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MULTIMODAL TASKS TO SUPPORT SCIENCE LEARNING IN LINGUISTICALLY DIVERSE CLASSROOMS: THREE COMPLEMENTARY PERSPECTIVES

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Abstract

MULTIMODAL TASKS TO SUPPORT SCIENCE LEARNING IN LINGUISTICALLY DIVERSE CLASSROOMS: THREE COMPLEMENTARY PERSPECTIVES

Preetha Krishnan Menon

English Language Learners (ELLs) is the fastest growing segment of the public school population. Today's schools face unprecedented challenges in preparing ELLs as they lack instructional supports and fair and valid assessments to support academic learning in classroom settings. This study invokes the principles of design-based research, where both qualitative and quantitative data were triangulated and analyzed to further advance the theory of multimodality and assessment within a sociocultural perspective for linguistically diverse students in two sixth grade classrooms during a unit in photosynthesis. The main research question guiding this study: *How do multimodal tasks support science learning in linguistically diverse classrooms?* This question leads to three main perspectives, first I examine the two teachers' perspectives on the use of multimodal tasks, next the students' perspectives on the use of multimodal tasks and finally using a science and language learning rubric, which I created, I examine student learning in the classrooms based on students' English learner status and proficiencies in English language arts, science, and vocabulary acquisition and usage. The teachers used some multimodal tasks to communicate ideas and the students created visual diagrams and comic strips to represent their understanding of photosynthesis. Results show the specific scaffolding strategies used by the teachers during the tasks, like analogies, contextualization of

vocabulary use, re-representation of ideas through different modes and re-representation of modes in every task were also appropriated by the students. Rubric scoring indicated ELLs had the highest gains in the scores in the visual diagrams, redesignated students had the highest scores in the comic strip and those designated as above proficient in language arts and science had the highest scores in final visual diagram, indicating how ELL status, proficiencies in language arts and science influence the integration of science and language learning. With the advent of Next Generation Science Standards and related assessments, the findings illustrate the importance of aligning the multimodal tasks to learning goals, weaving links amongst the multimodal tasks, modeling the use of representational tasks for ELLs to integrate the understanding of science content and language and assessing students' learning over time using visual representational tasks.

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CHAPTER 1: INTRODUCTION

My research examines the use of multimodal tasks in science classrooms by exploring ways in which they can be used to support learners from culturally and linguistically diverse backgrounds. In this chapter, the introduction to my dissertation, I describe how sociocultural theoretical orientation, through a Vygotskian lens, provides a more nuanced approach on how multimodal tasks can support learning. Finally, I provide an overview of my dissertation design —single mixed-methods with some elements of design-based research, a brief summary of each chapter with their unique methodologies, and how the findings complement each other to provide a unique perspective on the use of multimodal tasks in linguistically diverse science classrooms.

Theoretical Orientation

The ideas central to this research proposal include the notion of multimodality, the use of assessment in science classrooms, and the interaction of these components for supporting science learning for linguistically diverse learners including English language learners (ELLs). My research speaks to the construction of science knowledge in a classroom setting with culturally and linguistically diverse students. Hence, I approach this study through a sociocultural lens, wherein learning and knowing is construed as fundamentally social (Gutierrez & Rogoff, 2003; Lave & Wenger, 1991; Vygotsky, 1978). Having a sociocultural theoretical perspective provides a lens on examining how teachers and students use the multimodal tasks to support science learning. Furthermore, an interpretive lens can reveal the intended and unintended consequences of the classroom-based assessment (Andrade, 2013).

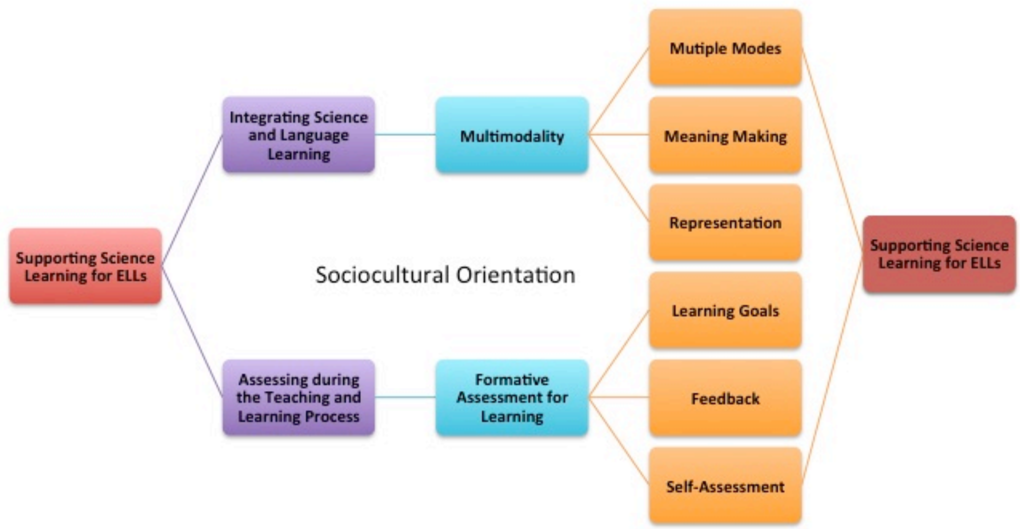

Figure 1. The schematic representation of the conceptual model of integrating and assessing science and language content for science learning.

Sociocultural Learning

A sociocultural lens construes learning and knowing as fundamentally social (Gutierrez & Rogoff, 2003; Lave & Wenger, 1991; Vygotsky, 1978). According to Vygotsky (1978), "Learning is a necessary and universal aspect of the process of developing culturally organized, specifically human, psychological functions" (p. 90).

Learning is mediated between a person and other people and their cultural artifacts (interpsychological plane), then appropriated by individuals (intrapsychological plane; Wertsch, 1979). Vygotsky posited that an initial understanding of concepts can provide the basis for the subsequent development of highly complex internal processes in students' thinking. Within the sociocultural perspective, learning is constructed through joint activity between teachers and students rather than being transmitted from teacher to student. In a classroom, learning on the interpsychological plane often involves mentoring by more culturally knowledgeable persons such as teachers or peers through the process of scaffolding (Bruner, 1975; Cole & Wertsch, 1996). While Bruner (1975) used the term *scaffolding* to describe how young children are provided with informal instructional formats within which they develop oral language skills, Wood, Bruner, and Ross's (1976) idea of scaffolding parallels the work of Vygotsky, where scaffolding includes an expert assisting a novice.

Congruent with the idea of scaffolding is the concept of the zone of proximal development (ZPD) advocated by Vygotsky (1978) in the theoretical foundations of sociocultural learning. Vygotsky described the ZPD as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers" (p. 86). In science classrooms, teachers can help students move through their ZPD by using multiple aspects of oral and written language, multiple strategies for language support such as using informal and formal styles of language, and multiple modes of representation (gestural, oral, pictorial, graphic, and textual). Chaiklin (2003) posited that new psychological functions, like conceptual understanding, develop in conditions where a child's current capabilities and possibilities are challenged by the current learning contexts. This idea resonates with the tenets of assessment for learning or formative assessment, which emphasizes the value of knowing where the students are, where they are going, and how to get them there. It can be assumed that using multimodal tasks in a science classroom as formative assessment can help the students to learn on two levels—developing local expertise about the task and learning how to structure his or her own learning and reasoning, as Black (2013) cited Wood et al.'s (1976) sociocultural perspectives on learning.

Vygotsky (1978) described the importance of language in helping students distinguish between *scientific concepts*, which they learn consciously through language, and *everyday concepts*, which children are socialized to understand unconsciously (p. 168). So one of the goals for teachers in science is to move students from everyday ways of thinking and talking about natural phenomena to the construction of more scientific ways of thought and expression (Vygotsky, 1978). Academic language or language used in classrooms builds on and modifies everyday language and the thinking that it reflects (Vygotsky, 1978). Martin and Veel (1998) suggested that abstractions that are central to subject-specific discourses must be seen as tools through which a subject can be understood. Hence, engaging students in multimodal science tasks can provide for a basis for an initial understanding of concepts and move from everyday and informal language to subject lexicons to express their understanding of concepts.

Assessment. Working from a sociocultural stance, it is important to have a teaching and learning environment that fosters productive interactions among students and teachers and includes tasks that can be used for assessment (Cowie, Moreland, & Otrel-Cass, 2013). So paying attention to the social and cultural contexts of learning and assessment will contribute to validity and fairness in assessing for science learning. In assessment this involves having a dynamic and distributed view of assessment (Gipps, 1999, p. 273). Vygotsky (1978) argued that because learning takes place in the ZPD, teaching should extend the student beyond what he or she can do without assistance but not beyond the links to what the student already knows. This extending is congruent with the idea of formative assessment for learning. In this study, multimodal tasks will be used to assess learning in which both the task and the process of using the task will be assessed, *a dynamic view of assessment.* When multimodal tasks are used as formative assessment for learning, the *distributed notion of assessment* enables both teachers and students to use the tasks as guides for the next steps of teaching and learning. Further alignment with the distributed notion of assessment is connected with how students appropriate the various multimodal tasks as tools for learning and how teachers can use these tasks as scaffolds, which provides support and guidance to help students achieve what they cannot do alone (Wood et al., 1976).

Bennet (2011) critiqued the lack of theory of action in most research in formative assessment in science and claimed that a lack of theory can lead to use of formative assessment as objective evaluations, similar to summative tests. However, Black and Wiliam's (2006) retrospective analysis of their projects on formative assessment revealed the usefulness of examining the intersection of classroom assessment and cultural historical activity theory. They described the classroom as an activity system where the tools and resources for formative assessment included the ideas for the subject matter; methods for framing formative aspects of interaction were questions and feedback; subjects included teachers and students, either in a group or as individuals; and the objects or outcomes were the teacher's expectations. Bell and Cowie (2001), Cowie (2005), and Cowie et al. (2013) placed their studies on formative assessment in science in a sociocultural perspective as well—they analyzed the interactions, the artifacts produced by the students, and the appropriation of multimodal resources over extended periods of time in the science classroom. Examining formative assessment from a sociocultural perspective in a classroom provides a way of supporting interactions within a subject matter using different resources for assessing within the learning objectives of the lesson. Hence, in this study, the use of the multimodal tasks by the students and teachers will create opportunities to assess and support science learning.

Multimodality. Another aspect of the sociocultural perspective of teaching and learning means studying the world as scientists do and "learning the socially learned cultural traditions of what kinds of discourses and representations are useful and how to use them" (Lemke, 2001, p. 298). Besides language being a tool to learn about the natural world, mathematical, visual, and graphic modes combined with written and oral elements represent the inherent features of both science and science learning. Therefore, multimodal tasks used to support science learning can have an ever-shifting range of possibilities that are dependent what a student already knows, the nature of the task to be learned, the activity structure in which learning takes place, and the quality of students' interactions with others, including peers and teachers.

A sociocultural interpretation of teaching and learning points out that when children share in cultural activities, they can be inducted into ways of knowing and appropriate values, skills, and knowledge that are enacted (Wells, 1999). So while engaging in the activities of the science classroom, it is possible to appropriate the language of the science classroom, which includes both modality—"multiple aspects of the oral and written channels through which language is used"—and registers—"the multiple features of students' and teachers' language use in the classroom while engaged in science and engineering practices" (Lee, Quinn, & Valdes, 2013, p. 8).

The goal of instruction in science should be to equip students with the content knowledge assumed necessary to pursue science, regardless of whether they plan to do so. From this perspective, subject-matter teaching depends on ways of engaging with disciplinary language and text. Norris and Philips (2003) argued the following:

> When it is also recognized that science is in part constituted by text and the resources that text makes available, and that the primary access to scientific knowledge is through the read of texts, then it is easy to see that in learning

> how to read such texts a great deal will be learned about both substantive science content and the epistemology of science. (pp. 236–237)

Learning is enabled when students are able to effectively negotiate between everyday discourse, cultural discourse, and the discourse of the scientific community, and develop explicit understanding of the norms of science knowledge production and communication. The notion of multimodality in science ascribes to this tenet of learning. However, Moje (2007) cautioned that the current theorization of using social semiotic theory in multimodality does not address the important details of how students are able to articulate the "thematic patterns" in a science lesson (Lemke, 1989, p. 137). An examination of the finer elements of a representation of a mode—a fine-grain analysis—may enable researchers to analyze how the various compositions and configurations thematically give rise to different meanings as interpretation (Tang & Moje, 2010). By claiming that a "multimodal approach assumes that the different modes have different affordances," it will be useful to examine how the different modes afford learning, which mode supports the best form of communication, or whether particular combinations of modes afford learning (Kress et al., 2006, p. 175). Moreover, Kress, Charalampos, Jewitt, and Ogborn (2006) argued that such an approach will also give a clearer perspective on what and why the teacher does a particular thing at a particular point in the classroom. So it is important to include data about how students and teachers make meanings from the various multimodal elements, including spoken words and gestures, of their representations (Lemke, 1989). Therefore, a sociocultural approach may allow researchers to examine the nuances of meaning made by teachers and students as they work with graphic and print representations, may generate further insights into how students learn scientific concepts, and may develop content area literacy in the process (Ford, 2008).

Science learning for linguistically diverse learners. The common rhetoric of educational reformers is that all students in science classrooms should be engaged in the activities or practices of scientists, rather than just learning about the results of those practices. From a sociocultural perspective, language is a medium or tool for learning. Most children use language while engaging and participating in social activities, during which language is appropriated (Lantolf, 2011). For ELLs, this use means they are engaging in the language of the science classroom through a language that they are still acquiring (Lee et al., 2013). In many classrooms, it is true that English language learners may develop a fair amount of oral fluency in English. But when it comes to the usage of language in academic settings, like science classrooms, ELLs may still struggle (Cummins, 1981; Valdes, 2001). They will need additional support to engage in academic work in classrooms. Duff and Talmy (2000) emphasized the importance of social interaction for ELLs for the acquisition of a second language. They claimed, "Social interaction with more proficient members of a particular community mediates the development of both communicative competence and knowledge of the values, practices and identities of the community" (p. 98). Thus, by engaging in science practices with teachers and English speaking peers, ELLs can engage not only talking in science but also in the meaning-making capacity of science language. In a science classroom, language is integral to the content and the medium of science learning and thinking. The construction of meaning through discourse, inquiry, and investigation is central to science learning (Brown & Kloser, 2008; Brown & Ryoo, 2008; Rosebery & Warren, 2008; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Most of the studies in science education from a sociocultural perspective have examined the nature of participation of the students, especially from diverse backgrounds, than in articulating what disciplinary resources they had acquired. The sociocultural perspective tends to focus more on how science is learned than what is learned. Supporting science learning by taking into account the students' home language and culture, development of identity, and communities they live in has inherent value (B. A. Brown & Kloser, 2009; B. Brown & Ryoo, 2008; Rosebery, Ogonowski, DiSchino, & Warren 2010; Warren et al., 2001). This centrality and inherency is valid across a wide range of student backgrounds—from students who are recent immigrants and speak English as a second language to students who are from different racial ethnicities and low socioeconomic backgrounds. However, what tends to be overlooked is how students make explicit connections to nature when learning content that is new to them, thus engaging in sense-making accountable to disciplinary practices (Ford & Forman, 2006).

Having a grasp of practices in science—a sort of road map that highlights the relationships among facts, methods, values, and a set of abilities for reasoning coherently across these dimensions—is key to learning informational content in science (Ford & Forman, 2006). For ELLs, a grasp of science practice will include multiple aspects of oral and written language, multiple modes of representation (gestural, oral, pictorial, graphic, and textual), and multiple strategies for language support such as using informal and formal styles of language (Lee et al., 2013).

Therefore, at the classroom level, providing instructional scaffolds in the form of multiple modes can help students acquire the science language and register. Viewing the learning process of ELLs through a sociocultural perspective will enable us to understand science practices, the language of the science classroom, and the strategies used to support their intergration in the science classroom. The multimodal tasks can work as scaffolds, within the ZPD of the students, and connect the goals of the tasks to the teaching and learning goals of science unit, which will include paying attention to both science and language content and supporting the students in appropriating the scientific discourses and representations.

In sum*,* the common themes of the sociocultural approach include using language as a medium or tool for learning (Vygotsky, 1978); participating in discourse as a primary characterization of learning and knowing (Lemke, 2001; Vygotsky, 1978); enlisting the support of knowledgeable others like teachers (Lave & Wenger, 1991; Vygotsky, 1978); utilizing scaffolds that provide support and guidance to help students achieve what they cannot do alone (Wood et al., 1976); studying the world as scientists do; and “learning the socially learned cultural traditions of what kinds of discourses and representations are useful and how to use them” (Lemke, 2001, p. 298).

In this study, I intend to explore the intersection of multimodality and assessment for learning from a sociocultural perspective in a science classroom with ELLs using a design-based approach (see Figure 1).

Research Design

My research aims to investigate and articulate how teachers and students use multimodal tasks to formatively assess the learning of science content. The purpose of the study is to support and expand on the theory that the integration of multimodality and formative assessment within a sociocultural perspective can support science learning for ELLs. Hence, the methods are undergirded on an approach grounded in design-based research—a systematic design and study of instructional strategies and tools in the context of learning in a classroom setting. I chose this approach because design research supports the development of tasks to support science learning and studying the learning that occurs in these settings (Bannan-Ritland, 2003; Design-Based Research Collective, 2003). Design-based research is an emerging paradigm drawn from Brown's (1992) notion of design experiment, which entails engineering particular forms of learning, systematically studying those forms of learning, and creating and extending knowledge about developing innovative learning environments (Cobb, diSessa, Lehrer, & Schauble, 2003).

Model of design-based approach for this study. My study is located in the social milieu of a science classroom setting, where, along with the teachers, I am examining the use of multimodal tasks as assessment for learning or formative assessment to support science learning. Before I delve into why I chose a design-based approach, I will explain some of the basic ideas of design-based research. The idea of design experimentation by Brown (1992) and her colleagues evolved into the notion of design-based research as an effort to bridge laboratory studies of learning with studies of complex instructional interventions. Design-based research simultaneously pursues the goals of developing effective learning environments and using such environments to study learning and teaching. According to this idea, design-based research should be theoretically framed and include empirical research of learning and teaching based on particular designs for instruction (Sandoval & Bell, 2004). Wang and Hannafin (2005) captured its critical characteristics: "A systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories" (p. 6).

Design-based research is an emerging paradigm that creates and extends knowledge about developing innovative learning environments. Contrary to traditional educational research in which theories are tested in controlled environments, in design-based research theory, testing is performed in real-world environments where design is the undergirding factor in which theories are later refined, modified, and enacted. Design-based research is based on both theory and the real-world context where the theory driving such a research acts as a framework throughout the research process (Design-Based Research Collective, 2003). Barab and Squire (2004) argued that design-based research should not only advance theory but also demonstrate the value of the design in creating an impact on learning in the local context of study. Thus, theory not only becomes both the foundation but also the outcome of design-based research. The design must lead to sharable theories that can help communicate relevant implications to practitioners and other curriculum designers (Design-Based Research Collective, 2003).

Some researchers focused on student learning of domain-specific instructional theories to document the process of learning in that student domain and the means by which the learning can be supported. For instance, Cobb and Gravemeier (2008) analyzed the use of software to understand how students learn statistics, and Holmqvist, Gustavsson, and Wernberg (2008) used the framework of a learning study cycle to describe how students study English as a second language. In mathematics, Cobb (2000) analyzed how students attempted to understand student mathematical learning through the organizational and structural activities of the classroom, and Lesh (2002) examined how students can use mathematical constructs for problem-solving situations. Lesh and Zawojewski (2007) demonstrated how students designed a mathematical model to explain how to make a quilt. Some researchers also focused on professional development, like Zawojewski, Chamberlin, Hjalmarson, and Lewis (2008), who conducted research on teachers' growth when they undergo long-term professional development in teaching mathematics, and Bannan-Ritland (2008) who studied how science teachers engaged in a technology prototype that integrated science inquiry processes and reading comprehension.

In my study, examining the confluence of the potential of multimodal tasks as assessments for learning from a sociocultural perspective lends to the advancement of a few theories of how to support the science learning of ELLs. By examining from a sociocultural perspective, I highlight how the grasp of practice—the relationships among facts, methods, values, and a set of abilities for reasoning coherently across these dimensions—is key to learning informational content in science. Further, design-based science pedagogy can help students develop the modeling and the representational abilities that are needed in scientific domains (Fortus, Dershimer, Krajcik, Marx, & Mamlok−Naaman, 2004). A high quality design-based research study (a) is situated in a real educational context, (b) focuses on the design and testing of a significant intervention, (c) uses mixed methods for analysis, (d) consists of multiple iterations, (e) contains a collaborative partnership between researchers and practitioners, (f) involves the evolution of design principles; and (g) includes practical impact on practice (Anderson & Shattuck, 2012).

The study was conducted in two sixth-grade middle school science classrooms in collaboration with their teachers with the aim of using multimodal tasks to assist and represent learning process, which can lead to a few iterations within one unit and show how to improve the multimodal tasks in the form of modifications to their design and usage. Figure 2 illustrates a model of how I have incorporated some of the essential tenets of design-based research into my study. I have adapted the osmotic model of design-based research (Ejersbo et al., 2008). Ejersbo et al.'s (2008) model sought to address the ways of navigating between the various aspects of the design research process. The word *osmosis* indicates the iterative and synchronous relationship between designing the artifact and theory reflection (Ejersbo et al., 2008). The essential tenets of design-based research used in the context of this study are (a) placing the design in a theoretical context—to integrate the theory of multimodality and formative assessment within a sociocultural perspective for ELLs; (b) identifying the problem, the lack of assessment for learning during the process of teaching and learning for linguistically diverse students in science; (c) developing the hypothesis—the use of multimodal tasks that will support the teachers in formative assessment and support students' science learning; (d) utilizing the artifacts—the multimodal tasks reproduced by the students; and (e) collecting the data before and during the implementation, usage, and creation of the multimodal tasks. The data were triangulated and analyzed to further advance or modify the theory of multimodality and formative assessment within a sociocultural perspective for linguistically diverse students in science. Because this study invokes the principles of design-based research, the teacher and the researcher was involved in the selection, planning, and implementation of multimodal tasks.

