a tree? S3: Yesterday, when we saw the tree trunk, we saw the rings . . . The rings tell the age of a tree. T: Very good, and . . . Could you describe the rings? S4: The rings are big and small. T: The rings are . . . big or *wide*? Which word best expresses what we want to say about the rings? S2: Wide. T: Ok, I will write here the word *wide* in red to point out that there is another word that best expresses the meaning of what we want to say. And, what else do we know about the size of the rings? S5: The rings are big . . . wide or small because of the amount of water. T: Let's see . . . José, explain once again this idea to us . . . What relationship exists between water and the size of the rings? S1: It depends on how much water the trees drink . . . When they have a lot of water, the rings are big, and if they do not have water, they are small. T: Fine then . . . The size of the rings depends on the amount of water that they will absorb per year. Here we will replace *how much water* for *quantity of water,* to write like the scientists do. Do you agree? S4: Yes. T: What do we call the rainless season? Ss: (silence). T: Remember what we read yesterday. The informational text told us that the rainy season and the season of d____ affects the growth of the trees. S8: Oh . . . the drought! T: Vey good . . . The drought season affects the growth of the trees . . . What do you think about it? [. . .] During the drought season, will the rings become thinner or wider? S3: Thinner . . . *smaller* because they did not drink too much water. T: Ok, then . . . On the circle map I will write the sentence in blue and the word *thinner* in red because it is the word that we have been discussing. Then we write "the thinner rings represent the growth of the tree during the drought years." (2006, L OBS 9; translation from Spanish)

This IA has multiple layers of analysis including: questioning techniques, content-specific vocabulary, discussions about sentence structure, as well as a review of science concepts which were previously learned. It exemplifies the high level of integration of academic language with science content that Mrs. Lee manages in her pedagogical practice. The following section presents examples of Mrs. Saldana's IAs and the strategic practices she uses to teach both language and content in science.

Mrs. Saldana's Focus on Vocabulary Building and Higher-Order Thinking

In Mrs. Saldana's case, data were collected from a pool of 18 audio-recorded lessons, 24 observed lessons, and 2 interviews done in a 2-semester period. The two examples used here were judged as being representative of most of Mrs. Saldana's lessons and activities. The following criteria were used: classroom arrangements, instructional materials used for lesson delivery, the format of the lesson, communicative exchange between the participants, and the focus of the lesson. The first activity presented here is part of a life science unit on the body's systems. This activity was planned for the science block and was organized as an introduction or background knowledge builder for the rest of the unit which discussed multi-cellular organisms, the skeletal, muscular, circulatory, respiratory, digestive, and nervous systems.

The lesson began with students following along with the text as they listened to a tape about the body systems. Here, Mrs. Saldana used a trade book, *Inside your Body* (Freed & Hill, 2004), to provide an opportunity for understanding for all of her students. This book, from the collection *Reading A-Z*, had pictures for clues and was accessible to all of the reading levels in the class. Once students finished the listening activity, Mrs. Saldana introduced the *brace map* and explained that it was an appropriate graphic organizer to use for analyzing whole objects and its parts. Mrs. Saldana displayed the graphic organizer on the overhead projector for students to fill out as they came to the front, selected the picture of a part of the body, and placed each part where it belonged in the human body figure. Once they completed both the figure and the graphic organizer, students returned to their seats. During this activity, Mrs. Saldana and the students discussed the functions of each system of the human body, defined each system broadly, and provided examples to make connections to the readings. Table 5 shows the analysis of the graphic organizer used by Mrs. Saldana and the students during IA1.

Table 5
Analysis of Mrs. Saldana's IA1

IA1 Topic: The body systems	Strategies used	Data which supports findings
Focus on content-specific and general academic vocabulary. It fosters higher-order thinking as the students discuss language embedded in science content.	reading	Students follow along with the text as they listened to the book *Inside your Body* (Freed & Hill, 2004) on tape.
	graphic organizer	Target advanced skills, build schema they discuss, and complete the graphic organizer using visuals, labels, and the text. **1. Teacher explicit explanation:** Root words and cognates were pointed out so that students could make connections among them: skeletal– skeleton glands– *glándulas* stomach– *estómago* intestine– *intestino* circulatory– circle (Blood moves in a circle through the veins and arteries around the body). **2. Group discussion:** S2: Yes, the human body is made of different systems . . . they are all systems. T: Yes! The word *system* is a pattern . . . so each system will perform a specific function. What is the function of the circulatory system? S: To carry blood. T: Yes, *circulatory* comes from the word *circle* and it means that the blood goes around the human body in circles many times a day. (2006, S OBS 11)

The information in this table reflects Mrs. Saldana's emphasis on academic science concepts and vocabulary development. At many points in the IA, Mrs. Saldana used different strategies to teach scientific information about the human body and its systems, reinforcing language skills and reviewing content.

A similar analysis is done with the second physical science IA which was on matter, volume, weight, and chemical reactions. The lesson started with an overarching question to use for students to focus their reading and discussion: *¿Cuáles son las propiedades físicas de la materia?* [What are the physical properties of matter?] Table 6 summarizes the analysis of IA2 and provides examples from the data to support the analysis.