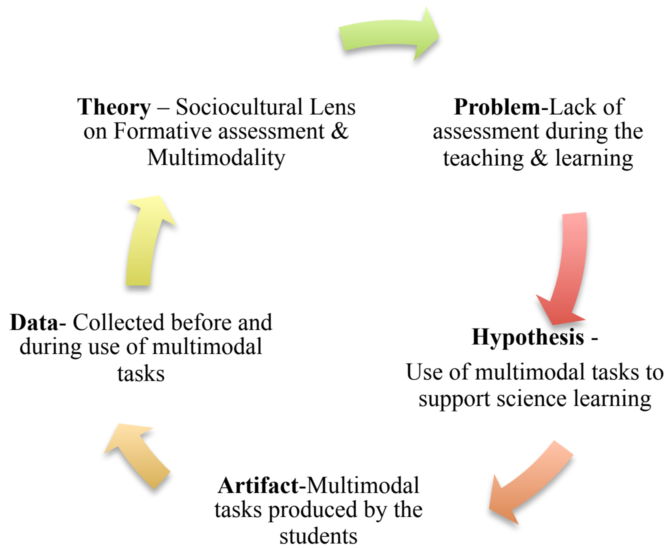

Figure 2. Model of design-based approach of the study, adapted from Ejersbo et al. (2008).

Research Questions

The main research question guiding this study: *How do multimodal tasks support science learning in linguistically diverse classrooms?* This question leads to the three main perspectives of the role of multimodal tasks in two linguistically diverse sixth grade science classrooms. In the chapters that follow, I describe each perspective in detail. Chapter Two describes in detail the first perspective, which examines the two teachers' perspectives on the use of multimodal tasks to support science learning in their linguistically diverse classrooms. Chapter Three switches the focus onto the students' perspectives on the use of multimodal tasks to support their science learning in the classrooms. Chapter Four is the third perspective which looks at how multimodal tasks support science learning through a science and language learning rubric, which I created, by examining student learning based on students'

English learner status and proficiencies in English language arts, science, and vocabulary acquisition and usage.

In each chapter, I examine each perspective from a sociocultural lens to address my main research question. Emerging from these three perspectives, I developed more concrete research questions, which corresponds to a self-contained chapter. To answer each research question, I have three guiding questions.

Research Question One

How do the multimodal tasks support the learning of linguistically diverse students—teachers' perspectives?

Guiding questions.

1. What are the teachers' views and beliefs about teaching and student learning in their linguistically diverse classrooms before and after the unit? (Teacher Beliefs: Initial & Final Phase)
2. How do the teachers use multimodal tasks in their linguistically diverse science classrooms? Teacher Actions (Planning and Implementation)
3. How do teachers support science learning using the multimodal tasks for students in their linguistically diverse classrooms? (Teacher Decisions)

Research Question Two

How do the multimodal tasks support the learning of linguistically diverse students—students' perspectives?

Guiding questions.

1. How do the students view the potential of the multimodal tasks in two

linguistically diverse classrooms? (Forethought Phase)

2. How do the students use the multimodal tasks to support their science learning in two linguistically diverse classrooms? (Performance and Control)

3. How do the students reflect on the use of the multimodal tasks to support and represent their science learning in two linguistically diverse classrooms? (Reflection)

Research Question Three

How do the multimodal tasks (visual diagrams and comic strips) represent the science learning of linguistically diverse students using a science language rubric?

Guiding Questions.

1. To what extent do the visual diagrams demonstrate the science learning of linguistically diverse students using the science language rubric? (Response to Feedback)

2. How do the comic strips demonstrate the science learning of linguistically diverse students using the science language rubric? (Integrating Science and Language)

3. How do the final visual diagrams demonstrate the science learning of linguistically diverse classrooms using the science language rubric? (Learning Over Time)

Dissertation Summary

The focus of this dissertation is to examine the use of multimodal tasks in linguistically diverse classrooms to support science learning through three complementary perspectives with each following the research questions outlined above. The three chapters of this dissertation can be treated as self-contained research papers. While each chapter follows a distinct line of inquiry with its own framework for analysis and results, together the chapters provide an important narrative on the use of multimodal tasks to support science learning in two linguistically diverse sixth-grade classrooms.

While each chapter's analyses and results are unique, they are all grounded within a sociocultural framework showing the affordances and constraints of multimodal tasks as supports for learning. Using multimodal tasks in a science classroom as a conduit for assessment for learning can help the students to learn on two levels—developing local expertise about the task and learning how to structure his or her own learning and reasoning (Black, 2013). This idea resonates with the tenets of assessment for learning, which emphasizes the value of knowing where the students are, where they are going, and how to get them there, by establishing learning goals and providing feedback. A sociocultural approach to multimodality "assumes that the different modes have different affordances" and can give a clearer perspective on what and why the teacher/student employs a particular mode at a particular point in the classroom. It will be useful to examine how the different modes afford learning, which mode supports the best form of communication, or whether particular combinations of modes afford learning (Kress et al., 2006, p.175).

To that extent, in Chapter 2, I used a model adapted from Clark and Peterson (1986) and Ruiz-Primo and Li (2013b) for analysis of teacher views and beliefs on teaching, learning and assessment, planning and implementation of multimodal tasks, and teacher decision-making based on the multimodal tasks during a unit of photosynthesis. In Chapter 3, I analyzed how the students of these two sixth-grade classrooms view and use the same multimodal tasks to support their science learning during a unit of photosynthesis, through the Andrade model of learning through self-regulation and self-assessment (Andrade, 2013). In Chapter 4, I analyzed the multimodal tasks (visual diagrams and comic strips) created by the students for their science learning through a science and language-learning rubric that I created. The purpose of the rubric analysis of the multimodal tasks is to demonstrate the students' response to feedback, integration of science and language, and progress of learning over time through the use of symbols, images, and vocabulary. In Chapter 5, I have synthesized the findings from the analysis of the data from the three lenses: teachers' and students' perspectives and science and language rubric. I summarized my analysis and wove a common theme connecting the three complementary perspectives of how multimodal tasks support science learning in the two linguistically diverse sixth grade classrooms.

Table 1
Dissertation Summary of Multimodal Tasks to Support Science Learning in Linguistically Diverse Classrooms: Three Complementary Perspectives

Chapter	Chapter Title	Research methods	Model of analysis	Research questions
One	Multimodal tasks to support science learning in linguistically diverse classrooms: teachers' perspectives	Interviews: before and after the unit During feedback Video analysis of lessons	Adapted model of Clark and Peterson (1986) and Ruiz-Primo and Li (2013)	How do the multimodal tasks support the learning of linguistically diverse students—teachers' perspectives?
Two	Multimodal tasks to support science learning in linguistically diverse classrooms: students' perspectives	Self-efficacy surveys Interviews Self–assessment questions Self-reflection survey	Andrade (2010) model of learning through self-regulation and self-assessment	How do the multimodal tasks support the learning of linguistically diverse students—students' perspectives?
Three	Multimodal tasks to support science learning in linguistically diverse classrooms: Using a science-language learning rubric	Rubric analysis of representational multimodal tasks in different student groups based on English Learner status and Proficiency in English Language Arts, Science and Vocabulary Acquisition and Use	Science-language rubric	How do the multimodal tasks (visual diagrams and comic strips) represent the science learning of linguistically diverse students?

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CHAPTER 2: MULTIMODAL TASKS TO SUPPORT SCIENCE LEARNING IN LINGUISTICALLY DIVERSE CLASSROOMS—TEACHER PERSPECTIVES

Introduction

Over the past 15 years, the number of English Language Learner (ELL) students—children ages 5–17 who speak a language other than English at home—rose from 3.5 million to 4.9 million between 1980 and 2009 (National Center for Education Statistics [NCES], 2012). By 2025, nearly one out of every four public school students will be an ELL (NCES, 2011, 2012). The academic achievement of ELLs has lagged behind that of native English speakers in science and literacy (Lee & Luykx, 2006; NCES, 2011; Rodriguez, 2001, 2003). The 2009 National Assessment of Educational Progress (NAEP) showed a 30-point difference in average science scores between ELL students and students who are native speakers of English with the gaps in achievement actually increasing from elementary school to secondary school (NCES, 2011).

Today's schools face unprecedented challenges in preparing ELL students to meet academic expectations (NAS, 2010; NCES, 2011) and the implementation and maintenance of high-level academic programs in science (Tate, 2001; Wong-Fillmore & Snow, 2000). Furthermore, ELLs face the daunting task of learning the academic curriculum and a new language concurrently. Science instruction for most ELLs is still conducted in English; thus students must learn new academic content in a language that they are still acquiring (Warren, Balleneger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). In addition, many schools lack the material resources and instructional supports needed to provide exemplary science instruction to all students on a regular basis. With the increasing ELL student population, it is likely that all teachers, many of whom have not had the preparation to provide high-quality instruction to this population of students, at some point in their careers will encounter students who do not yet have sufficient proficiency in English to fully access academic content in traditional classrooms (Ballantyne, Sanderman, & Levy, 2008). Of those teachers who had ELLs in the classroom, only 29.5% received training in working with this population (Ballantyne et al., 2008). Given that less than one-sixth of all postsecondary institutes require ELL-oriented content in their preparation of mainstream teachers (Menken & Atunez, 2001), there are teachers entering the workforce who are less prepared to teach ELLs in content-specific areas. In research conducted with 279 teachers in a school district with a minimal number of ELLs, Reeves (2006) found that 81.7% believed that they did not have adequate training to work effectively with ELLs and 53% wanted more preparation, which is quite similar to an earlier survey wherein only 27% of teachers felt that they were “very well prepared” to meet the needs of ELLs, and 12% reported that they were “not at all prepared” (NCES, 2001). Even credentialed teachers feel inadequately prepared to teach English learners (Gándara, Maxwell-Jolly, & Driscoll, 2005). More than half of the teachers who participated in a comprehensive survey of teaching English learners in California stated that they had had limited or relevant professional development (Gándara et al., 2005).

This study serves to examine how two sixth-grade teachers experienced and trained to teach ELLs science content, integrated science, and language learning in their respective classrooms by using multimodal tasks (diagrams with labels, written narratives with pictures, making models, videos, and read-alouds) to help support science learning in their linguistically diverse classrooms.

Context: Choice of Site and Participants

This study was conducted in an urban school in Northern California with classes from kindergarten to eighth grade. About 41.2% of the school population is designated as ELLs, 33% as fluent English proficient, and 19.5% as reclassified English proficient. This classification is based on the performance of the students on the California English Language Development Test (CELDT), given annually to students who are classified as English language learners. About 69% of students are on free or reduced lunch, 48.6% are Vietnamese, and 40.7% are Hispanic/Latino. With a considerable percentage of students as ELLs, this school was considered a suitable site for data collection. The design research study was conducted in two sixth-grade classrooms during the study of a unit in photosynthesis, whose respective teachers, Vicky and Klara, have a combined experience of 27 years, (one teacher has 20 and the second teacher has 7 years of experience). Currently, both the teachers are working in a school district that has placed emphasis on the incorporation of language arts into every content subject matter, including science. Thus, while teaching a variety of subject matters, the teacher uses curriculum materials that embed language art practices. Because these teachers have taught ELLs for a considerable period of time, they are familiar with ways of how to embed activities as a means to engage students in meaning-making in subject matter. Both the classes are self-contained sixth-grade classrooms wherein each class has one teacher to teach all subjects, with the exception of physical education. As each class has about 30% ELLs and 50% students have been redesignated as English proficient within the last 2 years, the teachers have engaged in scaffolding multimodal activities with their students to support content learning. Further, these teachers have also participated in the Effective Science Teaching for English Language Learners (ESTELL) practice workshop and taught pre-service teachers the ESTELL practices in their methods course at a local university.

At the beginning of the academic year, the teachers identified their respective strengths, and each teacher took the lead on teaching either science or social studies, which included creating the lesson plans, activities, and assessments for that subject. In this study, Vicky took the lead for science, planning the types of tasks and assessments required for the unit. Klara's contribution included identifying the sequence in which the tasks had to be administered. My role as a researcher was to help identify those tasks related to photosynthesis and to make suggestions related to the science content of the tasks. The teachers were responsible for the final decisions on the task choice and implementation.

Guided Literature Review

This paper draws from prior research on (a) the teacher's beliefs in assessment and teaching science to ELLs, (b) science teaching and learning of ELLs in science education, and (c) assessment of ELLs in science education. I examine the confluence of teacher beliefs and practices, science teaching and learning, and the assessment of science learning within the social milieu of a linguistically diverse science classroom. My literature review examines each of these aspects within classroom settings. From these key areas in science education, I explore the importance of using multimodal formative assessment in science to support science learning of students in a linguistically diverse classroom.

Teacher Beliefs on Assessment

If the development and implementation of formative assessment serves to support science standards and promote learning, formative assessment should be an essential feature of classroom practice (Atkin, Black, & Coffey, 2001). If formative assessment is to be carried out seamlessly as part of instructional activities, it is contingent on the teacher's ability at eliciting and recognizing ideas articulated by students and using students' responses as resources to direct subsequent instructional decision making in a way that supports learning (Abell & Volkmann, 2006; Otero & Nathan, 2008; Ruiz-Primo & Furtak, 2007). In this regard, a worthy educational goal—but one not easy to implement in real practice—is to support practices that connect teachers' thinking about pedagogical strategies (e.g., lesson planning, selection of teaching strategies, and artifacts) directly to their thinking about evidence of student understanding (Darling-Hammond & Snyder, 2000). This support also means assessment must shift away from grading and evaluation toward gathering and using evidence in informing the teaching/learning process of formative assessment (Shepard, 2005).

Several factors can possibly influence teacher beliefs on assessment: teaching experience and development, characteristics of the tasks or curriculum, and the student characteristics. Some studies have demonstrated how teaching beliefs can influence formative assessment practices. During the KMFOAP project, the science teachers claimed that they transformed themselves from being *presenters of knowledge* to helping students take charge of their learning (Black, Harrison, Lee, Marshall, & Wiliam, 2004, p. 89). The teachers also ascribed to the view that “assessment for learning is a way of thinking, almost a philosophy” (Black et al., 2004, p. 80). Through action research, Buck, Trauth-Nare, and Kaftan (2010) showed how formative assessment practices guided preservice teachers through their science inquiry process in their classrooms. Cowie and Bell (1999) and Cowie, Moreland, and Otrel-Cass (2013), in their effort to improve teachers’ perspectives on formative assessment practices, analyzed teacher beliefs on assessment and found that those who implemented or planned formative assessment tasks in their science lessons viewed assessment as integral to teaching and as a combined responsibility of both teachers and students. In sum, being supporters of assessment for learning meant “not getting through the curriculum at all costs” but seeing “the purpose of lessons as primarily to help students learn” (Black et al., 2004, p. 91). Most often, the perceived notion of their students’ abilities determines a teacher’s choice of tasks for assessments (Buck and Trauth-Nare, 2009). In their project, Buck and Trauth-Nare

(2009) demonstrated the value of openly constructed responses using a combination of pictures and terms to illustrate student understandings, causing the teacher to understand the value of open response items. These studies illustrate the need to understand teachers' conceptions and beliefs about the forms and purposes of assessment in science as it influences how students are assessed in science classrooms.

Some researchers have examined assessment practices in science classrooms with linguistically diverse students. Lee (2004) described patterns of change in teachers' beliefs and practices as they learned to establish instructional congruence frameworks by exploring the relationship between academic disciplines and students' cultural and linguistic knowledge. Through the instructional congruence framework, the teachers changed their beliefs and practices to meet students' learning needs in science, language and culture, and English language and literacy, which caused the teachers to realize the importance of science for ELLs in school and at home. Ash and Levitt (2003, p. 89) demonstrated how, in using the science inquiry skills rubric as a formative assessment tool, teachers were able to improve their teaching strategies in elementary classrooms. Further, Lyon (2013) revealed how preservice teachers' expertise in assessment increased during the student teaching process in linguistically diverse classrooms by aligning assessment tasks with learning objectives and considering the role of language while assessing.

Science Teaching and Learning of ELLs

Most of the research which have examined the science teaching and learning of ELLs falls into three categories: (a) development of preservice and in-service teachers to teach science inquiry to ELLs, (b) interventions that involve integration of literacy and science content through professional development programs and through curriculum-based programs, and (c) addressing the notion of cultural validity of science assessments for ELLs. Even though most of this research evaluated the efficacy of the programs or interventions on student learning through summative assessments given to students after the program or intervention, there are certain aspects of intervention that focused on enhancing student learning of science content. In the following section, I have examined how most of the interventions attended to the language and literacy needs of ELLs, the development of science concepts and vocabulary, and cultural and linguistic backgrounds of the students.

Teacher Development

Stoddart, Pinal, Latzke, and Canaday (2002) designed an evaluation instrument to analyze teacher understanding of how inquiry-based science teaching can be combined effectively with language development. Building on the idea of integrating science and language development, Stoddart, Solis, Tolbert, and Bravo (2010) created the Effective Science Teaching for English Language Learners (ESTELL) framework, which embodied the same principles of integrating science inquiry and literacy while simultaneously adopting the Center for Research on Education excellence standards, in which the science content provides a meaningful context for the learning of language structure and functions. In their commitment to science education with elementary students from diverse languages and cultures, Lee and Fradd (1996, 1998, 2001) developed an instructional congruence framework that highlights the importance of developing congruence, not only between students' culturally based interactional norms and those of the classroom, but also between academic disciplines and students' linguistic and cultural experiences. The various research studies, which incorporated this framework paid specific attention to the language and literacy strategies to address the needs of English language learners (Cuevas, Lee, Hart, & Deaktor, 2005; Lee & Luykx, 2005; Lee, Maerten-Rivera, Penfield, LeRoy & Secada, 2008). They included student booklets to strengthen students' reading and writing comprehension, focusing on language functions within the context of scientific inquiry and using "multiple modes of communication and representation (e.g., verbal, gestural, written, and graphic) to enhance students' understanding" (Lee et al., 2008, p. 38).

Science-Literacy Programs

Science-literacy programs are those curriculum studies that capitalize on potential synergies between science and literacy, wherein science and literacy share highly complementary learning processes and discourse practices. Students can utilize skills such as posing questions, making predictions, or making inferences that can be used for both science inquiry and for reading comprehension.

While Amaral, Garrison, and Klentschy (2002) examined professional development in promoting science with predominantly Spanish-speaking elementary students, in the Science Instruction for All project (Bravo & Garcia, 2004), the instructional intervention utilized household materials for conducting scientific inquiry activities as a medium for examining language, literacy, and collaborative interactions in the classroom. Another group of studies which adapted the Seeds of Science and Roots of reading science-literacy curriculum programs strategically employed multiple learning modalities in their curricula providing ample opportunities to support ELL learning (Cervetti, Pearson, Barber, Hiebert, & Bravo, 2007; Duesbery, Werblow, & Twyman, 2011; Goldschmidt & Jung, 2011). In some studies that supported science-literacy integration, there was specific focus on professional development to support teachers in integrating science and literacy in their classrooms. Gibbons (2003) demonstrated how teachers mediated language learning, helping English learner students use the appropriate science register by revoicing their contributions and helping students reformulate their talk to fit the broader objectives of the science curriculum. Unique to Santau, Martin-Rivera, and Huggins's (2011) study was the inclusion of teachers' guides that contained a glossary of science vocabulary with corresponding definitions and transparencies of pictures, drawings, tables, graphs, and charts. Similarly, in the study by Lara Alecio et al. (2012), the literacy-integrated science intervention on fifth-grade ELLs' science and reading literacy achievement consisted of ongoing professional development and specific instructional science lessons with inquiry-based learning, direct and explicit vocabulary instruction, and integration of reading and writing. In a study among sixth-grade ELLs and native English speakers (August, Branum-Martin, Cardenas-

Hagan, & Francis, 2009), the teachers involved with the intervention were encouraged to use visuals, graphic organizations, demonstrations, experiments, , explicit vocabulary instruction, and reading integration, and modeling to students.

Assessment of ELLs in Science

While assessing students from diverse cultural and linguistic backgrounds, the factors related to culture and language are often seen as sources of measurement errors (Solano-Flores, 2011). In order to address this issue, Solano-Flores and Nelson-Barber (2001) introduced the idea of *cultural validity,* which is "the effectiveness with which science assessment addresses the sociocultural influences that shape student thinking and the ways in which students make sense of science items and respond to them" (p. 555). They posited that, in order to attain cultural validity, attention must be paid to how students are affected by sociocultural influences and interactions and how that determines their perceptions of science assessment items, what they feel they are expected to do, and what strategies they use to solve them. Durán (2011) argued that an important aspect is to have assessments for ELLs embedded in ongoing classroom context so the students can draw on their understanding of "the everyday social and cultural characteristics of classroom life and its academic linguistic and task demands in responding to task" (p. 119). To assess ELLs in science, separate criteria should be used to assess English language proficiency and science knowledge (La Celle-Peterson & Rivera, 1994). These separate criteria will enable teachers to identify strengths and weaknesses of ELLs in each area and understand their learning needs (Lee, Santau, & Maerten-Rivera, 2011).

Kopriva and Sexton (2011) suggested that different kinds of knowledge and skills should be assessed in an ongoing classroom with ELLs, by using a variety of approaches including formative assessment practices.

The essence of most of the studies allowed both teachers and students to use all modes of language skills (listening, speaking, reading, and writing), which provided a strong base for establishing background knowledge and vocabulary for students and consequently promoted academic achievement for ELLs. For harnessing the considerable power of formative assessment to support student learning, other factors that influence implementation in a classroom setting have to be taken into consideration. Emphasis has been placed on the importance of teachers' roles in mediating and interpreting the results of alternative assessments in the classroom context (Wolf, Bixby, Glenn, & Gardner, 1991). Teacher beliefs on assessment practices have a major influence on the type of tasks constructed and used for assessments and how are they are used formatively. The value of formative assessment has also been realized in promoting students' self-perception of competence in learning (Black & Wiliam, 1998; Crooks, 1988; Yin et al., 2008).

Assessments and the interpretation of their outcomes have direct and lasting impacts on teachers, learners, and classroom activities. To that extent, this study addresses what most researchers have posited—assessment systems embedded in classroom contexts devised for ELLs that allow for a more genuine participation of students enable both teachers and students to support the learning of science. This study examines such an assessment system that incorporates the notion of multimodality in two sixth-grade science classrooms with 25 ELLs, 18 redesignated as English-proficient, 20 English-only students, thus enabling both the teachers and students to use the various tasks to communicate and represent science learning. This paper focuses on the teachers' perspectives on the potential of multimodal tasks to support science learning in their linguistically diverse classrooms.

Research Questions

The main research question informing this study was the following: How do the teachers use multimodal tasks to support the science learning of the student in their linguistically diverse classrooms? In order to understand the full potential of the multimodal tasks in science classrooms in this paper, I further examined these items: (a) the teachers' views and beliefs about their assessment practices in linguistically diverse science classrooms, (b) the teachers' use of multimodal tasks during the process of teaching and learning in the unit, and (c) the teachers' reflections on the use of multimodal tasks to support the students' learning processes during the unit.

Table 1
Research Questions Guiding the Paper, Data Collected, and Themes of Analysis

Research question	Data collected	Analysis
1. How do the teachers view science teaching and learning in their linguistically diverse classroom? Teacher Beliefs—Initial & Final Phase	Semi-structured interviews with teachers before, during, and after the unit	Views of assessment Views on using multimodal tasks Views on how to support science learning of ELLs
2. How do the teachers use multimodal tasks in their linguistically diverse science classrooms? Teacher Actions (Planning and Implementation)	Semi-structured interviews with teachers before the unit Video-recordings of the lessons implemented during the unit	Planning of multimodal tasks Implementation of multimodal tasks
3. How do the teachers understand and reflect on students' science learning using the multimodal tasks for students in their linguistically diverse classrooms? (Teacher Decisions)	Semi-structured interviews with teacher on the providing feedback on visual tasks Video-recordings of lessons during the implementation of multimodal tasks	Teachers' understanding of students' use of tasks Teachers' understanding of students' representation of ideas Feedback and Reflection

For this paper, I analyzed the transcribed recordings of the semi-structured interviews with the teachers and the video recordings of the lessons while the teacher implemented the tasks. The two sets of interviews included the following information: (a) interviews conducted before and after the unit of photosynthesis—the interviews before the unit were conducted with the goal of exploring the teachers' beliefs and practices of teaching and assessing student learning in a linguistically diverse classroom and their use of multimodal tasks to support learning; the interviews after the unit were conducted to explore their views on why they used particular multimodal tasks and their affordances and constraints in supporting ELLs science learning; (b) interviews conducted when the teachers examined the two multimodal tasks of the students to assess the students' understanding of the process of photosynthesis, the visual drawing and the comic strip. The video recordings of all the lessons were analyzed, with a special focus on how the teachers used the read-alouds, discussed the videos on photosynthesis, and demonstrated the making of the molecule model.

Method of Analysis

This study examines the formative potential of multimodal tasks in science in linguistically diverse classrooms where the teachers have considerable experience using multimodal forms of assessing and learning in most subject areas. While McMillan (2013) posited that it is important to understand the conditions in the classroom, which can support formative assessment (assessing during the process of teaching and learning), Cowie (2013) emphasized the need to understand these conditions in content areas like science. Therefore, it is important to not only examine how and why these teachers implement and use multimodal tasks in science but also the decisions which influence future implementation and usage of multimodal tasks.

This study uses a sociocultural perspective of teaching, learning, and assessment which involves having a "dynamic and distributed view" of assessment

(Gipps, 1999, p. 273). Using multimodal formative assessment tasks to support learning where both the task and the process of using the task will be assessed aligns with the dynamic view of assessment. The distributed notion of assessment not only enables teachers to use these tasks as scaffolds but also affords teachers to use the tasks as guides for the next steps of teaching and learning (Wood, Bruner, & Ross, 1976). Hence this study was conducted in two sixth-grade science classrooms in collaboration with teachers with the aim of examining the impact of how the multimodal tasks aided the teachers in supporting science teaching and student learning. The teachers had planned and implemented the unit in collaboration, with the intent of keeping the method of instruction similar in both classrooms. The goal was to identify modifications to the implementation of multimodal tasks, its utility for providing feedback, and the impact the feedback has on subsequent performances on other multimodal tasks.

My analysis was focused on creating a unified theme of potential of the multimodal tasks and not for a comparative view of the teachers' use of the tasks in the two classrooms. As the student demographics were quite similar in both classrooms, it was easier to find merging themes. To this extent, I have adapted the Clarke and Peterson (1986) heuristic model of teacher thought and action and Ruiz-Primo & Li (2013b) model of feedback to examine and reveal the processes in the two science classrooms. Clarke and Peterson contended that teachers' actions are largely caused by teachers' thought processes, which in turn affect teachers' actions. In their reciprocal and cyclical model, the two main domains of teachers' thought processes and teachers' actions are intricately involved in the process of teaching. Therefore, I have analyzed the data with the intention of not only analyzing the teacher thoughts and beliefs and the influence on their actions and decision making processes in the classrooms, but also how their actions further influence their beliefs and consequent decision-making process.

Figure 1. Conceptual model of analysis. Adapted from Clark and Peterson's (1986) model and Ruiz-Primo and Li (2013b) model of feedback.

The data collected were analyzed to address the following themes:

1. The *teacher thoughts and beliefs* were examined with the intent of finding the teachers views on assessment and learning in their linguistically diverse classrooms and to explore the reasons for using multimodal tasks in their classrooms.
2. The teacher actions and their observable effects were examined through two main strands namely, a) teacher planning of multimodal tasks, b) teacher actions involved in the implementation of the various multimodal tasks

(Clark & Peterson, 1986).

3. The teacher decision-making processes were examined in fine details through teacher interviews after the unit and while they assessed the visual diagrams and comic strips, through the lens provided by the model of feedback advocated by Ruiz-Primo (2013a). Ruiz-Primo and Li (2013b) have reiterated for feedback to be formative feedback where the content of feedback focuses on reducing the difference between a current understanding or performance level and what is expected and ensure that the feedback focuses on the big ideas of the lesson. Thus feedback should not be a discrete activity; rather, it combines looking for evidence of students' ongoing learning and communicating to students in every opportune situation (Ruiz-Primo, 2011; Ruiz-Primo & Furtak, 2006, 2007). To align with the cyclical model of Clark and Peterson (1986), finally how *teacher thoughts and beliefs* were further influenced through the implementation of multimodal tasks and how it impacted their decision making process was examined.

Analysis

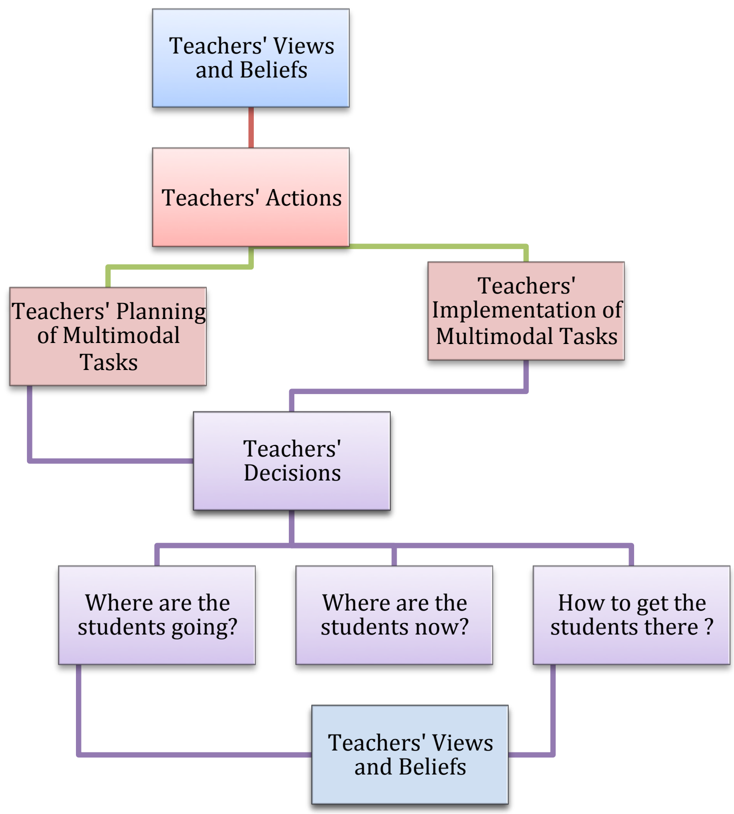

Figure 2. Schematic representation of the method of analysis of the teacher data.

Summary of Method of Analysis

The model represents the method of analysis of the teacher data and how it answers the research questions guiding this study. In the first phase, I analyzed how the teachers viewed the use of potential multimodal tasks in their linguistically diverse classrooms. In the second phase, I analyzed how the teachers planned and implemented the multimodal tasks, and in the third phase, I analyzed how they used some of the tasks to make decisions on how the students are learning about the process of photosynthesis. Finally, I concluded by analyzing how the teachers' views and beliefs shifted and provided insights into future decision-making processes.

Teachers' Views and Beliefs (Initial Phase)

RQ 1: How Do the Teachers View Science Teaching and Learning in Their Linguistically Diverse Classroom?

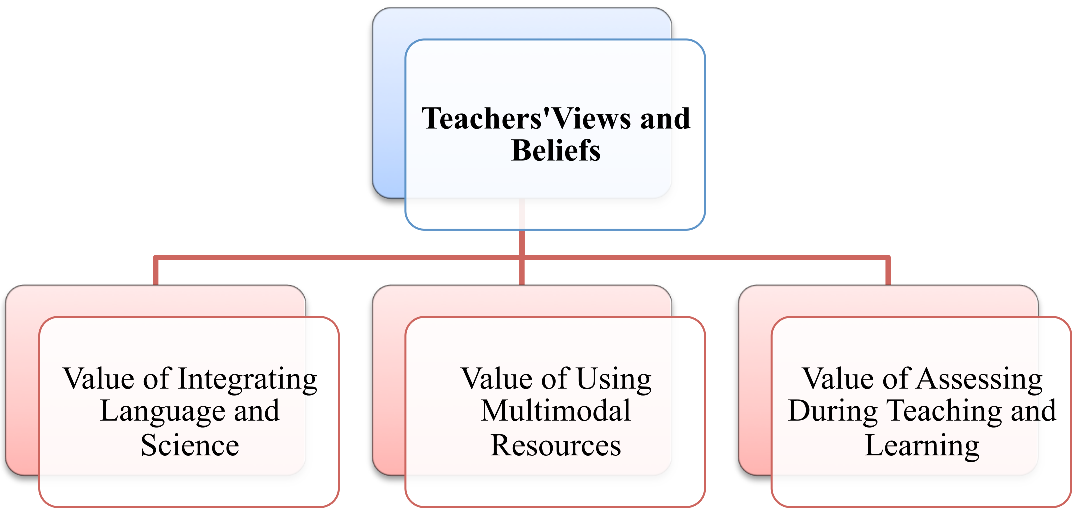

Figure 3. Schematic of teachers' views and beliefs.

In the following section, the initial phase of the teachers' thoughts and beliefs are examined through the interviews before the unit. The following three main themes emerged from the analysis of the data and provided an insight to the teachers' initial thoughts and beliefs in assessing and teaching science in their linguistically diverse classrooms and the potential of using multimodal resources in their classrooms.

Value of Integrating Language and Science

Science, as a discipline, has particular linguistic registers (Halliday & Martin, 2003; Lemke, 1990; Schleppegrell, 2004), whereby "every science lesson is a language lesson" and "learning the language of science is a major part of science education" (Wellington & Osborne, 2001, p. 1). A sociocultural interpretation of teaching and learning points out that when children share in cultural activities, they can be inducted into ways of knowing and appropriate values, skills, and knowledge that are enacted (Wells, 2000). So, while engaging in the activities of the science classroom, it is possible to appropriate the language of the science classroom, which includes both modality ("multiple aspects of the oral and written channels through which language is used") and registers ("the multiple features of students' and teachers' language use in the classroom while engaged in science and engineering practices"; Lee, Quinn, and Valdes, 2012, p. 2).

Research for ELLs in science education have paid special attention to simultaneously supporting their language learning and science content learning by engaging in classroom discourse through reading and talking and paying attention to their cultural and linguistic backgrounds. From the interviews, the teachers believed in the importance of engaging in the language of the classroom for ELLs. For instance, Vicky claims

> My students right now who are level one ELLs . . . for them like, on structure of the plants is, do they know stem cell or stem root, you know. Do they know fruit um, so it becomes completely different, it almost becomes science more as an opportunity to learn English rather than it being an opportunity just to learn science?

Further, Klara reiterates that "I do have lots of . . . language learners . . . in the class that they have access to the curriculum and they can't do that without the words." Her views suggested that much as it is important for ELLs to learn vocabulary, it was also essential they appropriated the words through "multiple aspects of the oral and written channels" (Lee et al., 2013, p. 2). She feels that

> you need to have an activity where they're taking what's in the book and making it your own, whether that's a picture, diagram, story writing, taking what you've read and not just answering the questions but pulling it together and that's where they synthesize it.

This view was upheld by Vicky who stated that for instance "What we're doing right now with the . . .word sort . . . where they're going to work with that several different times in many different ways."

Language is seen as a medium or tool for learning and, in a science classroom, language is integral to the content and the medium of science learning and thinking (Vygotsky, 1978). For ELLs, this means they are engaging in the language of the science classroom through a language they are still acquiring (Lee et al., 2013). As Vicky eloquently stated, "My big recommendation for ELLs will be to really make sure that the words aren't getting in the way, using lots of pictures um and not assuming that they know . . . words."

Value of Assessing During Teaching and Learning

Durán (2011) posited that one way to ensure that ELLs can be assessed in valid and fair manner is to embed assessments within an ongoing classroom context so the students can draw on their understanding of "the everyday social and cultural characteristics of classroom life and its academic linguistic and demands in responding to task" (p. 119). Vicky believed that by creating her own assessments she could better assess her student learning—"I do try to make it that they are teacher created test so that I am testing what I taught." Both teachers had specific views on what defined assessments and tests. While Vicky defined it as " I see projects as more of a learning opportunity rather than as an assessment opportunity," Klara exemplified it as "I guess that's where I think when I see the word *assessment*. I often think everything's a learning experience till the test."

The idea of formative assessment also includes students activating themselves as their own learning resources and using their peers as resources as well (Wiliam and Thompson, 2007). Teacher comments like "A big part of assessing needs to be that you give kids a chance to figure out if they know it or don't know it" and "I let them grade their own work a lot in the beginning because I want them to immediately know where their mistakes were so that they will hopefully change their ideas and learn correctly early on" reflect how they viewed students' roles during the teaching and learning process. Both teachers described assessing during the teaching process as "ongoing little checks" and "checking in with kids . . . seeing their work . . . seeing where they're at."

To describe the purpose of their ongoing assessment during the teaching process, they relate their expectations as "they're not just doing the requirements to get the grade for the project" and "helpful for me to know if the kids are getting what they need." The teachers describe the potential benefits of their ongoing assessment as "it's about building that knowledge . . . that prior knowledge and give them the ideas" and "they are making a connection between all the pieces."

Value of Using Multimodal Resources

Lemke (2001) emphasized that language emerges by taking on an increasing amount of representational function from other modalities. Vicky posited the value of learning language through multimodal resources by saying,

> There might be a song or a something so we're doing a video. So we're just trying to do hands on. We do the same thing in history. We try to bring in artifacts. We try to bring in pictures.

Central to the idea of multimodality is the notion that one moves away from writing as key to learning. A key aspect to multimodal perspectives on learning is the assumption that meanings are made through many representational and communicational resources, of which language is but one (Kress & van Leeuwen, 2001). The teachers emphasize the need "to give them as many opportunities to work with that material using different media" and "give them a foundation of understanding. It gives a common experience that they all saw, and we can refer back to it. It gives them language that is really rich."

To understand a certain concept, students engage in certain modes and transform that learning by representing and communicating their understanding through different ways (Jewitt, Kress, Ogborn, and Tsatsarelis, 2001). Vicky discovered that "They pick it up because they get excited about it, and when they're touching the seed and examining the seed and hearing the word 'wrinkly' when somebody says it, maybe they tune in to that." Klara feels that "Hands on give them the words, get them excited. A quick movie, a 5-min YouTube movie that gives them the images and the pictures so that they can relate and understand."

In sum, as these teachers were known to implement strategies to support science learning in linguistically diverse classrooms, it was important to learn their views and beliefs shaped the way they taught in their science classes. The teachers' value of using multimodal resources, assessing during teaching and learning, and integrating science and language while teaching has influenced how they planned and implemented the multimodal tasks.

Teachers' Actions (Planning and Implementation of Tasks)

RQ 2: How Do the Teachers Use Multimodal Tasks in Their Linguistically Diverse Science Classrooms?

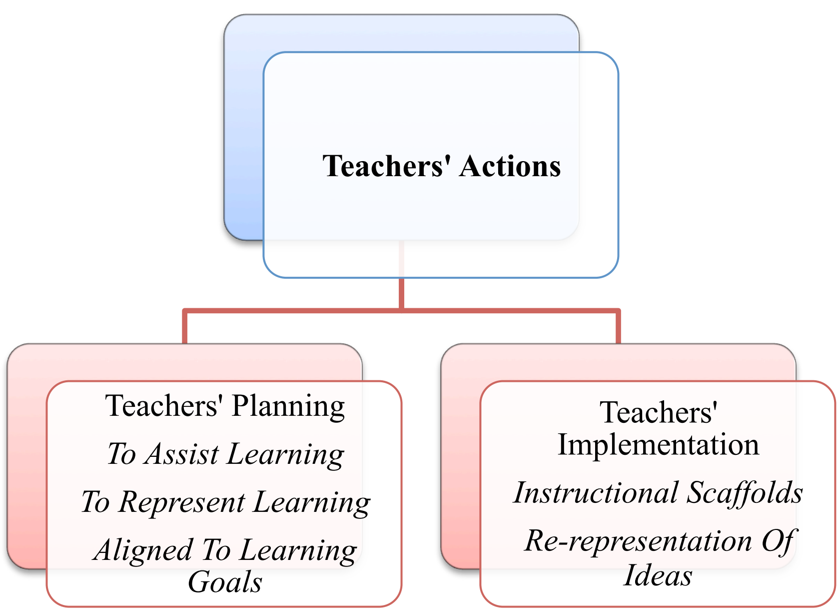

Figure 4. Schematic representation of teachers' actions.

Clark and Peterson (1986) described "the action domain" of a classroom as where classroom teaching is actually taking place and teacher behaviors have effects on students. In this study, I have focused "the action domain" as to those teachers' actions in the classroom that contributed to the support of the learning of photosynthesis. Data revealed that teachers' actions included a) the planning of the multimodal tasks for the unit of photosynthesis and b) the implementation of multimodal tasks to support the learning of photosynthesis.

Planning of the Multimodal Tasks

In this section, I have elucidated how the teachers planned and initiated the implementation of the various multimodal tasks during the unit of photosynthesis. Vicky, a more experienced teacher with a background in science, initiated the science lesson planning while Klara took the initiative for the planning of the social studies lessons. As this school does not have subject teachers for the middle school classes, the classroom teacher typically teaches science. So the teachers implemented the science lessons in their respective classrooms. Being part of the planning process, I (researcher) also contributed to the planning by providing insights to the types of multimodal tasks which the teachers could use. The teachers made the final decision on the types of tasks used.

In science education, the idea of multimodality stems from the increasing salience of using multiple modes in meaning-making, an approach that extends understanding of content across a range of modes to represent meaning (representational) and to communicate meaning (communicative). So, in a science classroom, the "multiplicity of the modes of communication that are active are given equal attention" (Kress, Charalampos, Jewitt, & Ogborn, 2006, p. 1). In the two sixth-grade classrooms of this school, the teachers planned the multimodal tasks in the classroom to capture the representational and communicative essence of the tasks.

To Assist the Learning Process

To support learning, the teachers selected activities, which involved students engaging in multimodal tasks. These were specific tasks, which the teachers created to encourage student participation and include all students. Of importance is how the teachers did not compromise on the quality of tasks chosen and set high expectations from all students in the class including the ELLs. A view of all students as capable learners is particularly critical to the success of those from diverse cultural and linguistic backgrounds (Villegas & Lucas, 2002). Also of interest is that the teachers did not create any tasks of their own but mainly used online or other teacher resources. The only task designed by the teachers was the molecule model. Here is a description of the tasks used:

Videos. Two videos were selected for showing to the students. It was decided that the YouTube "Make Me Genius" videos (makemegenius, 2011) would be used for an introduction to photosynthesis. The second video, Pearson videos, was available on the school textbook website. The second video was to be shown after the students engaged in the seed germination task.

Read aloud task. The students read a handout called *A Tree is Like a Hungry Kid* which explained the concept of chlorophyll in a plant which was selected by the teacher (Sadil, 2014).

Seed germination task. Before the teachers started this project, the students were engaged in an ongoing hands-on guided inquiry process where the students germinated lima beans in a plastic Ziploc bag. The class was divided into five groups, and each group had three bags of lima beans. One bag was placed in light, the second in the dark (inside a cupboard), and the third bag was exposed to light only for half a day and then placed in the cupboard.

Molecule model. The students created a model of each molecule of carbon dioxide, water, glucose, and oxygen. They depicted the molecular equation of photosynthesis, using the models created. The teacher provided the instructions to create the model and also demonstrated the steps for this task.

To Represent Student Learning

The multimodal tasks include (a) draw schematic diagrams; and (b) write narratives with drawing, which enabled the students to engage in more than one mode namely drawing and writing (Alvermann & Wilson, 2011; Jewitt & Kress, 2003; Prain & Waldrip, 2006). In the following multimodal tasks, the students responded to prompts (administered by the teacher) to help them communicate their learning through their multimodal representations.

The visual drawing task (picture, symbols, and text). The students had to draw and label a schematic representation of the process of photosynthesis using words, symbols, and images. All the students used this multimodal task to represent their understanding of photosynthesis (Ainsworth, 2006).

The narrative task (text, drawings and symbols). The students created a comic story about the process of photosynthesis. An example shown by the teacher was the story of the Magic School Bus, where the narrator of the story travels inside the plant to explain the process of photosynthesis. In this task, the students had to write a narrative explaining the process of photosynthesis by drawing pictures to illustrate the process and explain each step of the process. The students also used the task to represent their understanding of the process of photosynthesis.