Table 6
Analysis of Mrs. Sadana's IA2

IA topic: Physical properties of matter	Strategies used	Data which supports findings
Focus on content- specific vocabulary. It fosters higher-order thinking as the students use features of academic texts to identify academic language embedded in science content.	graphic organizer	T: Matter . . . Write *matter* on the first line of the graphic organizer and check if you have space to write the definition. What is the definition of *matter*? S: It is something that has mass and takes up space. T: Oh . . . I am looking at Jazmín . . . She went back to the text and saw that the word *matter* was in bold and highlighted with yellow and the definition is given to us in that sentence directly. T & S: Matter is anything that has mass and takes up space. (2007, S OBS 36; translation from Spanish)

As described in Table 6, Mrs. Saldana used multiple strategies to help students understand concepts better. These strategies ranged from contextualizing the instruction and building students' schema through the use of a graphic organizer, to making multiple connections, and were useful in bringing the difficult material to life. All the actions that the students and the teacher engaged in demonstrate the complexity of many of the IAs that occur simultaneously in every classroom. Mrs. Saldana's classroom is no exception. Here, students use reading strategies to find information in the text, complete a graphic organizer, discuss content-specific vocabulary with their neighbor, and share definitions orally as they use different tools such as an overhead projector, textbooks, etc., to accomplish the task. Multiple cognitive domains are activated as students define key terms, search for information, and represent the information from the text in a different form through the graphic organizer. This multiplicity fosters the development of higher-order thinking skills.

Unpacking the Findings of both Cases

Through the cross-case analysis of the two IAs of both teachers, it is clear that both of them pre-taught vocabulary, focused on definitions, and had oral discussions with students about the content vocabulary they needed to learn. The teachers made connections to prior knowledge and students' personal experiences to enhance comprehension of difficult concepts. They also pointed out cognates and did extensive readings from a variety of sources to enhance comprehension of the key terms and scientific concepts.

A difference evident between the two teachers was the degree of depth and complexity that each one used in the teaching of vocabulary. Mrs. Lee used an inquiry-based approach to frame the teaching of science vocabulary. She created multiple-layered activities where students were able to learn the vocabulary in context. She activated

students' cognitive processes by using color-coded information and graphic organizers to help students acquire the vocabulary needed to perform well in scientific tasks. On the other hand, Mrs. Saldana used reading to frame her instruction of content-specific vocabulary. She read to and with the students and focused on finding definitions in the text. Her expectation for students was that they would be able to respond to questions as the reading progressed based on their new understanding of key content words.

In both of the classes, I observed an emphasis on the use of graphic organizers. Both teachers used graphic organizers, but they used them for different purposes and with a different degree of complexity. Mrs. Lee used graphic organizers with the goals of activating students' *metacognitive* processes such as categorizing different types of ecosystems and of developing their metalinguistic skills. For example, she worked to help them understand the use of specific terms and correct syntax in order to express scientific ideas more clearly. Mrs. Lee used graphic organizers for different purposes from those of Mrs. Saldana. She used them to compare and contrast key scientific concepts; to describe the characteristics of scientific phenomena which students were studying; to categorize information; and to organize ideas for a science report. In addition, students were challenged to discuss at the metacognitive level what type of graphic organizer better served the purpose of the activity. Through *wonder* and metacognitive questions, Mrs. Lee helped students develop higher-order thinking skills as they completed different types of graphic organizers.

Conversely, in Mrs. Saldana's class, only one type of graphic organizer was used. In both IAs analyzed, Mrs. Saldana used a brace map, a visual representation which utilizes braces {like these} to identify the physical parts of a whole object, developing part-whole reasoning skills (Struble, 2007). Mrs. Saldana used the brace map to categorize information and describe concepts such as different systems of the human body and properties of matter: density, solubility, weight, mass, and volume. While Mrs. Saldana used these graphic organizers often, they were used as a fill-in type of activity to record concepts that students needed to learn for a test. The graphic organizers were provided by the teacher and were completed by the students as the teacher read to or with them from different resources. Students at this grade level were not able to discuss the value of each graphic organizer in consideration of the purpose of the activity. Students were encouraged to use the graphic organizers to prepare for the test and for their few writing opportunities they had during this unit being studied.

In sum, both teachers used graphic organizers effectively but with different degrees of depth in the application. This dissimilar use

of graphic organizers by each teacher in the study supported students in their development of higher-order thinking skills, the enhancement of vocabulary acquisition, and the development of their academic language of science. It also provided diverse opportunities for the development of the academic knowledge of science as the students reasoned, talked, and developed their scientific literacy in different instructional contexts.

Conclusion

Contrastive analyses across the two teachers' data made it clear that in order to support student learning of academic language and science content, the teachers needed to have a wide range of content, pedagogical, and linguistic knowledge. The examples used in this paper demonstrate the effectiveness of using graphic organizers with students who are simultaneously developing language and content in an L2. The study showed that graphic organizers in particular were tools that allowed both teachers to examine their students' thinking and learning on the topic which the class was studying (Struble, 2007).

Also, the creation of a visual representation of a concept or topic through the different graphic organizers used by both teachers helped their students sort, summarize, show relationships among ideas, and make meaning from texts. Moreover, through the use of graphic organizers, teachers were able to connect with students' prior knowledge and promote the active oral and written participation of all of their students to facilitate comprehension, regardless of levels of linguistic proficiency. Lastly, both teachers used graphic organizers to assess ongoing learning, and for designing and modifying instruction to meet students' needs. Therefore, graphic organizers were proven to be useful in a future-focused view to improving educational situations, such as the ones examined in this article.

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