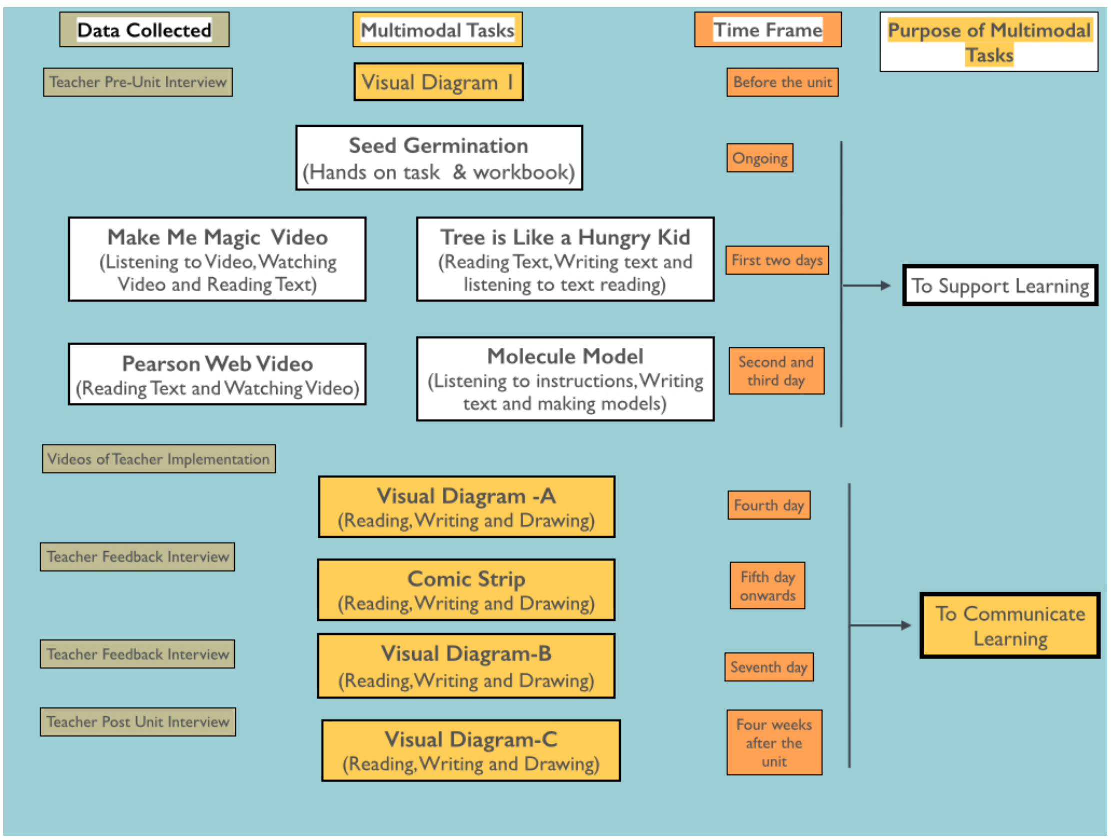

Figure 5. Schematic representation of how the teachers planned the implementation of multimodal tasks during the unit of photosynthesis.

Alignment to Learning Goals

The multimodal tasks were also designed to attain specific learning goals, which were aligned to specific core ideas of photosynthesis. After discussion with the teachers, the following ideas were finalized as the learning ideas or disciplinary core ideas, which they expected the students to learn by the end of the unit. These ideas include (a) making carbohydrate/sugar from carbon dioxide and water, (b) knowing that photosynthesis requires energy/ sunlight, (c) understanding that photosynthesis releases oxygen, and (d) learning that starch/food is used for growth or storage.

The videos were used to explain the entire process of photosynthesis. The reading tasks emphasize the importance of chlorophyll and the use of sunlight as energy. The molecule model was used to explain the chemical equation of photosynthesis and how oxygen is released during the process of photosynthesis. The seed germination task was used to explain the value of sunlight in the process of photosynthesis. The visual drawing tasks and the comic strip were chosen as tasks to represent understanding, as the students were familiar with drawing and writing narratives in social studies, and the teachers felt the students would be confident in executing the tasks.

For the visual diagram task, the written prompt, “Please draw a picture of the plant which will explain the process of photosynthesis,” was created by the teachers to help the students engage in the visual drawing task. For the comic strip, the prompt given by the teachers was as follows: “Create a comic strip which will describe the process of photosynthesis. An example can be like *The Magic School Bus*, where you enter the plant in a bus and describe the process as you are going through the bus."

The teachers also provided a list of vocabulary words which was to be used in the comic strip.

Teacher Implementation of Multimodal Tasks

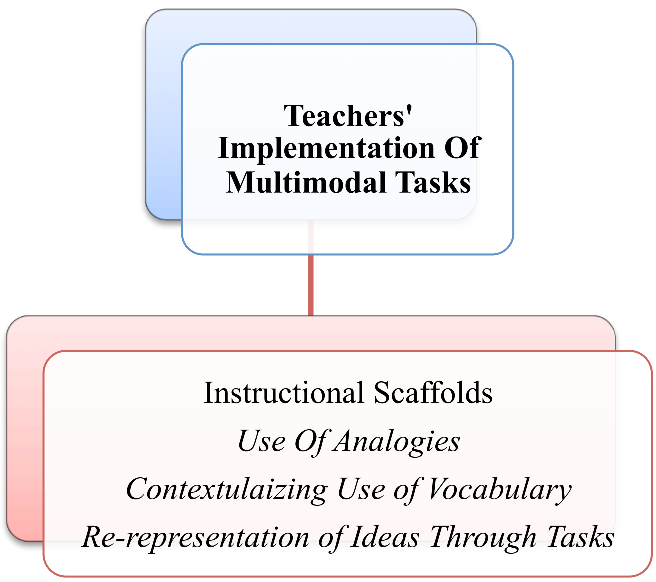

Figure 6. Schematic representation of teachers' actions.

In the following section, I have described how the teachers implemented the following tasks that were intended to support student learning of the process of photosynthesis. They include the videos, read-aloud task, molecule model, and seed-germination task. As the teachers used these tasks to support the learning process, I examined those specific strategies, which helped students understand the process of photosynthesis through (a) instructional scaffolds and (b) representation of disciplinary core ideas.

Instructional Scaffolds to Support Learning

As discussed earlier, the teachers implemented several multimodal tasks to support the student learning of photosynthesis. Ruiz-Primo & Li (2013b) have identified some key tenets to providing feedback to students in science classrooms, whereby the information provided by the teacher is helpful, precise, and at the appropriate level. Cowie et al. (2013) suggested that scaffolding is a form of feedback that provides students with information about learning. Instructional scaffolds should not only include oral or written comments but also communicate to the students on how their learning is aligned to the learning goals. To support ELLs, instructional scaffolds can take a variety of forms over multiple occasions (Puntambekar & Kolodner, 2005). Classroom observations and initial analysis of the data revealed that the teacher provided several scaffolds during the implementation of the various multimodal tasks. They served to guide the students towards the learning goals. Analysis of the data revealed the following recurring themes in how the teachers provided the instructional scaffolds.

Use of Analogies

Analogies have long been tools of discovery in science and are often used to indicate resemblance in some particulars between things otherwise unlike: similarity or comparison based on such resemblance (Harrison & Treagust, 2000). It is also used to understand the transfer of relational or functional structure from a known domain (the analog) to another fundamentally similar but lesser known domain (the target), where the transfer is accomplished by mapping processes through which the similarities between the two systems are detected (Mason, 1994). Analogous objects do not only share necessarily a relation, but they can also express an idea, a pattern, an attribute, an effect or a function (Ogborn, Kress, Martins, & McGillicuddy, 1996). In this study, analogies and metaphors were used to explain disciplinary core ideas and enhance student understanding of curriculum based vocabulary. The interactive read-aloud task, *A Tree Is Like a Hungry Kid,* was jointly read and discussed by the entire class along with their teachers (Sadil, 2014). While one class read the handout silently at first and then discussed the handout with the teacher, in the other class, the teacher identified certain students to read. The title of the read-aloud task itself was a simile which the teacher asks the students to explain, “How could a tree be like a hungry kid?” Both the teachers asked the students to explain the figurative language used and expanded on the idea of how the tree is hungry. Besides the title, in this read aloud task, the process of photosynthesis was described as a recipe, where the ingredients were the reactants of the process namely, carbon dioxide and water and the energy provided for the process came from sunlight producing oxygen and glucose. In subsequent classes, the teachers used the word “recipe” and “ingredients of the recipe” to refer to the process of photosynthesis and its reactants. In subsequent multimodal tasks, phrases like “We are going to write the recipe,” “What does it make?” and “When it does this photosynthesis what does it make?” were used by the teachers to refer to photosynthesis. Similarly, other metaphors include describing stomata as holes. As Vicky asks, “In the little holes. Anybody remember what the name of those little holes are? Stomata.” Another interesting nature of using analogies was the usage of certain colors to highlight certain terms when making the molecule model. For example, blue was used to denote the water molecule, chlorophyll as green, sunlight as yellow, and oxygen as red (to denote its combustion). Further, the molecule model was created on a green sheet of paper to emphasize the importance of chlorophyll.

Contextualizing the Use of Vocabulary: Use of Non-Curriculum-Based Words

An effective method for helping English language learners in science classrooms is to combine good science teaching with scaffolding with a focus on language development (August, Artzi, and Mazrum, 2010). Vocabulary instruction encompasses much more than a list of words to teach at the beginning of the unit but also involves integrating in all content areas across the school day (Blachowicz, Fisher, & Watts-Taffe, 2005). Likewise, in this study, the teachers also incorporated the use of non-curriculum words to enhance the integration of learning of both science and language. The vignettes illustrate the use of the words *dormant, convert*, and *naked eye*.

Klara: When the chlorophyll starts to go . . . so you're really seeing the real leaf without all that chlorophyll in the winter. We can't see them until the chlorophyll is gone as winter begins to approach the tree uses the food during the spring and summer and it goes into a rescue year, period. It hibernate*s* just like bears do. Let's use a fancier science word. [The teacher proceeds to write the word *dormant* on the board.]

Klara: What does convert mean?

Students: Change

Klara: Change—let's write that word in there. . . . synonym.

The term *with your naked eye* was used in the read-aloud with the teacher. Klara noted that most students had highlighted that phrase as one which they did not understand. She explained, “When they say that it just means that you’re not using the microscope. . . . I know that your eye magnifies so much to fix that, so there’s millions and millions and millions of itty bitty tiny cells so small you can’t even see them.”

The Use of Curriculum-Based Vocabulary

The teachers had identified certain vocabulary words associated with the unit of photosynthesis, which they expected the students to understand and use in their multimodal representations. As researchers have pointed to differences in word knowledge where language minority students have both less depth and less breadth of vocabulary (Lawrence, White, & Snow, 2011), new words should be encountered in varying contexts by teaching word analysis and vocabulary learning strategies (Carlo et al., 2004).

I have described the unique ways in which the teachers incorporated the words within each task. The following vignette took place just after the teacher introduced the videos which explained the process of photosynthesis.

Vicky: You write this word, and then we are breaking this up, and you notice I’m using color, and that’s what I love when you guys do because photosynthesis is a really great word for you to know….Okay, so photo synthesis. Somebody said photo like a camera. Yeah, what does a camera need to be able to take a picture?

Students: Batteries.

Vicky: Yeah, it needs some energy, batteries, perfect, but it really does need light. That’s actually what photo means. It is a Greek word meaning light. In fact, there was a Greek god whose name was Photon.

Students: Photon.

Vicky: Yeah and he was, guess what he was? He was the god of light. There you go.

Vicky: Then we have synthesis. Just synthesize. Anybody know?

Students: Make.

Vicky: Synthesis is when you put things together so to make; you synthesize something. You take a couple of different things, and you put it together. To put together.

Students: What about combine?

Vicky: Combine would be a really good way of saying it also. Awesome. When we are talking about photosynthesis, we are talking about putting it together with light.

Re-Representation of Ideas Through Various Tasks

Tang, Delgado, and Moje (2014) have emphasized the value of having different *grain analysis of modes*, where the practice of re-representing science concepts through different representations is typically of long timescale and large grain size. In both classrooms, the teachers used multimodal tasks to represent the ideas of photosynthesis. Even though the teachers aligned a disciplinary core idea of photosynthesis as knowing (a) the reactants,(b) the products, (c) the use of sunlight as energy, (d) the role of chlorophyll, and (e) the importance of glucose as storage for food and growth for each task (as explained earlier), the teachers further highlighted each idea in other multimodal tasks. For example, the read-aloud task emphasized the role of chlorophyll in the process of photosynthesis. The handout explained in detail how the leaves changed colors based on the presence of chlorophyll and the importance of chlorophyll in trapping sunlight. These aspects were further highlighted during the seed-germination task and construction of molecule model. In the former task, when the seedlings not placed in sunlight were pale in color in comparison to those placed in sunlight, the importance of chlorophyll was reiterated. The molecule model was designed to highlight how oxygen is released in the chemical process of the combination of carbon dioxide and water in presence of energy to produce glucose and oxygen.

In sum, the teachers planned the multimodal tasks to assist the learning process and to represent students' understanding of photosynthesis. They planned it in such a way that each task were aligned to certain learning goals which corresponded to the disciplinary core ideas of photosynthesis. While implementing the tasks used to assist the learning process, the teachers used certain scaffolds to assist the learning process through the use of analogies, by contextualizing the use of vocabulary, and re-representing the same core ideas through different tasks.

Teacher Decision Making Using Multimodal Tasks

RQ3: How Do Teachers Understand and Reflect on the Use of Multimodal Tasks to Support Science Learning for Students in Their Linguistically Diverse Classrooms?

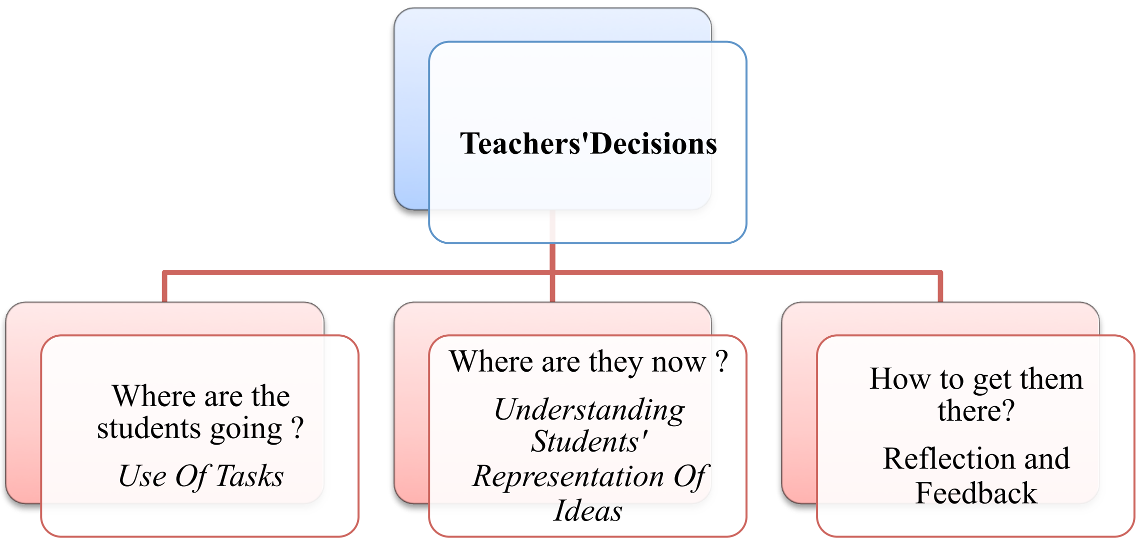

Figure 7. Schematic representation of teachers' decisions.

This study aims to explore the formative potential of multimodal tasks in linguistically diverse science classrooms. Assessment tasks are effective tools that can provide feedback for formative purposes (Hattie & Timperley, 2007; Ruiz-Primo & Li, 2013a). While effective teaching includes providing tasks to students and supporting their understandings, it is also important to assess and evaluate students (Hattie & Timperley, 2007). In research in science education, there has been limited focus on the pedagogical advances during feedback (Ruiz-Primo & Li, 2013b) with greater emphasis on the successful implementation of the assessment tasks (Ruiz-

Primo, Li, Ayala, & Shavelson, 2004). In this study, the multimodal tasks implemented by the teachers provided opportunities to support and assess student learning, whereas, the visual diagrams and comic strips created by the students provided the backdrop to examine the teachers' decision-making processes. The teachers used the visual tasks and comic strips (multimodal tasks designed for the students to represent their understanding of the process of photosynthesis) to identify "Where the students going?" and "Where are they now?" and "How do we get them there?" Hence, in this section, I have highlighted some aspects of the teachers' decision-making process to provide an insight into formative potential of visual diagrams and comic strips (Ruiz-Primo & Li, 2013b).

"Where Are the Students Going?" - Choice and Use of the Tasks for Representing Learning

The teachers had chosen three tasks for the students to represent their understanding of the process of photosynthesis. They include a cloze test, drawing a plant and labeling the process of photosynthesis, and making a comic strip. The students had to complete a cloze test designed by the teacher, where students had to fill in the blanks with the curriculum-based vocabulary words which were provided as a list. The students completed three visual diagrams (using the same prompt) with the same cloze tests at the beginning of the unit, during the unit, at the end of the unit, and four weeks after the completion of the unit. They also completed one comic strip during the entire unit. The teachers planned to observe and compare how well the students represented their understanding of the process of photosynthesis on the visual diagram (in response to the prompt) and completed cloze test. Visual representations of student learning have the potential to not only embody student ideas but also represent the progression of their ideas in successive iterations of the same visual representation (Wells, 2002). Thus the goal was to assess how well the students could make connections between the various parts of the plants and the different curriculum-based words. For the visual diagram, Vicky stated that, "My objective for them having a larger understanding of the plants that are producers that the sun's energy is going into it. That all the parts of the plant work together." Klara reiterated, "So they had their knowledge . . . that they were to apply it to a different scenario (draw a diagram), a different way of thinking about it."

While the visual drawing task was a static representation of the process, the comic strip depicted the process of photosynthesis in the form of a narrative. It is important for students to use various multimodal means to express their ideas (Kelly & Brown, 2003) and Klara described the comic strip as

> a way to synthesize their information so that they can present it in their own way. To show that they have taken all of their learning from these different pieces and putting it together in a new original way so they are not just copying something from a book. They can't copy the diagram; they've got to find a new way to tell the story.

Hence, the goal of the comic strip task was to enable the students to represent their understanding of photosynthesis over a sequence of events.

“Where Are the Students Now?” - Understanding and Supporting Students’ Representation of Ideas

In order to gauge the full potential of any multimodal task as a classroom resource, Bezemer and Kress (2008) have advocated the importance of realizing the processes of change to multimodal representations through *transduction*—how semiotic material is moved across modes, from one mode (or set of modes) to another mode (or set of modes), and/or *transformation*—changes within a mode.

In this study, the teachers noted how most students had utilized some of the features from one multimodal task and incorporated them into their own representations. For instance, as Vicky noted, “The Prentice Hall diagram really helped . . . they were really showing me the release of oxygen [as pairs].” Klara described a student’s effort to replicate that: “She knows they [water and carbon dioxide molecules] look like Mickey Mouse.” This was also seen in the molecule model, where Vicky had drawn the sun with cooling glasses in the molecule model. She noted that most of the students tended to draw the sun in the same manner in their diagrams.

The teacher had explained that the goals of the molecule model was two-fold, one was to show how molecules are formed, and, by showing the equation, demonstrate how oxygen is released as the by-product. The students created small models of water, carbon dioxide, glucose, and oxygen molecules. While showing how to balance the number of molecules on each side, the teachers were able to demonstrate how there were excess oxygen atoms, which were released as a by-product of the process of photosynthesis.

To further support students' understanding of the effect of sunlight in the process of photosynthesis, Vicky used the students as models, where the students were asked to stand in a line holding hands—demonstrating how this group represented a water or carbon dioxide molecule. The teacher turned off the lights and asked them to release their hands when she turned on the lights. She explained how the lights of the room represented the sun which helped in breaking the bonds of the molecules which was represented by the holding of the students' hands.

"How Do We Get Them There?" Feedback and Reflections on Visual Diagrams

Teacher feedback. Feedback is an essential component of formative assessment, and assessment tasks are effective tools that can provide feedback for formative purposes (Hattie & Timperley, 2007; Ruiz-Primo & Li, 2013a). The essential aspects to be noted in using assessment tasks formatively are that feedback should be based on student performances of the task and not on the quality of the product, and it also should be aimed at improving science understanding and supporting students achieve the learning goals of a task (Shavelson et al., 2008).

The teachers' goal was to grade the students separately based on their performance on the visual diagrams and the cloze test. Both teachers decided on a grade point system ranging from 0 to 4, so as to give the students a gauge on what they could improve on. Klara was the teacher who had created the rubric to grade the students' diagrams. Her explanation of the rubric was as follows:

> A 4 means that they can compete against any kid in California. I asked them for a definition [of photosynthesis] to get a 4. For a 3 I was looking for all those parts [the four things needed for photosynthesis] and the word *glucose*. Those who got twos had a lot of vocabulary, but just didn't tie it all together. The ones focused on the parts of the plants, so they internalized our last lesson [on plant parts], but hadn't connected.

Wiliam (2011) has posited that even though in their prior research "Inside the Black Box" (Black & Wiliam, 1998), they claimed that feedback should be in the form of comments and not grades, the feedback should be on "what to do improve student learning" (p. 120). The teachers in this study provided feedback, albeit in the form of grades on the visual diagrams. However, the teachers' goal was to help students identify their learning by giving them a grade and explaining what that grade means and what they have to do next. They made comments like "I give them a 3+ and say hey, don't forget this, when we do the final diagram." Further if they found missing terms, the teachers wrote the missing terms in markers to help the students realize what is missing. Like Vicky said, "When I realized they didn't have *chloroplasts* and *chlorophyll*. And I am just going to give them that." "She drew me a flower with no leaves. In fact, I'll draw that leaf." When the teachers distributed the students' diagrams the next day, they explained the grade number assigned to their visual diagrams and explained how each grade reflected their understanding of photosynthesis. Further, they stressed the importance of the learning the missing terms on the diagram and explained how to use each vocabulary term in the cloze test.

Teacher reflections. Assessing three iterations of the students' visual diagrams provided avenues to not only analyze how the students were able to utilize what the teachers taught through the various multimodal tasks and represent their learning but also assess their progress in understanding of the process of photosynthesis. Vicky claimed,

> The diagram is what changed my teaching on a daily basis. The first one let me know how little some of the kids knew [about photosynthesis], but the second time that we did it, it absolutely pinpointed what I needed to reinforce . . . so it gave me this is what I need to do, and it also gave me a real quick talk to the kids about drawing the parts.

She also noted that even if the final visual diagrams of some students did not have all the parts required to have a good score, examining all their diagrams gave an idea of their progress. “The nice thing is, if I didn’t have this beginning one, I would be sitting here going, ‘He learned nothing.’ Now I actually know that he did pick up something . . . otherwise I would have thought it would’ve been a complete failure.” Vicky stressed how “the diagrams allowed them to explain in such a way that you can tell that they had so many concepts.”

Other teacher reflections include their ability to assess the progress of ideas of the process of photosynthesis through the three visual diagrams. They explained how the students “went from plants need sunlight to make its own food in a process. Level of sophistication he has gotten from this process.” As Klara said, “She is picking up a lot of language. Not only was this a success for her understanding some of the ideas.” “He is just not labeling, he’s writing functions…he has everything happening in the flower.”

Summary of Teacher Decisions

The teacher used certain tasks to make decisions on student learning of the process of photosynthesis. These tasks were used to understand “How are the students doing?" "Where are they going?" and "How do we get them there?" The tasks used for decision making were the three visual diagrams—one collected before the unit, one during the unit, and one collected towards the end of the unit. The comic strips created by the students also helped the teachers realize the students' understanding of photosynthesis. They examined how the students progressed in their understanding of photosynthesis through the three visual diagrams. Finally, how and when the teachers provided feedback on the visual diagram task and the type of feedback in the form of grade numbers was discussed. The teacher reflections on how the students progressed in their understanding of photosynthesis through the visual diagram tasks were analyzed.

Summary of Teacher Views and Beliefs (Initial Phase—Final Phase)

In their heuristic model, Clark and Peterson (1986) highlighted the need to understand teacher beliefs and their influences in the classroom, especially in the realm of assessment during teaching. It is also important to understand how their beliefs change so as to further accommodate the needs of their students. This study examines how multimodal tasks can support the teaching and learning in two linguistically diverse classroom. The teachers planned and implemented multimodal tasks to assist the learning process and provide avenues for students to represent their understanding of the process of photosynthesis.

Importance of Learning over Time

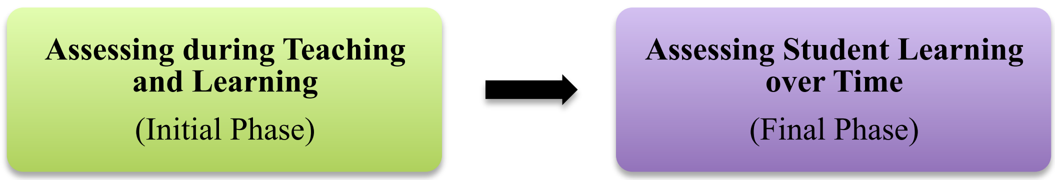

Figure 8. Schematic representation of shifting views and beliefs of assessing during teaching and learning.

As students interact and revisit ideas and relate them to other ideas, the students' understanding of these concepts become particularly complex over time. Kane et al. (2013) described how children's understanding of science concepts develop over time as an "ebb and flow" of connections between activities and concepts. While Vicky examined the sequential visual diagrams of each student, she noted that "This is just emphasizing how many different ways you need to present it and how often you need to repeat things and how often you need to go back and say." Through the different iterations of visual diagrams, the teachers could assess prior knowledge of students and the knowledge the students gained after teaching. Similarly for the comic strip, Vicky emphasized how "the value of it was that it was multiday thing and watching them get stuck and then have to talk through and finding questions and finding answers and coming back up to looking again at the model."

Additional Scaffolds for Student Representation of Learning: Diagram and Comic Strip

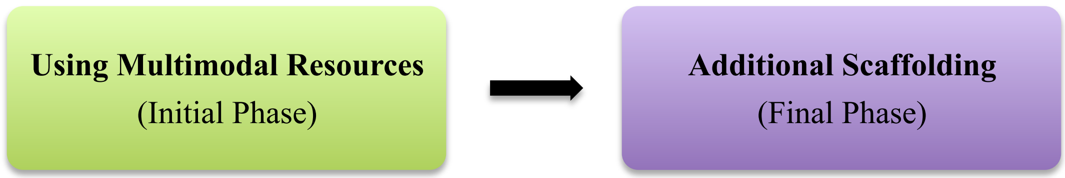

Figure 9. Schematic representation of shifting views and beliefs of using multimodal resources.

The teachers chose two separate multimodal tasks for the students to represent their learning—a visual diagram and a comic strip. As the teachers claimed, "Whereas the diagram is having it all happen at one time, which is kind of what is. But then the book (comic) would be breaking it down into time periods and different settings again." However, based on the students performed in the two tasks, the two teachers felt that modeling of these activities would have supported student learning. They noticed that "some of the learners did not move on because we did not spend as much time on me drawing and drawing it and using the GLAD type of mapping and putting the labels on it as I did on the tree structure."

Against their expectations, they realized that the comic strip was more difficult for the students to create. They both noted that "the comic strip was difficult for them and in telling the story they couldn't create the story, but they could create pictures with sequences, but they never had the flow with it." For students who struggled in language arts, they felt that providing additional scaffolds would have been more fruitful, as noted by this comment by Klara: “I think modeling the story, I would have worked and helped those kids who were struggling.”

Addressing ELL Needs While Integrating Science and Language

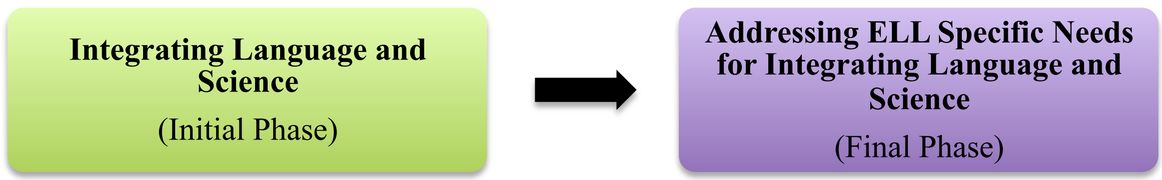

Figure 10. Schematic representation of shifting views and beliefs of integrating language and science.

The majority of the students in both the classrooms were once ELLs or redesignated within the last two years. As explained earlier, prior to the unit, both the teachers had strong opinions on certain aspects of how to support the needs of ELLs in learning science, one of which was integrating the use of science and language to address their content learning and English language needs. Interestingly, they stressed the importance of assessing the child’s work as a whole, not just the appropriate usage of vocabulary. “Occasionally you get kids, you think might not be successful by their handwriting, their spelling, or their ability to draw, but they actually have the ideas.” Despite the fact that the teachers employed strategies to aid science language integration, after the unit, they emphasized on certain aspects for subsequent lesson planning in science. Klara stated that, “Maybe what would have been using sentence starters like ‘Photosynthesis is . . .’ ” Using sentence starters is a very useful scaffolding strategy for integrating science and language learning especially for ELLs (Stoddart et al., 2010). Another word of caution by the teachers was regarding the use of analogies. They felt that the use of the analogy of photosynthesis is like a recipe was limiting in certain ways. Vicky felt that the students' understanding of photosynthesis was limited to listing its reactants and products. She claimed "I almost feel that while we really added to it, they almost like they lost that basic definition of Oh [photosynthesis], it's making food." Further she was concerned about the relevance of the analogy in the students' lives, "I think the recipe made sense to them, but so many of them do not cook."

Conclusion

This study examines the potential of multimodal tasks to support teaching and learning of science in two linguistically diverse classrooms through the perspectives of two sixth- grade teachers. This study addresses what most researchers have posited—assessment systems embedded in classroom contexts, enabling both teachers and students to support science learning. This paper examines a range of multimodal tasks as part of such an assessment system in two sixth-grade science classrooms with 20 ELLs, 18 redesignated students, and 25 English-only students.

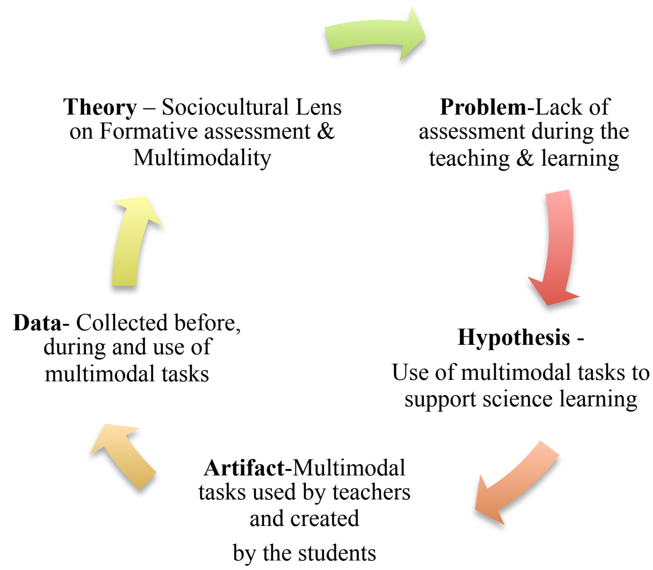

Figure 11. Model of design-based approach of the study, adapted from the osmotic model in Ejersbo et al. (2008).

As this study is located in the social milieu of a science classroom setting, where along with the teachers I examined the use multimodal tasks as formative assessment to support science learning. Contrary to traditional educational research in which theories are tested in controlled environments, this study incorporates some aspects of design-based research and examines the confluence of the potential of multimodal tasks from a sociocultural perspective lends to the advancement of theory of integrating science and language learning and assessing during the process of teaching and learning to support the science learning of students. Examining from a sociocultural perspective, through the integrated model of Clark and Peterson (1986) and Ruiz-Primo & Li (2013b), I have described how the teachers through their existing views and beliefs planned and implemented multimodal tasks to assist the students' learning process and used the tasks formatively to inform instructional

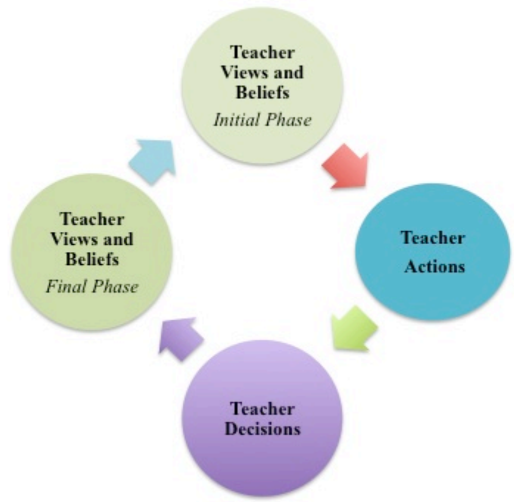

Figure 12. Schematic representation of the summary of analysis of teachers' perspectives on multimodal assessments in linguistically diverse students.

decisions and provide feedback. Finally, I analyzed through the cyclic process of planning and decision making, how the teachers' beliefs changed and how it further influences their future decision making.

Cowrie et al. (2013) have argued for a focus on teachers' developing "connections, continuity and coherency in classrooms" (p. 111) to support classroom-based assessment. In this study, this tenet serves as an overarching theme of how the teachers viewed, planned, and implemented multimodal tasks in their linguistically diverse classrooms and made decisions which influenced further curricular planning and instructional steps. In order to develop expertise needed to teach culturally and linguistically diverse students, many researchers have urged for the need for teachers to develop competencies in linguistically responsive pedagogical practices (Banks et al., 2005; Lucas & Villegas, 2013; Stoddart et al., 2010;). It requires the building of *pedagogical language knowledge*—development of understanding of *language as action* (Bunch, 2013; Galguera, 2011; van Lier & Walqui, 2012, p. 47). They posit that part of the process of developing this foundation to support ELLs is to engage them in challenging and meaningful academic tasks, where the language demands of such tasks have to be taken into account. Through the model used to describe this study, several instances of *language as action* can be seen, wherein the teachers planned multimodal tasks and addressed the language demands through instructional scaffolds while using the tasks.

Teacher Actions: Planning and Implementation

In order to create more *connections*, the planning of the multimodal tasks were such that they aligned to the learning goals of the unit which encompassed the disciplinary core ideas of photosynthesis. It is noteworthy that the teachers had planned the tasks in such a way such that some were used to communicate the ideas of photosynthesis, and others were used solely for representing students' ideas. Incidentally none of the tasks used to communicate learning were entirely designed by the teachers, other web sources and teacher resources were modified and used. To establish *continuity*, the teachers scaffolded the use of ideas within the tasks through the use of analogies, incorporated the modes like symbols or images used in one task and used them in other tasks, thus re-representing the modes. Zwiers (2007) has explained how analogies and personifying in science are particularly useful for students from diverse linguistic backgrounds. The use of analogies was intended to establish *coherency* amongst the different disciplinary core ideas of photosynthesis. Through identifying the language functions and vocabulary included in the tasks, the teachers demonstrated the ways of doing *language in action*. One such way was contextualizing the use of both curriculum-based and non-curriculum-based vocabulary in the unit within each task by the teachers. Finally, re-representing the core ideas through various tasks helped support the notion advocated by the National Research Council (NRC; 2014) on developing assessment tasks aligned with the Next Generation Science Standards (NGSS).

Teacher Decisions

The teachers used certain tasks created by the students namely the visual diagrams and comic strips to assess "How the students are doing?" "Where are they going?" and "How do we get them there?" Another idea posited by the researchers (NRC, 2014) is how assessment tasks should "provide information about where students fall on a continuum between expected beginning and ending points in a given unit" (p. 3). The visual diagram tasks were used for this very purpose. It provided insights as to how the students responded to the feedback provided by the teachers and improved on the visual diagram. Through the three iterations of the students' visual diagrams the teachers could not only analyze how the students utilized what was taught through the various multimodal tasks and represent their learning but also assess their progress in understanding of the process of photosynthesis. While it is important for students to use various multimodal means to express their ideas, it is equally important for students to apply science practices like creating explanations in the context of multiple disciplinary core ideas. The choice of using a comic strip addressed this issue by having an assessment task by which the students could use different modes to represent their understanding of photosynthesis through integrated use of both science and language.

Teacher Views and Beliefs

Although *English language learner* is a convenient demographic term, using this term in determining and assessing the progress of students for whom English is a second language can be problematic. Galguera (2011) argues for a shift of this standpoint and posit using the idea of *language use for academic purposes* by which teachers can view their planning and implementation of tasks. To attend to this, plans should include general support for use of language demands and support for students at different levels of language learning during content learning. While the teachers in this study attended to the language demands of the students using the multimodal tasks, one aspect they focused on was the use and integration of curriculum-based vocabulary through the various multimodal tasks. Even though the teachers believed in the potential of multimodal tasks to assist the learning process and for students to communicate their learning, they posited that multimodal tasks in the form of the narrative tasks like the comic strip represented challenges for *language use for academic purposes*. In their later interviews, they underscored the importance of providing more scaffolds and modeling for ELLs and students who were below proficiency in Language Arts and Science.

To conclude, when asked about the value of multimodal tasks, Vicky summarized it as “connection and synthesis for all students” and Klara called it “a way to synthesize their information so that they can present it in their own way.” They are trying to convey that for the multimodal tasks to support the teaching of learning of linguistically diverse students, the intent is to connect the content vocabulary with the disciplinary core ideas from each task and establish continuity with the science practices the students engage in. These quotes capture the essence of what the two teachers of the sixth-grade classrooms summarize as the formative potential of the multimodal tasks of the classrooms.

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Appendix A

Teacher Assessment Interview 1 Prompt

To be read: Thank you for participating in this interview. The purpose of this interview is to better understand your views about assessing student learning. There are no right or wrong answers for these responses. Please be honest. If you need more clarification or need me to elaborate/expand/justify at any time, just let me know. Please understand that your participation is voluntary and that you have the right to refuse to answer particular questions or discontinue this interview at any time without penalty. Your individual privacy will always be maintained.

1. Can you please describe your experiences while assessing in your current classrooms?

2. Can you please describe any experience you have had learning about educational assessment?

3. What do you think are effective ways of assessing of how students learn science?

4. How would you describe to a fellow science teacher what it means to assess for learning?

5. What are some of the criteria you will use when using a task for assessing student learning?

6. What would you do with the information you gathered about the students? Why?

7. Finally, how would you assess student learning for ELLs in science? Why

Appendix B

Teacher Multimodal Assessment Interview 2 Prompt

To be read: Thank you for participating in this interview. There are no right or wrong answers for these responses. Please be honest. If you need more clarification or need me to elaborate/expand/justify at any time, just let me know. Please understand that your participation is voluntary and that you have the right to refuse to answer particular questions or discontinue this interview at any time without penalty. Your individual privacy will be maintained in all published documents resulting from this study.

[Show prompt and response]

1. Can you take me through the (visual or narrative) task and explain how you would assess for science learning?

2. Can you take me through the (visual or narrative) task and explain how you would assess for language learning?

3. What are the criteria you are looking for *in this particular task* to assess for science and language learning?

4. What is the type of feedback you would like to give this student?

5. Based on the student performances on this task, do you have any suggestions or recommendations for other teachers who might like to use a similar task?

CHAPTER 3: MULTIMODAL TASKS TO SUPPORT SCIENCE LEARNING IN LINGUISTICALLY DIVERSE CLASSROOMS: STUDENTS' PERSPECTIVES

Background

ELLs: Science Teaching, Learning and Assessment

Today's schools face unprecedented challenges in preparing ELL students to meet academic expectations (National Academy of Sciences [NAS], 2010; National Center for Education Statistics [NCES], 2011) and the implementation and maintenance of high-level academic programs in science (Tate, 2001; Wong-Fillmore & Snow, 2000). ELLs face the daunting task of learning the academic curriculum and a new language concurrently. Science instruction for most ELLs is still conducted in English; thus students must learn new academic content in a language that they are still acquiring (Warren, Balleneger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). The traditional approach to science instruction for ELLs is to develop English language and literacy prior to teaching them science (Buxton, 2006; Lee & Luykx, 2006; Stoddart, Pinal, Latzke & Canaday, 2002). Often ELLs are relegated to remedial instructional programs focusing on the acquisition of basic skills that supposedly match their English-proficiency level (Lee & Luykx, 2006; Moll, 1992; Valdes, 2011). The result is that the majority of secondary-school ELLs do not have access to rigorous science instruction (LaCelle-Peterson & Rivera, 1994; Oakes, Joseph, & Muir, 2004; Pease-Alvarez & Hakuta, 1992).

Another interesting conundrum faced by school districts with large numbers of ELLs is their heterogeneous nature. Some English learners are immigrants, who were born outside the United States and moved to this country at some point in their young lives, often called first generation English learners. The second or third generation English learners are those who were born in the United States and represent their families' second or third generation in this country. Nationally, 57% of adolescent English learners are second or third generation, and in California they comprise of 49% (Batalova, Fix, & Murray, 2007). In California, second and third generation students tend not to have well-developed literacy skills in their family language or in English (Francis, Rivera, Lesaux, Kieffer, & Rivera, 2006). As such, adolescent English learners in California middle and high schools do not fare well in school, socially or academically (Walqui et al., 2010). The middle school years are a critical transition period for all adolescents as they help students in setting a course toward accomplishing the requirements for pursuing university options (Walqui et al., 2010). Further in middle school settings, there is more emphasis on disciplinary language development and subject matter knowledge and skills, which becomes more central to the success of all students (Moje, 2007). As such for adolescent second language learners who have a limited proficiency in English, this period is complex (Walqui et al., 2010).

Particular attention has to be paid to inclusive strategies to engage students from culturally and linguistically diverse backgrounds as science standards are translated into curricula, instruction, and assessment. The focus on developing English proficiency for ELLs rather than content area learning, the lack of valid and fair assessments to evaluate content area learning, and the importance of educating the middle school population provide the impetus for this study research.

Recent Reform Efforts for ELLs

To support the science learning of students from different social and linguistic traditions special attention has been placed on science and engineering practices. The NGSS (Next Generation Science Standards), a project coordinated by Achieve, Inc., documents a consensus view of what is important in K–12 science education and is grounded in an extensive review of the literature on science learning and designed to guide the work of 26 lead states in developing next generation science standards. It highlights what it means to promote learning science by moving away from prior approaches of learning facts or loosely defined inquiry to a three-dimensional view of science and engineering practices, crosscutting concepts, and disciplinary core ideas.

One of the goals of the NGSS is to ensure educational equity by creating rigorous standards that apply to all students. The science and engineering practices advocated by the NGSS can serve as productive entry points for students from diverse communities—including students from different social and linguistic traditions, particularly second-language learners. The authors of the NGSS also reiterate that as standards are translated into curricula, instruction, and assessment, particular attention has to be paid to inclusive instructional strategies to promote educational equity in learning science and engineering. To pursue the same goal, the NGSS Diversity and Equity Group focused on ensuring that the NGSS are accessible to all students by identifying emerging national initiatives for a new wave of standards. They identified four areas that can lend support to science and language learning for ELLs. First, various strategies for literacy development include having an explicit discussion of reading strategies for scientific texts, prompting students to use explicit academic language in science practices and engaging students in scientific genres of writing. Second is the implementation of language support strategies such as realia (real objects or events), and multiple modes of representation (gestural, oral, pictorial, graphic, textual) for ELLs in science classrooms. Third, discourse strategies should be used which can facilitate ELLs' participation in classroom discourse to enhance their understanding of academic content. Finally, it is important to use students' home languages to support science learning in English in classroom interactions in ways that reflect communication patterns from their home and community. Further, Lee, Quinn, and Valdes (2013) examined the intersections between the learning of science and the learning of language as ELLs engage in language-intensive science and engineering practices proposed by the NGSS within classroom settings. They posit that by identifying key features of the language of the science classroom, both science learning and language learning can be promoted for ELLs.

In the same vein, the Council of Chief State School Officers (2012) emphasize the reconceptualization of the way ELLs acquire and develop language as well as disciplinary knowledge and skills. The English Language Proficiency Development Framework (ELPD) envisions these skills as mutually enriching processes with the end goal being to ensure full participation of ELLs in school contexts (Pimentel et al., 2012). To achieve that goal, the ELDP outlines the supports needed to provide ELLs with the help they need to access grade-level content while building their language proficiency. The ELDP also helps educators prepare ELLs for the specific language demands of the NGSS and outlines ways to support content learning. Pimentel et al. (2012) described the key practices and disciplinary core ideas in science as described by NGSS and how ELLs can engage in the key practices by performing certain analytical tasks to make sense of and construct knowledge through engaging in both receptive (listening/reading) and productive (speaking/ writing) language functions (p. 28–42). Pimentel et al. (2012) posited that as ELLs engage in science practices in classrooms, they can clarify their language and thinking (p. 15). Another concomitant goal of the ELDP is to ensure that states have resources to assist them, such that the developing language needs of ELLs are met and all ELLs receive the rigorous and systematic education they need to graduate from high school.

I have highlighted the essential ideas put forth by the reform efforts in the development of standards in content areas like science, language arts and developing proficiency in English language and how these efforts can be specifically conceptualized for English language learners. The success of ELLs in science is to ensure the interplay between science, language and literacy at the classroom level, where discussion of scientific concepts and providing instructional scaffolds by engaging ELLs in multiple modalities or representations can help students acquire the science language and register. This study explores how students from different linguistic backgrounds use multimodal tasks to support their science learning in two sixth grade classrooms.

Guided Literature Review

In this paper, I examined the use of multimodal tasks in science to support the science learning of students in two sixth grade linguistically diverse classrooms through the students' perspectives. This study is situated within the confluence of multimodality and formative assessment of science learning within the social milieu of a linguistically diverse science classroom. Hence my literature review draws from research on (a) the potential of multimodality for ELLs in science education and (b) formative assessment in science education within classroom settings.

Multimodality for ELLs in Science

In science education, studies have aimed to examine the multiple modes of representation and communication for students who are learning English as a new language. Central to the conception of science learning through multimodality is the constructing and representing of meaning through scientific inquiry and discourse using multiple modes. Most of the research for ELLs in science education have paid special attention to supporting their science learning through simultaneously supporting their language learning and science content learning, engaging in classroom discourse through reading and talking, and attention to cultural and linguistic backgrounds.

Science and literacy integration. Science and literacy share highly complementary learning processes and discourse practices (Cervetti, Pearson, Barber, Hiebert, & Bravo, 2007). Hence, there has been research on *science-literacy programs* that capitalized on potential synergies between science and literacy, where students can utilize skills such as posing questions, making predictions, or making inferences, which can be used for both science inquiry and for reading comprehension. One of the ways this was attained was through using *multiple modes of representation and communication through talking, read aloud and visuals.* I have highlighted some of the studies that have examined the notion of science and language integration either through (a) teacher training programs or (b) through curriculum implementation in classrooms.

Teacher training. Stoddart, Bravo, Tolbert, and Solis (2010) created the Effective Science Teaching For English Language Learners (ESTELL) framework, which embodies the principles of integrating science inquiry and literacy. The ESTELL framework pays special attention to promotion of content-based vocabulary learning and engaging students in reading and writing activities that are authentic to the content area (i.e., reading science related articles, writing up investigation/experiment procedures and results and using science notebooks). Supporting teachers' understanding of the importance of integrating science and literacy for ELLs has been highlighted by Stoddart, Solis, Tolbert, and Bravo (2010), through science inquiry projects with an emphasis on language scaffolding and science scaffolding through multiple forms as visuals and graphic organizers. In their study, Echevarria, Vogt, and Short (2000) demonstrated how their Sheltered Instruction Observation Protocol (SIOP) Model of professional development supported English learners in content area knowledge and academic language development. Similarly, Unsworth and Bush (2010) outlined the practical ways in which the teachers used text and also scaffolded student learning with students learning English as a second language who were taught about image construction complementing the meaning-making resources of language in multimodal science texts.

Curriculum studies. The implementation of science-literacy integrated curriculum units and the efficacy of the curriculum in improving ELL science learning have been examined by some studies, which include the Seeds of Science and Roots of Reading science-literacy curriculum programs (Cervetti, Pearson, Bravo & Barber, 2006). The particular nature of the Seeds of Science and Roots of Reading units is that they strategically employ multiple learning modes through reading, writing and drawing, which provides ample opportunities to support ELL learning. Research results show that *Seeds of Science and Roots of Reading (Planet and Moon)* helped ELLs make large gains in science content, vocabulary, and reading comprehension (Duesbery, Werblow, & Twyman, 2011). Further, the curriculum units like Shoreline Habitats and Terrarium Habitats have also demonstrated the value of the process of summarization of scientific processes through verbal interaction, pictorial representation and written note taking (Goldschmidt & Jung, 2011; Hanaeur, 2005).

Multimodality in Classroom Discourse

Another group of studies also supported the notion of using multimodality for ELLs in science, wherein, it is described as the emergence of classroom discourse that shared features with language of science in classrooms with ELLs thus promoting learning (Lee et al., 2013; Varelas, Pappas, & Arsenault, 2013). Varelas, Pappas, and Rife (2006) revealed how hybrid classroom discourse, which incorporated and embedded both narrative and scientific genre features, supported student engagement and learning. Similarly, Brown and Ryoo (2008) posited that an approach that allowed students to transition from an everyday understanding of phenomena to the use of scientific language supported science learning through a web-based software promoted science understanding and improved ELL students' ability to use scientific language. Varelas and Pappas (2006) examined read-alouds of information books in an integrated science–literacy unit on the topic of changes of states of matter, which promoted and shaped children's engagement with science classroom discourse. Both studies showed that the combined efforts of engaging in talking, reading, writing, drawing and hands-on explorations supported the children's efforts in engaging in understanding science.

Multimodality and Cultural and Linguistic Backgrounds

Providing an alternative perspective, Warren, Ogonowski, and Pothier (2005) described how the everyday experiences of children could contribute to meaning-making in science. In their research, the notion of multimodality is mediated through the concept of intertextuality—identifying different types of text, modes of meaning the text draws upon and the ways they are all articulated together. Through oral discourse, the students, who were mainly Haitian Creole, developed understanding of ideas related to heat, heat transfer and the particulate nature of matter (Rosebery, Ogonowski, DiSchino, & Warren, 2010); linked playing with toy cars and a ramp with Newtonian Physics (Warren et al., 2005); and studied metamorphosis and science experimentation through embodied imagination (Warren et al., 2001). These studies highlighted how the children created links between their everyday experiences and science concepts, thus dispelling the contention that everyday language and talk are not compatible with science learning.

Notion of Multimodality in This Study

I have examined the notion of multimodality for ELLs in science education through science-literacy integration programs that support language and science content learning through curricula that embeds multiple modes into learning, and teacher development programs that support the development of multimodal instructional scaffolds. Engaging in classroom discourse through multiple modes has shown the value of integrating multiple modes in a science classroom through reading, talking, writing and attending to the students' cultural and linguistic backgrounds. Language serves as the vehicle with which to perform analytical tasks and ultimately to construct knowledge, and the language of the science classroom highlights two key elements: modality and registers. Modality refers to multiple aspects of the oral and written channels through which language is used, and registers refer to the vehicle used to perform analytical tasks and ultimately to construct knowledge. The types of analytical tasks that students engage in for science and engineering practices include receptive (listening/reading) and productive (speaking/writing) language functions. Lee et al. (2013) emphasized the importance of paying attention to the language of the science classroom that moves toward the disciplinary language of science. Thus, the ways of using language range from the informal styles—used by teachers to provide explanations, oral language used by students to interact with each other ; to the more formal styles—written styles used by classroom texts, describing models, constructing arguments and providing oral explanations of a phenomenon or system(Lee et al., 2013, pp. 4–6). In carrying out analytical tasks to engage in such practices, ELLs can grow in their ability to use appropriate registers.

Formative Assessment in Science

Formative assessment as tasks. In some studies in science education, certain tasks were chosen as vehicles for formative assessment in science classrooms. For tasks to be effective for formative assessment purposes, it is important that congruency exists between the tasks and the instructional activities of the classroom. The closer the assessment task is administered within curricular instruction, the greater is its sensitivity to elicit learning (Ruiz-Primo, Shavelson, Hamilton, & Klein, 2002)). This notion supports the idea of using tasks like concept maps, science notebooks, conversations, or embedded assessment tasks for formative assessment purposes. Studies also showed how tasks designed for formative assessment often facilitated learning through various modes like writing text, schematics, and drawings. One such study used the technique of concept-map (Novak & Gowin, 1984)—representative of students' knowledge structures—where concept maps were used to elicit knowledge (Yin, Vanides, Ruiz-Primo, Ayala, & Shavelson, 2005) where the students were either provided concepts and asked to construct a map using self-created linking phrases. Ruiz-Primo and Li (2004) found science notebooks to be an unobtrusive assessment tool for obtaining information about students' learning, the implementation of a curriculum's intended activities, and the quality of teachers' feedback. While Alonzo (2008) provided examples of informal uses of science notebooks as assessment tools, Amaral & Klentschy (2008) showed the potential of using science notebooks to support students beyond the simple completion of the task to making sense of the task.

Formative assessment as embedded curriculum. For a task to be used for formative purposes, it is important that the tasks enable both teachers and students to engage in the formative assessment practices. From the studies in science, it was shown that for the task to be useful for formative assessment purposes, it should also facilitate opportunities for assessment. It was found that while engaging in the tasks, if student conversations were encouraged, they provided opportunities for formative assessment (Bell and Cowie, 2001; Cowie, Moreland, & Otrel-Cass, 2013). The most common form involved the use of embedded assessments that were intended to provide thoughtful, curriculum-aligned, and valid ways of determining what students know rather than leaving the burden of planning and assessing on the teacher alone. Examples of such embedded assessments were Shavelson et al. (2008), who aimed to develop students' science understandings of why things sink and float; Minstrell, Anderson, Kraus and Minstrell (2008), who demonstrated the value of a web-based assessment system called *Diagnoser* and highlighted how the tools worked best when the teacher used the student response to generate conversation around the tasks; and

K. T. Anderson, Zuiker, Taasoobshirazi, and Hickey (2007), who also analyzed both tasks and processes and detailed an innovative approach to coordinating and enhancing multiple levels of assessment and discursive feedback around an existing multimedia curricular environment called Astronomy Village. The studies described have shown how some collaborative activities in and across conversations and written assessments supported as well as constrained meaningful understanding. In their study, Wilson and Sloane (2000) also showed the value of the embedded curriculum tasks by demonstrating how the students used multimedia and computer-based tasks to provide evidence for their explanations with evidence. Gotwals and Songer (2010) illustrated in their study how an elaborate assessment system included assessment tasks that provided scaffolds to guide students' development of evidence-based explanations to reason about food web and food chain disturbances.

In sum, the aforementioned studies examined different types of formative assessment practices including strategies, tasks, or processes. Some of the pertinent information regarding the strategies and processes include the following: (a) student participation should be encouraged; (b) opportunities should be provided for students to test their explanations with evidence from the assessment event; (c) teacher facilitation on the usage of tasks is pertinent; (d) teacher feedback on the tasks of conversations is crucial; and (e) what can be garnered from the aforementioned studies have highlighted the value of using assessment tasks for formative purposes. However, to be used effectively, certain aspects have to be attended to, namely, tasks should engage the students in conversation to enable building explanations and utilize different forms of communication.

Notion of Formative Assessment in This Study

Models of formative assessment in science. The Assessment Reform Group (2002) emphasized three key instructional processes: (a) establish where the learners are in their learning, (b) establish where they are going, and (c) establish what needs to be done to get the students there. Wiliam (2007) expanded on these processes to showcase five key strategies to demonstrate how they can be implemented in classrooms: (a) classifying, sharing and understanding learning intentions and criteria for success; (b) engineering effective classroom discussions, questions, and tasks that elicit evidence of learning; (c) providing feedback that moves learners forward; (d) activating students as instructional resources for one another; and (e) activating students as owners of their own learning.

The table below shows a theoretical model of assessment for learning. The numbers in parentheses indicate the key strategy related to each aspect.

Table 1
Assessment for Learning

	Where the learner is going	Where the learner is right now	How to get there
Teacher	Clarifying learning intentions and sharing and criteria for success (1)	Engineering effective classroom discussions, activities, and tasks that elicit evidence of learning (2)	Providing feedback that moves learners forward (3)
Peer	Understanding and sharing learning intentions and criteria for success (1)	Activating students as instructional resources for one another (4)	

Learner	Understanding learning intentions and criteria for success (1)	Activating students as the owners of their own learning (5)

Adapted from "Integrating Assessment With Instruction: What Will It Take to Make It Work?" by D. Wiliam and M. Thompson, 2007, in C. A. Dwyer, *The Future of Assessment: Shaping Teaching and Learning* (pp. 53–82), Mahwah, NJ: Erlbaum. Copyright 2008 by Lawrence Erlbaum Associates.

The *first strategy* involves classifying, sharing, and understanding learning intentions and criteria for success, either with specific goals or broad learning goals. What also makes this strategy distinctive is that the criteria for success or the goals are not entirely dependent of the formative assessment task. The *second strategy* focuses on the way the evidence for learning is collected, namely the engineering of effective classroom discussions, questions, and tasks that elicit evidence of learning. The way the evidence is collected and what is elicited from the evidence is predetermined by the learning intentions or goals. The purpose of the assessment can be either diagnostic or for monitoring or both. The *third strategy* is indicative of the prospective nature of the formative assessment, which includes providing feedback that moves learners forward. The essential point of this strategy is that the feedback should focus on how the learner works on the task and how the learner uses the feedback to work on the task. Furthermore, based on the outcomes seen with the current students, the teacher can modify the curriculum so it can be more effective for future students. The *fourth and fifth strategies* represent the students' role in formative assessment. The fourth relates to activating the students as owners of their learning in how they can guide their own learning according to the learning objectives which they can identify with. When students are interested in a task, they are more likely to engage in a task. Self-efficacy beliefs can motivate students towards the attainment of the goals. The *fifth strategy* focuses on activating students as resources for one another. This strategy incorporates some of the aspects of the other strategies, whereby students assess the work of their peers. For peer assessment to be effective, the students have to understand the learning intentions of the tasks they are assessing and what the effective ways of eliciting evidence are.

In this paper, as I have explained earlier, the focus is to highlight how students use the multimodal tasks to understand the process of photosynthesis. The model discussed above, the fourth strategy is related to the role of students in process of formative assessment. Hence one of the goals, the focus of this paper is to see how the students engage in this process. It includes taking ownership of their own learning by being active in guiding their own learning and realizing the curricular objectives. Researchers have claimed that the strategy of formative assessment which involves the role of students share many tenets with notions of self-regulation and self-assessment (Andrade, 2010; Wiliam, 2010). While self-regulation is broadly considered " a multilevel, multicomponent process that targets affect, cognitions, and actions, as well as features of the environment for modulation of one's goals" (Boekaerts, de Koning, & Vedder, 2006, p. 347); self-assessment is concerned with learners valuing their own learning and achievements on the basis of evidence from themselves and others (Boud, 2013).

Self-regulation, self-efficacy and self-assessment. According to Boekaerts et al., (2006), self-regulated learning is controlled both metacognitively and affectively. Students usually realize that being a responsible student involves more than performing well on a task **(**Boekaerts et al., 2006). It involves having "management skills, motivation and volition strategies" (Boekaerts et al., 2006, p. 33), and developing a sense of capability at succeeding in a particular task or type of task, which is often expressed as "I can't" or "I can" (L. W. Anderson & Bourke, 2000).

An area of research related to self-regulation is *self-efficacy*. The sense of feeling competent and confident, often termed as self-efficacy can influence the choices students make and the courses of action they pursue (Pajares, 1996). It has been posited that self-efficacy beliefs are strong determinants and predictors of the level of accomplishment that individuals finally attain (Bandura, 1982; Pajares, 1996). In science education, Yin et al. (2008) examined the link between formative assessment, self-efficacy and learning, where the students engaged in curriculum-embedded tasks that were used as formative assessment. In their survey, they analyzed student's self-efficacy beliefs (a component of motivation) in science and found it was positively associated with learning. Black, Harrison, Lee, Marshall, and William (2003) also noted that as teachers implemented formative assessment strategies, the students changed their perceptions of their work and used the teacher feedback or comments constructively with the support of their peers to improve their work. In the literacy and science integrated instruction units designed by the Lawrence Hall of Science (LHS) Seeds of Science/Roots of Reading Project

(Seeds/Roots), student interest, motivation, and learning were evaluated. It was noted that the student's enthusiasm with the different multimodal curriculum tasks contributed to the successful implementation of the unit.

Even though it has been shown that self-efficacy beliefs support learning outcomes, it is important to have specific self-efficacy assessments that have more correspondence to reflect the criterial task with which they are compared (Bandura, 1986). It is also important that researchers identify the affective state in which students make a mental representation of learning tasks (Boekaerts, 2003).

Those aspects of self-regulation closely related to *self-assessment* include self-observation and self -judgment. The judgments students make can be about what they have done, what they should be doing or why they should be doing it. Self-observations means tracking specific aspects of one's performance on tasks and the effects it produces (Andrade, 2010). Often, self-assessment occurs within a particular context, with respect to particular domains of knowledge and particular goals in mind (Boud, 2003). Some studies in science education have demonstrated the value of self-reflection as shown in the study by White and Frederickson (1989). They showed that implementation of scientific inquiry activities coupled with reflection allowed the students to develop a "mature understanding of scientific inquiry" (White & Frederickson, 1989, p. 10).

From the review of studies in science education, there is a paucity of research examining the extent to which multimodal tasks can support science learning for culturally and linguistically diverse students. In this study, I have focused on the formative potential of multimodal tasks in science and its benefits for English language learners. In this paper, I intend to highlight how they viewed the potential of the multimodal task, used the tasks to support their learning and reflected on the use of the tasks to support their learning.

Research Questions

The overarching goal of this study is to address the problem of improving ELL science learning by addressing (a) instructional supports to concurrently develop English proficiency while learning science content and knowledge, (b) fair assessment for student science learning during the process of teaching and learning in the classroom, and (c) how the combined use of these can support science learning for ELLs. The research questions guiding this paper explore the potential of multimodal tasks as formative assessment (assessment during the process of teaching and learning) to support the science learning in a middle school linguistically diverse science classroom for both teachers and students.

The research questions are:

1. How do the students view the potential of the multimodal tasks in two linguistically diverse classrooms?
2. How do the students use the multimodal tasks to support their science learning in two linguistically diverse classrooms?
3. How do the students reflect on the use of the multimodal tasks to support and represent their science learning in two linguistically diverse classrooms?

Table 2

Research Questions Guiding This Paper, the Data Collected, and the Themes of Analysis

Research question	Data collected	Theme of analysis
How do the students view the potential of the multimodal tasks? (Forethought Phase)	Self-Assessment questions on tasks used to support learning Semi-structured interviews with students during unit (Tasks used to support learning: "Tree is like a Hungry Kid," molecule model, seed germination)	Understanding of disciplinary ideas before the use of multimodal tasks to support learning Understanding of learning goals of multimodal tasks to support learning
How do the students use the multimodal tasks to support their science learning? (Performance and Control Phase)	Semi-structured interviews with students during unit Self-Assessment questions on tasks used to support learning (Tasks used to support learning: "Tree Is Like a Hungry Kid," molecule model, seed germination)	Use of tasks to support learning
How do the students reflect on the use of the multimodal tasks to support and represent their science learning? (Reflection Phase)	Semi-structured interviews with students during unit Final Self-Reflection Survey Pre and Post Self-Efficacy surveys (Tasks used to support learning: "Tree is like a Hungry Kid," molecule model, seed germination; tasks to represent learning: visual diagrams and comic strip)	Value and limitations of multimodal representational tasks Value and limitations of multimodal support tasks Final self-reflections on the tasks used to support learning and tasks to represent learning Change in Self-efficacy scores

Setting and Participants

This study was conducted in a K–8 urban school in northern California called Garden Brooks Elementary School. About 41.2% of the school population is designated as ELLs, 33% as fluent English proficient, and 19.5% as reclassified English proficient (RFEP) based on the performance of the students on the California English Language Development Test (CELDT), given to annually to students who are classified as ELLs. About 69% of students are on free or reduced lunch, 48.6% are Vietnamese, and 40.7% are Hispanic/Latino. The study was conducted in two sixth grade classrooms during the study of a unit in photosynthesis. The table below illustrates the cultural and linguistic diversity of the students in the two classrooms. In these two classrooms, there are a total of 63 students (32 males and 31 females). About 17 students speak Spanish as their first language, 24 speak Vietnamese, and four speak Chinese (two Mandarin and two Cantonese). The languages in the Others category include Urdu, Somali, Japanese, Tagalog, and Cambodian. Thirteen students declared English as their native language.

Table 3
Demographic Data of Students in the two classrooms

Category	Number
Total students	63
Male/Female	32/31
Students designated as ELLs	25

Redesignated in the last 2 years	18
English only	20
Vietnamese	24
Spanish	17
Chinese	4
Others	5
English	13

Multimodal Tasks

In science education, the idea of multimodality stems from the increasing salience of using multiple modes in meaning-making, an approach that extends understanding of content across a range of modes, to represent meaning (representational) and to communicate meaning (communicative). So, in a science classroom, the "multiplicity of the modes of communication that are active are given equal attention" (Kress, Charalampos, Jewitt, & Ogborn, 2006, p. 1). In the sixth grade classrooms of this school, the teachers planned the multimodal tasks in the classroom, to capture the representational and communicative essence of the tasks.

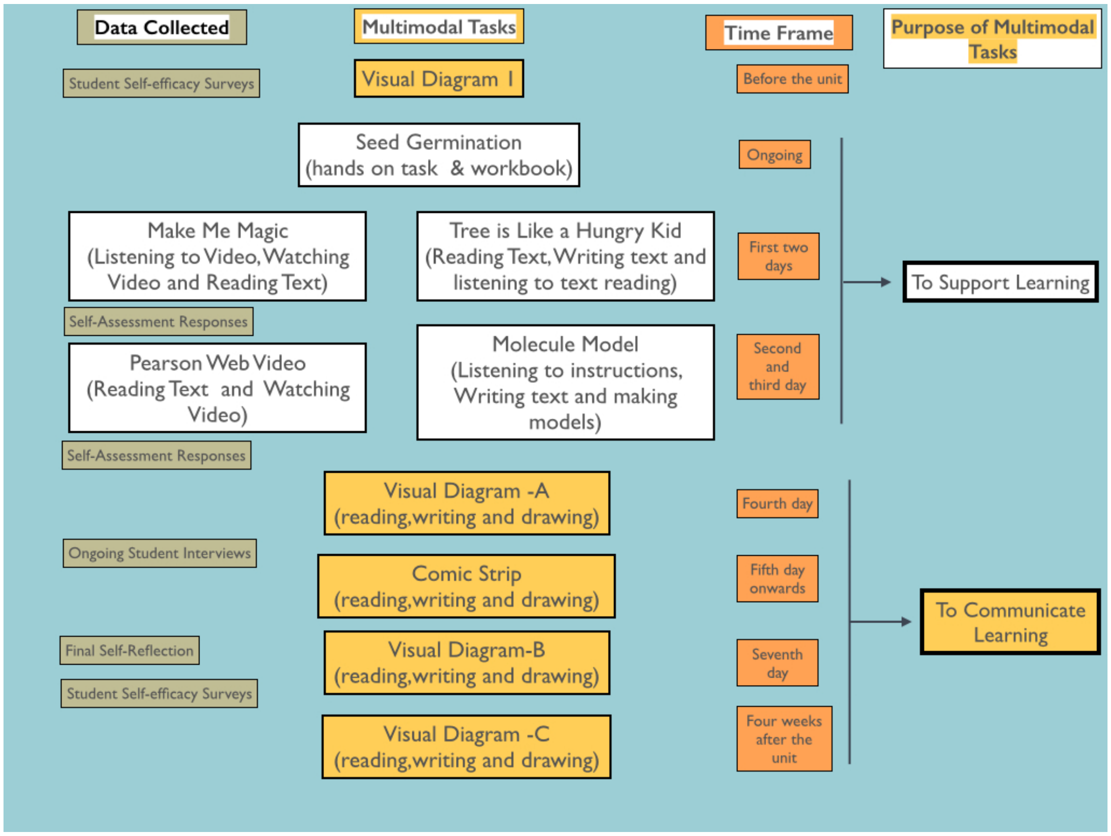

Figure 1. Schematic representation of data collected and analyzed for students' perspectives of the potential of multimodal tasks.

To Support Learning of Photosynthesis

The teachers selected activities, which involved students engaging in multimodal resources. For the purpose of this study, these activities were identified as multimodal tasks, created by the teachers to involve student participation and learning (See Figure 1).

Videos. Two videos were selected for showing to the students. It was decided that the YouTube video "Make me genius videos" would be used for an introduction to photosynthesis (makemegenius, 2011). The second video was available on the school textbook website. The second video was to be shown after the students engaged in the seed germination task.

Read-aloud task. (See Appendix E). The students read a teacher-created handout called "Tree Is Like a Hungry Kid," which explains the concept of chlorophyll in a plant (Sadil, 2014).

Molecule model. (See Appendix F). The students created a model of each molecule of carbon-dioxide, water, glucose and oxygen. They depicted the molecular equation of photosynthesis using the models of molecules created. The teacher provided the instructions to create the model and also demonstrated the steps for this task ($6CO_2 + 6H_2O$—-→ $C_6H_{12}O_6 + 6O_2$).

Seed germination task. (See Appendix G) Before the teachers started this project, the students were engaged in an ongoing hands-on guided inquiry process where the students germinated lima beans in a plastic Ziploc bag. The class was divided into five groups and each group had three bags of lima beans—one bag was placed in light, second in the dark (inside a cupboard) and the third bag was exposed to light only for half a day and then placed in the cupboard.

Represent Learning

The following multimodal tasks were planned with the intention of helping the students *represent their learning of photosynthesis*. The multimodal tasks include a) draw schematic diagram and b) narratives with drawing, which enabled the students to engage in more than one mode namely drawing and writing (Alvermann & Wilson, 2011; Jewitt & Kress, 2003; Prain & Waldrip, 2006).

The visual diagram (drawings, symbols and text). The students drew and labelled a schematic representation of the process of photosynthesis using words, symbols and images in response to a prompt (Ainsworth, 2006).

The comic strip task (text, drawings, and symbols). The students created a comic story about the process of photosynthesis. An example shown by the teacher was the story of the Magic School Bus where the narrator of the story travels inside the plant, to explain the process of photosynthesis. In this task the students wrote a narrative explaining the process of photosynthesis, by drawing pictures to illustrate the process and explain each step of the process.in response to a teacher prompt. This task was also used to represent their understanding of the process of photosynthesis.

The multimodal tasks were also designed to attain *specific learning goals*, which were aligned *to specific core ideas of photosynthesis*. After discussion with the teachers, the following ideas were finalized as the learning ideas or disciplinary core ideas, which they expected the students to learn by the end of the unit. They include (a) making carbohydrate/sugar from carbon-dioxide and water, (b) photosynthesis requires energy/ sunlight, (c) releases oxygen, and (d) starch/food is used for growth or storage.

The videos were used to explain the entire process of photosynthesis. The reading task emphasized importance of chlorophyll and the use of sunlight as energy. The molecule model was used to explain the chemical equation of photosynthesis and how oxygen is released during the process of photosynthesis. The seed germination task was used to explain the importance of sunlight in the process of photosynthesis. The visual drawing tasks and the comic strip were chosen as tasks to represent understanding as the students were familiar with drawing and writing narratives in social studies, and the teachers felt the students would be confident in executing the tasks. A written prompt—"Please draw a picture of the plant which and explain the process of photosynthesis"—was created by the teachers so as to help the students engage in the visual drawing task. For the comic strip the prompt given by the teachers was as follows. "Create a comic strip which will describe the process of photosynthesis. An example can be like 'Magic School Bus' where you enter the plant in a bus and describe the process as you are going through the bus." The teachers also provided a list of vocabulary words which was to be used in the comic strip.

Data Instruments

As the research questions are attempting to explore the perceived value of the multimodal tasks by the students, I have analyzed the data with the view of answering how the students reflected on their use of the various tasks. I have described the data collected and the themes of analysis for each piece of data.

Science attitude survey. (See Appendix A). The science attitude surveys were also given to the students at the beginning and at the end of the unit of photosynthesis. The survey used was the Feelings Toward Science Inventory (FTSI) to serve evaluation purposes in the context of various explorations of elementary and middle school science teaching and learning (Girod, 2001). It was hypothesized that high quality science instruction may also effect students' attitudes toward science, students' efficacy beliefs about themselves as science learners, and students' identity affiliations toward science or perceptions of themselves as a "science-type person"(Girod, 2001). The measure used for this study was a 25-item, self-report instrument with items corresponding to four factors namely, affect, interest, efficacy and identity. The response were on Likert-type scales varying level of agreement with each statement and included—"Helped me a lot," "Helped somewhat," "Helped me very little," and "Did not help me at all."

Self-assessment open-ended response survey. (See Appendix B). The students were given four self-assessment open-ended response surveys where they were given three prompts to reflect on their understanding of the process of photosynthesis. In order to capitalize on the similarities between self-regulation and self-assessment, the questions given to the students after they completed the multimodal tasks served to promote both. The questions given to the students after they participated in each task focused on three aspects of the students' learning of photosynthesis: "What are the facts they already knew about photosynthesis?" "What did they learn about photosynthesis?" "What were they still not sure about photosynthesis?" These questions refer to the students' learning process and how they used the various tasks to understand the process of photosynthesis. Self-regulation of learning aims to examine what the students learned from each multimodal task. As the students were given these questions after the completion of each task, the purpose of these questions was to elucidate how the tasks supported their understanding of the process of photosynthesis. It was designed that each survey would be given after the interactive read aloud, after the molecule model, seed germination task and finally after the completion of the comic strip. However, some of the self-assessment questions could not be given to the students soon after the completion of the tasks. But the answers to the questions provide an insight to the progress of understanding of photosynthesis through the unit. Fifty-three post seed germination task self-assessments, and about 62 post self-assessments following the molecule model and interactive read alouds, and about 62 following the completion of the comic strip.

Interviews. (See Appendix C). After the students had completed those tasks, which were designed for supporting their understanding of photosynthesis like watching the videos, reading task—"Tree Is Like a Hungry Kid," making the molecule model, individual student interviews were conducted with those students who had given consent. A few group interviews were also conducted later while the students were making their comic strip. The interview questions were directed towards understanding how the students reflected on the use of multimodal tasks. About twenty-nine students were interviewed.

Final self-reflection survey. (See Appendix D). After the completion of the unit, the students were given a survey which asked them to rate how each multimodal task helped them understand the process of photosynthesis. The tasks which they had to give their opinion on included "Tree is Like a Hungry Kid," website and videos, and the molecule model—tasks chosen to support their understanding. The students had to also give their opinion on the tasks used to represent their learning included, the visual drawing tasks and comic strip. The response were on Likert-type scales varying level of agreement with each statement and included—“Helped me a lot,” “Helped somewhat,” “Helped me very little,” and “Did not help me at all.” A total of 60 self-reflection surveys were collected.

Data Analysis

Model of Analysis

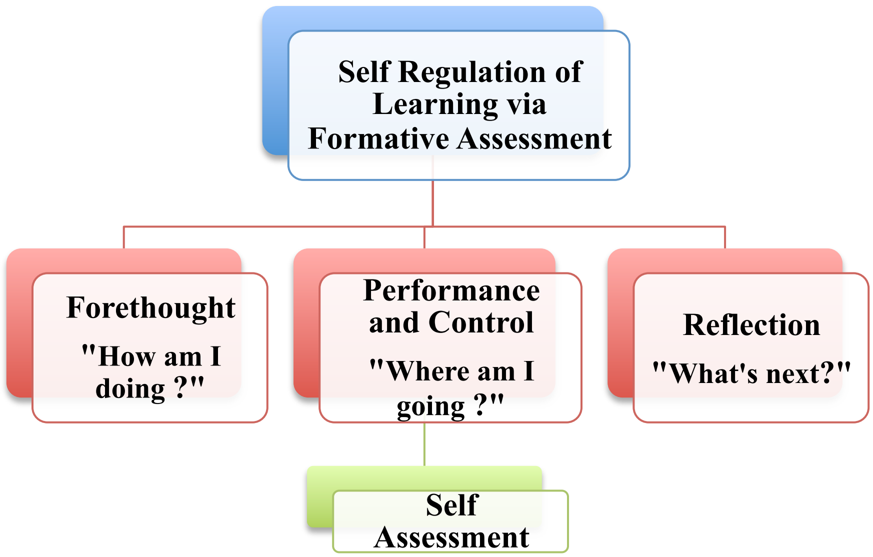

Figure 2. Model of data analysis adapted from Andrade and Cizek (2010).

Self-regulation and learning via formative assessment. In order to examine how the multimodal tasks designed to support and represent student learning help students engage with the given subject area (photosynthesis), I have adapted a model of self-regulation via self-assessment (see Figure 2) to analyze the data described above.

To understand the scope of self-regulation and self-assessment as supports for learning within a classroom setting, Andrade (2010) proposed an integrated model (see Figure 1) which draws on the three phase self-regulation model proposed by Zimmerman (2000) and the conception of feedback in learning as proposed by Hattie and Timperley (2007). The commonly accepted model of *self-regulation* proposed by

Zimmerman (2000), includes three phases that function cyclically. The three phases include (a) *forethought*, which precedes efforts and involves consideration of the goals and expectancies of the task at hand, and strategic planning and self-efficacy judgments;(b) *performance or volitional control*, which occurs during learning process and includes self-monitoring and use of learning management strategies; and (c) *self-reflection*, which follows learning efforts, and involves self-evaluation and reactions to task. The self-reflection phase leads back to forethought phase that precedes the next learning efforts. According to Hattie and Timperley (2007), effective feedback to support student learning should address three questions, "Where are the students going?" "How are the students doing?" and "Where to next?" Self-regulation theory also posit that "effective learners ask similar questions, and engage in regular self-assessment of their work" (Andrade, 2010).

Context for Data Analysis

As explained earlier, in order to understand the formative potential of the multimodal tasks in a linguistically diverse science classrooms, I have grouped the students based on their English Learner status—whether or not English was their first language and their proficiency in English language. For the purpose of having substantial number of students in each group, I have divided the student sample into three groups. The first group are students who were designated as ELLs and who were redesignated in the last year, named as *ELL*. The second group consisted of students who were redesignated within the last 2 or 3 years, named as *Redesignated within 2 years*. The third group comprises students who are considered English only and students who were redesignated over 3 years ago, named as *English only.* In order to analyze the formative potential of the multimodal tasks described above, I have adopted the integrated model proposed by Andrade (2010) to examine the different types of data collected. Each phase of the model aligns with each research question and examines different types of data, with specific purpose of analyzing how the students used the various multimodal tasks (designed to support and represent learning) to support their understanding of photosynthesis.

The decisions on the type of tasks and how to use each task were entirely dependent on the teacher. Hence student input was not part of the planning of the tasks. It is also important to note that I designed and implemented the data instruments used for this paper. The teachers only had a cursory glance at the student reflections, and did not discuss it with the students. Also the teachers did not take the reflections into account for further decision-making. However, how the students viewed the tasks partly determined how they used the tasks, which in turn influenced how they used the tasks to understand the core ideas of photosynthesis. Further, in order to provide an insight into how the linguistic diversity of the students factored into the way the students used the task, the data were also analyzed based on the groups created by their English Language proficiency. If there was significant difference between the groups' approaches to the themes of analysis, I report the data under the entire group. The students' reflections on the tasks highlighted the value and limitations of the multimodal tasks. Further, the result of the self-efficacy surveys were used to determine whether the particular ways in which the science unit was designed with the usage of multimodal tasks affected the self-efficacy of the students.

Adapted Model for Data Analysis

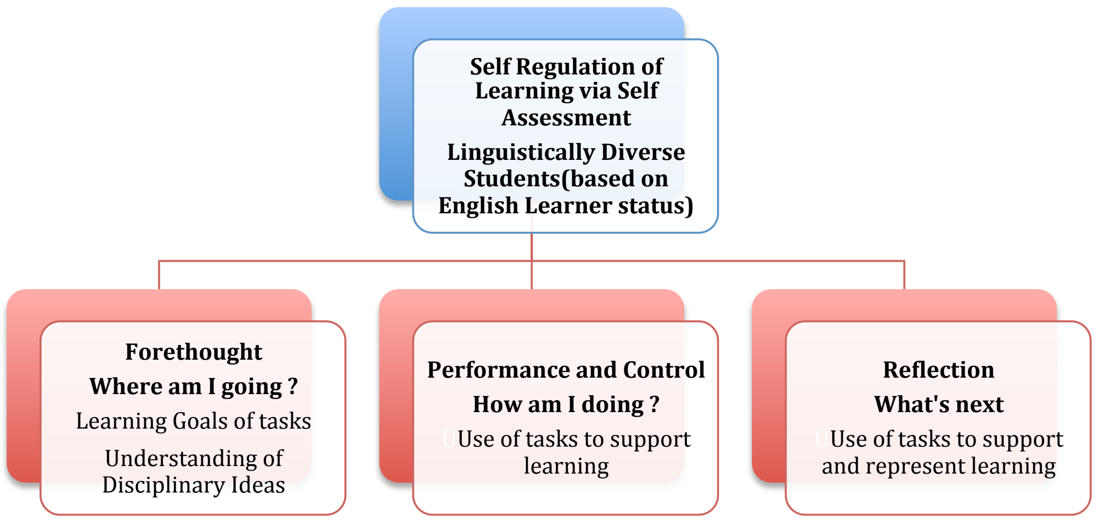

Figure 3. Model of data analysis adapted from Andrade and G. Cizek (2010).

Figure 3 explains the adapted model of integration of self-regulation and self-assessment and how it can contribute to effective student learning. The integrated and adapted model can be described as having three phases includes (a) *Forethought*: when students set goals which aligns to "Where am I going?," (b) *Performance and Control*: occurs during learning and focuses students' use of learning strategies which aligns to "How am I doing?," and (c) *Reflection*: students evaluate and reflect on their work which aligns to "Where to next?." For effective learning to take place, learners must develop the capability of monitoring what they do and modifying their learning strategies appropriately. Individual self-monitoring and checking progress to promote good learning practices can consolidate learning over a variety of contexts (Boud, 2013). Further, as the role of assessment is central to the field of self-regulation research, it is important to understand its conceptualizations in individual and classroom implementations (Cascallar, Boekaerts & Costigan, 2006).

To explain the *phase of Forethought - "Where am I going?"* I examined the data to explore how students viewed the learning goals of the multimodal tasks. In this phase I also analyzed the students' understanding of photosynthesis prior to the use of the multimodal tasks. For the next *phase of Performance and Control—How am I doing?"* I examined the data to see how the students used the various tasks to support their learning processes. I also analyzed how their understanding of photosynthesis has progressed. For the next *phase of Reflection—"What's next?"* I examined how the students reflected on the value of the two types of tasks they used for representing their understanding of the process of photosynthesis—visual diagram and comic strips.

One cannot presume that all students will have a common range of context-specific skills required to be able to judge their own work, especially in linguistically diverse classrooms such as the ones described in this study. So I have examined the data based on the students' English Learner Status. If the ELLs data differed from the redesignated and English only group, I have described that data under those specific headings. However, if the data analyzed in the three groups are very similar within the themes identified I have described that data under the total student sample.

RQ1: How Do the Students View the Potential of the Multimodal Tasks?

Data used. For this section, I have analyzed the data to explore how the students the first phase Forethought: "Where am I going?" How they viewed the learning goals of the tasks and to answer the question "Where am I going?" I also analyzed the beginning responses to the self-assessment questions to gauge the students' baseline understanding. This question helps in understanding the first phase of the model "Where am I going?" and the data used for analysis include, transcribed student interviews and self-assessment questions.

Themes. As the goal for the analysis of this phase is to explore "Where are the students going?" it is also important to explore the baseline student understanding of the process of photosynthesis. Further, as each multimodal task was aligned to certain learning goals, I analyzed student interviews to look for their understanding of the learning goals of each task. By identifying the multiple content goals that students identify, allows a closer examination of the patterns that students have established between the tasks' intended goals and their personal views of the goals of the tasks.

Understanding the core ideas of photosynthesis

In this section, I have analyzed the data to gauge the students' understanding of the process of photosynthesis before they used the various tasks. This provides a comprehensive view of their progressive understanding of photosynthesis, as they engaged in the various tasks.

Photosynthesis is an enormously complex biochemical process and to get an understanding of the more complex models learned later in high schools it is important that students get a good grounding of the process of photosynthesis in elementary and middle schools. Photosynthesis is the process, which generates most organic material on earth and is the cornerstone of any biology curriculum. It is the most important biochemical process where plants absorb sunlight as a source of energy to converts carbon dioxide and water into carbohydrates and oxygen.

Various researchers have examined how children have understood the process of photosynthesis. Some researchers have examined the discrepancies between students' way of understanding and scientifically accepted views of photosynthesis; for instance, Eisen and Stavy (1993) noted that children have ideas reminiscent of scientific theories that were espoused in the past. Likewise, in their study, Smith & Anderson (1984), found that students had two levels of misconceptions, one was the factual level about facts or scientific principles, and the second was the deeper level of scientific ways of thinking. Driver, Asoko, Leach, Scott, & Mortimer (1984) and Tamir (1989) found that students' invalid explanations of photosynthesis often took the form of tautologies, teleologies, and anthropomorphisms, where the plants shared human or animal characteristics. Many researchers have also explained how knowledge about photosynthesis can be organized (Anderson, 2009; Eisen & Stavy, 1993; Lin & Hu, 2003). According to Lin & Hu (2003), the first level of understanding of photosynthesis, at the level of organisms is called phenomenal knowledge, where energy flow and cycling of matter can be depicted in the ecological conceptions of the food chain and its three main participants namely the producers—plants, consumers, and decomposers.

In their first self-reflection, most of the students in the *English learner group* had a basic level of understanding of photosynthesis. Such a level of understanding was displayed by the ELLs, through responses like: "It's about plants"; "Something about the plant"; "The leaves make its own food"; "It involves the sun"; "They need sun and magic"; "They need light."

The *redesignated group*, the students displayed the same level of understanding of photosynthesis, at the level of participants and organisms, as seen in the first level of understanding of Phenomenal Knowledge. However, the students identified more reactants of photosynthesis, compared to the previous group. For example, "Plants need water, sunlight, and carbon dioxide"; "A tree needs light, water, CO2, and chlorophyll for photosynthesis"; "I knew the food is called sugar (glucose)." In the *English only group*, a few students had responses which encompassed the second level of knowledge of photosynthesis, as described by Lin & Hu (2003)—Mechanical Knowledge, at the level of cells, where carbon-dioxide and water are converted into carbohydrates and oxygen. Only one student had a response in the third level, at the molecular level, where photosynthesis can also be illustrated in terms of matter and energy, namely sun's light energy being converted to chemical energy in the form of carbohydrates. This level is the category of Physical Knowledge (Lin & Hu, 2003) and the response included

> Plants absorb carbon dioxide and sunlight in the leaves. The sunlight is trapped in the chlorophyll. The carbon dioxide sucked into the stomata and

> into the leaf. Water and carbon change into sugar where (sunlight) reads to if and changes its molecular structure or cellular structure. The oxygen waste is released out the stomata and the glucose is carried into the phloem.

Alignment to Learning Goals of Multimodal Tasks

"Tree Is Like a Hungry Kid": The interactive reading aloud task. The *ELL students* and *English only students* understood that the reading aloud task "Tree Is Like a Hungry Kid," explained the role of chlorophyll and how and the role of chlorophyll in giving the green color to the leaves. Most of the students in the redesignated group too understood the goal of the reading aloud task "Tree Is Like a Hungry Kid," but expanded on the explanation of the role of chlorophyll on how it contributes to the change in the color of the leaves during various seasons.

Molecule model. While all the students made the molecule model, a few students could not make the connections between the model and the process of photosynthesis. The *ELL students* understood the formulae for water, carbon-dioxide, oxygen and glucose, through the molecule model. Like a few students said, "I know H_2O is water and CO_2 is carbon-dioxide." "Yes glucose is $C_6H_{12}O_6$." But they did not relate it to the reactants reacting together and forming glucose and oxygen. For instance, a couple of students claimed, "What are you [teacher] adding up there? The adding of H+H+O, I didn't know really know what it meant." "Writing down the different molecules . . . these confused me." Comments made by some of the *redesignated and English only* students included, "How does the sun fit in all this?"; "I was sort of confused." However, the same students claimed that they found it helpful after completion of the task as the model showed the interaction of the molecules and how products were formed (Lin & Hu, 2003). "The role of the sun is that it splits and puts together molecules"; "I didn't know why plants need oxygen, now I know they had extra oxygen"; "How glucose looks like and how oxygen is being released as waste." As one student aptly summarized, "It showed me a picture about what it [photosynthesis] looked like."

Seed germination task. All the students realized the goal of the *Seed germination task* was to understand the role of light to help seeds germinate. Most students also had an advanced understanding that the task also helped to distinguish the role of light between seeds and plants as evidenced by remarks made by the students from the three groups such as, "I learned that seeds can germinate with or Without Sunlight"; "I learned that plants don't need sunlight to germinate but needs light to keep the plant healthy." They also understood the goal of the *seed germination task*—role of light in photosynthesis. Statements made by the students showed that they understood the purpose of the task such as, "I learned that Plants could grow in both light and dark"; "I learned that seeds don't need light to germinate"; "I learned that YOU don't Need sunlight or soil/dirt to grow A Plant."

Summary

It can be seen in the *Phase of Forethought* that the students had a baseline understanding of the process of photosynthesis, where they had knowledge of some of the main participants of the process of photosynthesis, namely the plant or the sun. Just one student belonging to the English only group had an advanced understanding of the process of photosynthesis. Regarding the learning goal of each task, the students were quite ambiguous of the goals of the molecule model. While the main learning goal was to understand the reactants and products of photosynthesis, one of the other goals was to understand how the sun's energy helped in breaking the bonds of the reactants to form the products. However, many students did not realize this goal.

RQ 2: How Do the Students Use the Multimodal Tasks to Support Their Science Learning? (Performance and Control)

Data used. For this section, I have analyzed the data to explore how the students used the tasks to support their science learning. This question helps in understanding the second phase of the model, Performance and Control which explains the idea of "How am I doing?" from a students' perspective. For this analysis, I have analyzed the following data: student interviews and open-ended self-assessment questions by students.

Themes

For this analysis, I have explored the data to examine certain patterns where the students themselves make specific references as to how they use the multimodal tasks. What I have described in the subsequent sections is a thematic version of the students' perspectives based on their English Learner status. I have attempted to describe the data under specific categories of English learner status, ELLs, redesignated and English only. However, if there were no specific differences amongst the groups, the data were described as under the entire student sample. The following themes emerged from the data as to how the student used the data to support their learning: 1) scaffolding strategies: (a) student use of analogies, (b) underlining and highlighting, (c) specific aspects of making models, (d) re-representation of ideas using different modes; 2) progression of disciplinary ideas: (a) level of understanding of photosynthesis, (b) use of curriculum-based words.

Scaffolding strategies. Building on Vygotsky's (1934/1986) and Bruner's (1974) theories of learning and development, Applebee and Langer (1983) proposed a model in which "the novice reader or writer learns new skills in contexts where more skilled language users provide support necessary to carry through unfamiliar tasks" (p. 168). Langer and Applebee (1986) discussed instructional scaffolding as an especially effective model for planning and analyzing instruction in reading and writing. In this study, the "skilled language users" were the teachers who provided the scaffolds either by demonstrating some strategies or by embedding them in the main multimodal tasks.

Student use of analogies. In this study, analogies and metaphors were used to explain disciplinary core ideas and enhance student understanding of curriculum based vocabulary. The interactive read-aloud task, "Tree Is Like a Hungry Kid" was jointly read and discussed by the entire class along with their teachers. While one class read the handout silently, at first, and then discussed the handout with the teacher, in the other class the teacher identified certain students to read the paper aloud. In this task, the process of photosynthesis was almost always described as a recipe, where the ingredients were the reactants of the process namely, carbon-dioxide and water and the energy provided for the process came from sunlight producing oxygen and glucose. Like their teacher, the students also used the word "recipe" and "ingredients of the recipe" to refer to the process of photosynthesis and its reactants.

A few students in every group alluded to the recipe and the ingredients mentioned in the read aloud task, however, an overwhelming large number of students in the ELL group described the recipe card in more detail than the redesignated group and English only group. In the interviews, students' comments from the ELL group were, "This helps me about the recipe of the tree like . . . and sunlight plus chlorophyll plus water and it makes glucose"; "It showed me the ingredients on how photosynthesis happens, like the four main ingredients." Similarly the redesignated group said, "It helped with the ingredients and how it made photosynthesis," and the English only group said, "My mom and I bake and I memorize a bunch of recipes, so I think I know the process." "Because they had all the ingredients."

Underlining and highlighting. There is widespread agreement among researchers that instruction should include scaffolding, guided practice, and independent use of cognitive strategies so that students can appropriate strategies independently and monitor and regulate their use (Block and Pressley, 2002). Olson and Land (2007) emphasized that using specific curricular approaches can help reinforce the reading/writing connection; one such was a color-coding strategy, where the students could "visually see how the writer skillfully builds" (p. 283). In this study, all the students emphasized how the underlining with red pens or highlighting with yellow pens helped them read and understand the main ideas of the interactive read aloud task "Tree Is Like a Hungry Kid." All the students made comments like, "We underlined the stuff that made photosynthesis important." However, in this category, the English only and redesignated category described how by highlighting certain sentences helped them understand the main ideas of photosynthesis. Whereas, the ELL students emphasized that the teachers' prompts helped them understand what they had to underline or highlight as described by one student, "Some paras I understood, but like others didn't really make sense I didn't really know what to underline. When Klara [teacher] was talking she helped me understand what to underline." This shows the color-coding strategy had to be modeled by the teachers for the ELLs.

Making models. All the students created the molecule models where the teacher modeled each step in the creation of the model. Certain aspects of the making of the molecule model were highlighted which particularly helped them. Irrespective of their English Learner status, a few students in all the groups highlighted similar aspects of the model making process, which they found particularly useful. Their comments included, "Cutting and making the molecules helped me understand their role in photosynthesis." "It helped me understand the formula." "I didn't understand first, and then when it was time to glue this and it was like okay it connects with that (H+H+O)." At the time of the creation of the molecule model, the students were also introduced to the equation of photosynthesis and the formula for each compound.

Even though the teacher modeled every step of the model-making process, it is interesting to note that the students could reflect on some of the steps and how it helped them learn the process of photosynthesis.

Re-representation of ideas with different modes. In order to gauge the full potential of any multimodal task as a classroom resource Bezemer and Kress (2008) have advocated the importance of realizing the processes of change to multimodal representations through *transduction*—how semiotic material is moved across modes, from one mode (or set of modes) to another mode (or set of modes) and/or *transformation*—changes within a mode. It was interesting to note how some students incorporated semiotic material observed in one task into another task.

During the interview, most students from the all the three groups described the release of oxygen as pairs as witnessed in the videos shown to the students at the beginning of the unit. For example, "That little cartoon helped me a lot with like releasing oxygen, the plant was releasing oxygen"; "Oxygen comes out as by a group of two." Even in the self-assessment questionnaire after the tasks, most of the students mention the release of oxygen in a similar manner. For example, "That plants send out a lot of oxygen. Oxygen comes out in Pairs." Similarly some of the students alluded to the role of sunlight in a manner, which was like how the teacher had demonstrated the role of sun's energy in splitting the molecules. Some of the students' responses include, "The role of the sun is that it splits and puts together molecules." It was also noteworthy to see how the ELLs used images in their open-ended self-assessment questions to explain their understanding of photosynthesis by drawing the sun and the flow of oxygen and carbon-dioxide.

Progression of Disciplinary Ideas

Level of understanding of photosynthesis. The questions in the self-assessment targeted towards helping the students explain "What do you already know?" "What have you learned better?" "What is the thing you are not sure of?" These self-assessment questions were given at certain times during the unit. A total of four self-assessments were collected from most students, one soon after the interactive read-aloud, the second one after the molecule model, the third one after the completion of the comic strip and the fourth one after the completion of the seed germination task. In Vicky's class, the first two self-assessment questions were combined and given to the students after the completion of the molecule model. The responses to all the self-assessment questions were examined and compared. The goal was to see if there were any changes to the level of understanding of photosynthesis by the students, from the beginning of the unit to the end of the unit. In this analysis, I examined the range of responses from students' initial response to the self-assessment questions "What do you know about photosynthesis?" to the final self-assessment questions after the comic strip "What do you know about photosynthesis?" It was observed from the self-assessment questions that the students understanding had progressed from lower level of conceptual understanding to a higher level of understanding based on Lin & Hu (2003) stages of understanding of photosynthesis.

Table 4
Progression of Students' Ideas of Photosynthesis Among ELLs

Initial Reflection →	Final Reflection
English Language Learners	
Photosynthesis something about how do plant eat food.	*The process is the thing that I learned now, before that I just that photosynthesis is the thing that photosynthesis is thing about how plants eat food.*
I knew photosynthesis is need sun and water.	*That photosynthesis need sunlight, water, carbon dioxide, chlorophyl and knew more about leaf. What inside leaf? I knew that and I hope I will knew more about leaf, flower, seed, plant.*
I think I just know that photosynthesis is something about Plant.	*I learned better is that the basics—I learned all the basics of photosynthesis. Most important is thing is that the photosynthesis meaning. I learned about the trees recipe, recipe is water, sunlight, chlorophyll.*
I just know that photosynthesis is something about Plant.	*The plant use the sun energy to make food. During Photosynthesis, chlorophyll traps the sun energy.*

Some of the initial responses did not include all the participants in the process of photosynthesis and those students definitely progressed to a better understanding of the Phenomenal Knowledge.

Table 5
Progression of Students' Ideas of Photosynthesis Among Redesignated Learners

Initial Reflection	→ Redesignated Learners	Final Reflection
I just know that photosynthesis is		*It makes more sense, the leaves takes in*

something about Plant.	*carbon dioxide and sunlight, and the roots for water, and it makes Glucose/sugar/food.*
was that the Plant needed carbon water sun light and Chlorophyll to create sugar.	*that the chlorophyll + the sunlight can create chelcmal energy and that chlorophlly is store inside of chloroplast and that chlorophyll maikes the Plant green.*
it makes food for the Plant	*when it breaths out oegen it comes out in Pairs it breaths in carbon dioxide and breaths out oxegen. it obsorbes water from its roots to make Food for the Plant you need four ingredien carbon dioxide sunlight, water, Chlorophll.*

For redesignated students, as seen in the table above, it can be seen that they progressed from understanding photosynthesis at the organism stage (Phenomenal Knowledge) to a better understanding at the cellular level (Mechanical Knowledge).

Table 6
Progression of Students' Ideas of Photosynthesis Among English Only Students

Initial Reflection	→ English Only	Final Reflection
Plants absorb carbon dioxide and sunlight in the leaves. The sunlight is trapped in the chlorophyll. The carbon dioxide sucked into the stomato and into the leaf. Water and carbon change into sugar where (sunlight) reads to if and changes its molecular structure or celluar structure. The oxygen waste is released out the stomata and the glucose is carried into the phloem		*Sunlight is trapped in the chloroplasts not chlorophyll Plants need Water, sunlight, carbon dioxide, and …. . Chlorophyll to carry out the process of photosynthe chloroplast is inside mesophylls under the epidermis chlorophyll makes the leaves green. Leaves are red, yellow, orange, red or brown already, but the chloro blcoks the real (. . .) the leaf.*
Photosynthesis happens in the leaves. The leaves have cells that helps them turn the sunlight into food. Food is sugar called glucose. Something about		*You need water for photo-synthesis. Oxygen is realeased when plants make food. (I thought they breathe in Carbon and breathe out oxgen). upper part of*

chloraphyll	*leaf throws out lower takes in.*
I knew that the water that is poured on the ground gets absorbed by the roots. I knew that H2O means water, and CO2 means carbon dioxide.	*I learned better about the formula of sugar aka glucose, how water absorbs, and how leaves change color during the winter.*

For English only students, as seen in the table above, following Lin and Hu's (2003) stages of understanding of photosynthesis, it can be seen that they progressed from understanding photosynthesis at the organism stage (Phenomenal Knowledge) to a better understanding at the cellular level (Mechanical Knowledge).

Use of curriculum based words in other contexts. The teachers had identified certain vocabulary words associated with the unit of photosynthesis, which they expected the students to understand and use in their multimodal representations. Researchers have pointed to differences in word knowledge where language minority students have both less depth and less breadth of vocabulary (Lawrence, White, & Snow, 2011). As it has been advocated that language minority students should encounter new words in varying contexts (Carlo et al., 2004), in this paper, I analyzed how the students incorporated the use of the curriculum-based vocabulary in the self-assessment tasks or in the interviews. The purpose was to see if the students could appropriate the use of these words in new contexts, and not just in the visual diagrams and comic strips where they were expected to use the words.

In the self-assessment tasks following the interactive read alouds, the following examples illustrate some of the ways all the students from each group effectively displayed their knowledge of the vocabulary. Statements like "Chlorophyll traps the sun energy"; "chlorophlly is store inside of chloroplast" and that "chlorophyll maikes the Plant green" reveal the ability of the students to use the vocabulary words to show their understanding of some of the core ideas of photosynthesis. Following the creation of molecule models, self-assessment statements which students wrote showed their current understanding of photosynthesis: "Oxygen is released when plants make food" and "Carbondioxide is sucked in through the stomata and oxygen is released through the stomata." In the self-assessment task following the seed germination task, most ELLs used the word germinate to show the understanding of how seed grow in the absence of light. For example, "the seed growing/germination"; "I learned that seeds do not need light to germinate"; "it does not have to germinate in soil."

Summary

In sum**,** the analysis in *the Phase of Performance and Control was* to understand the students' idea of "Where am I going?" It can be seen that the students employed different scaffolding strategies while using those tasks which the teachers assigned to assist in the learning process. During the interactive read-alouds, they appropriated the use of analogies and used highlighting and underlining important ideas to assist in the reading process, in the molecule model the cutting and pasting of the molecule models assisted in the learning process. The re-representation of ideas from one task into another were also seen where the students used the ideas from the video to express their understanding in the self-assessment questions and in their interviews. All these strategies were very helpful to the students. To understand another facet of, "Where am I going?" I also examined the students' progression of disciplinary ideas and their usage of curriculum-based vocabulary words. Through the self-assessment responses, it was clear that the students had a better understanding of the process of photosynthesis than they had at the beginning of the unit and were also able to use the curriculum-based words (chlorophyll, chloroplast, stomata, oxygen and carbon-dioxide) appropriately in their interviews and self-assessment responses.

RQ 3: How Do the Students Reflect on the Use of the Multimodal Tasks to Support and Represent Their Science Learning?

Data used. For this section, I have analyzed the data to explore how the students used the tasks to support their science learning. This question helps in understanding the third phase of the model *Reflection:* which explains the idea of reflection from a students' perspective, "Where to next?" For this analysis, I have analyzed the following data**:** self-reflection survey, self-efficacy surveys, student interviews and open-ended self-assessment questions.

Themes. The themes relates to What's next? or how do the students reflect on the tasks.

Reflection on use of multimodal tasks

To analyze how the students reflected on the use of multimodal tasks to assist the learning process, I analyzed the students' response on the final self-reflection survey. On the survey, each multimodal task was listed. The students' responses were on Likert-type scale level of agreement with each statement and included— "Helped me a lot," "Helped somewhat," "Helped me very little" and "Did not help me at all." It is important to note that the number of student responses on the survey collected from each task was different. The results were as follows: For the interactive read aloud—"Tree Is Like a Hungry Kid*"*—a total of 13 students did not find this task useful and a total of 47 students found it useful. Website and videos: a total of seven students did not find this task useful and a total of 51 students found it useful. Molecule model: six students did not find this useful and 52 students did not find this task useful. Six students did not find the visual diagram useful and 52 students found it useful. For the comic strip, nine students did not find this useful and 49 students found it useful.

Table 7
Final Self-Reflection in Total Sample

Visual diagram		Comic strip	
Useful	Not useful	Useful	Not useful
52	6	49	9

In this survey, for the *website and videos tasks*, there are 19 students who belong to the *English learner group*, four students who did not find the website and videos useful, and 15 students who found it useful. In the *redesignated group*, there were 17 students, three students did not find it useful and 14 found them useful. In the *English only* group, all 19 students found the website and videos useful. For the *"Tree Is Like a hungry kid,"* there were 17 students in English learner group, 17 in the redesignated group, and 20 students in the English only group. In the English learner group, 14 found the task useful and three did not find it useful. In the redesignated group, 15 students found it useful and three did not find it and in the

English only group, 13 found it useful and seven did not find it useful. For the *molecule model*, there were 17 students in English learner group, 17 in the redesignated group, and 20 students in the English only group. English learner group, only one student found it not useful, in the redesignated and English only group only two students did not find them useful.

The majority of the students found the tasks useful and there were no particular trends on which group based on ELL status found any task more useful than the others.

Table 8
Final Self–Reflection Based on English Learner Status

Student category	Website/videos		Tree is Like a Hungry Kid		Molecule model	
	Useful	Not useful	Useful	Not useful	Useful	Not useful
ELL	15	4	14	3	16	1
Redesignated	14	3	15	3	16	2
English only	19		13	7	18	2
Total sample	51	7	42	13	50	5

Science Attitude Scores

Girod (2001) hypothesized that high quality science instruction may also effect students' attitudes toward science, students' identity affiliations toward science or perceptions of themselves as a "science-type person" and students' efficacy beliefs about themselves as science learners. By administering the science attitude surveys before and after the unit, the goal was to examine if the use of multimodal tasks during the unit of photosynthesis served to increase the science attitudes of the students. Further, I also wanted to examine if the use of multimodal tasks were particularly helpful for students based on their ELL status.

Table 9

Science Attitude Scores Based on Interest, Affect, Identity, and Efficacy in Total Sample and Based on English Learner Status

English Language Proficiency		Gain Interest	Gain Affect	Gain Efficacy	Gain Identity
English Learner	Mean	**−0.8486**	**0.3218**	**−1.5839**	**−0.4490**
	Std. Deviation	3.45273	3.76514	1.93290	3.82562
Redesignated	Mean	**1.3571**	**1.0096**	**−1.2459**	**1.7143**
	Std. Deviation	3.17701	2.40957	2.23347	2.61441
English only	Mean	**0.1000**	**0.0000**	**−2.3426**	**0.0049**
	Std. Deviation	3.68353	3.21182	2.46945	2.17891
Total	Mean	**0.1101**	**0.3844**	**−1.7952**	**0.3080**
	Std. Deviation	3.51466	3.18369	2.23588	3.02831

The pre and post science attitude surveys were analyzed to see if there is an improvement in interest, affect, identity and efficacy in science following the engagement in the various multimodal tasks during the unit of photosynthesis. In the total sample of students, there was gain in interest (M = .11, SD = 3.51), affect (M = .38, SD = 3.18) and identity (M = .31, SD = 3.02). Based on the English Learner status group, for all the three groups, there was a decrease in efficacy scores. The ELLs had a small gain in Affect (M =.32, SD = 3.76). However following the unit, there was a decrease in Interest (M = -.84 SD = 3.45), Efficacy (M = -1.58, SD = 1.93) and Identity (M = -.45, SD = 3.83). For students redesignated two years ago, there is a small gain in Interest (M = 1.36, SD = 3.18), Affect (M = 1.00, SD = 2.41) and Identity (M = 1.71, SD = 2.61). In the English only category, there was no change in affect (M = .00, SD = 3.21), small gain in interest (M = .10, SD = 3.68) and very small gain in identity (M = .005, SD = 2.18).

Independent sample *t*-tests showed that the means of the constructs between groups were not statistically insignificant. This analysis shows that engaging in the multimodal tasks during the unit of photosynthesis produced highest gains for redesignated students for affect, interest and identity for most students except for the English only students. Interestingly, there was a loss in efficacy for all groups. This could be attributed to two reasons: *First,* the post survey was administered by the teachers who had mentioned the lack of compliance on the part of the students to complete another survey as they were complaining about the number of surveys they had to complete during this unit. *Second,* several students had to redo their comic strips as their first version was either incomplete or did not meet the teachers' expectations. So quite a few students completed the post unit survey, while they were still completing their second or third revisions of the comic strip. Some of the efficacy questions were targeted towards how well they did in science class: "I think I will get a good grade in science" ; "I think I am able to learn science ideas. "; I think I will do well on science tests and class work." Towards the end of the unit, it was obvious the students felt they were not doing well as they had to revise their comic strips which could have led to the drop in scores.

For the ELLs, there was a small gain in affect. The questions of the science attitude surveys targeted towards the construct of affect, "I have a good feeling about science”; “If I knew I would never have science again I will feel sad”; “I feel comfortable with science and I like it very much.” Since there was a small gain, ELLs may still have good feeling about science after the use of the multimodal tasks. However, for the constructs of interest and identity there was a decrease in the scores. The questions for interest included “I enjoy learning science” and “Science is interesting to me” and for identity included “I am a science-type person” and “I can imagine myself as a scientist.” Much as the decrease or increase of scores cannot be entirely attributed to the use of the multimodal tasks, after the unit the ELLs had a decrease in the interest in science and did not relate to being a science-type person.

The science attitude surveys were given to provide an insight as to how the students may have felt about the various multimodal tasks and how they could perform the tasks. Results show that the ELLs had a lowering of all the scores except in the construct of affect. Results may suggest that the ELLs liked science but definitely did not have a positive experience during the unit, thus lowering their scores in interest, affect and identity. This could also be attributed to their general feeling towards science or towards the various tasks they used during the unit. There was a small gain or no gain in the scores for English only students, so they maybe more non-committal to the value of multimodal tasks or that the multimodal tasks did not influence their attitude towards science, compared to the other groups. The redesignated group had an increase in all the scores, indicating that they had a positive experience during the science unit with the use of multimodal tasks in the classroom which may have led to the increase in all science attitude scores.

Final Self Reflection

In this section, I have focused on how the students reflected on the use of representational tasks—visual diagrams and comic strip and how these tasks helped them show their science learning, through the interviews.

Visual diagram. The multimodal task—the visual diagram—the students used to represent their understanding of photosynthesis three times during the unit was the most useful task for the students. Most students felt that the 'pictures,' as the students referred to the visual diagram was most helpful. The reasons attributed to its usefulness was the ease with which the students could show their understanding through pictures and not words. The students claimed that the process of creating the visual diagram—drawing and labeling the plant, using arrows, symbols and pictures and words to represent the process of photosynthesis, actually helped them not only show their understanding but also assist their learning process. The students also explained how the repeated drawing of the same visual diagram over the course of the unit presented opportunities to develop an in-depth understanding of the process which would not have been possible if they drew the diagram only once. Further, this was the only task modeled by the teachers as part of the feedback process.

Comic strip. The multimodal task—comic strip—the students used to represent their understanding of photosynthesis towards the end of the unit was considered useful only by about half of the students who participated in the interviews. Their views on the use of comic strips were quite ambivalent. While a few ELLs felt that the combination of story-writing and science explanations really difficult, all other students found that aspect of writing the story of photosynthesis quite appealing. Other ELLs found the idea of writing a story and explaining science quite conflicting.

Summary. Given students form their self-efficacy beliefs by interpreting information from other sources (Bandura, 1986, 1997), one of which is the interpretation of experience or performance. Britner and Pajares (2006) posited that students engage in tasks, interpret the results of their action in the tasks to develop beliefs about their ability to engage in subsequent tasks, and act in accordance with the beliefs created. However, the personal experiences during various tasks do not alone determine self-efficacy beliefs. Rather they are also influenced by support received during the tasks, relative difficulty of the tasks and efforts involved during the tasks. The decrease in the self-efficacy scores could be attributed to the lack of support received during the comic strip, and the relative difficulty of the task.

During the underlining and highlighting of read-alouds, creation of molecule models and modeling the visual diagrams, the added teacher support in emphasizing what needs to be done is what supported their learning. Creating the different iterations of the visual diagrams and modeling of the diagram by the teachers, provided supports to improve their understanding of the process of photosynthesis. For the comic strip, teacher support was considerably reduced as the teachers expected the students to create it independently. While some of the scaffolding strategies provided assistance that allowed students to engage in tasks they could not do alone (Wood, Bruner & Ross, 1976), it did not provide the students ‘‘to participate at ever-increasing levels of competence'' (Palincsar & Brown, 1984, p. 122) as evidenced by the difficulty experienced by the ELLs while creating the comic strips independently. For most of the ELLs, besides the scaffolding strategies used by them during the tasks, additional teacher support was the mainstay of all the scaffolding strategies.

Summary of Data Analysis

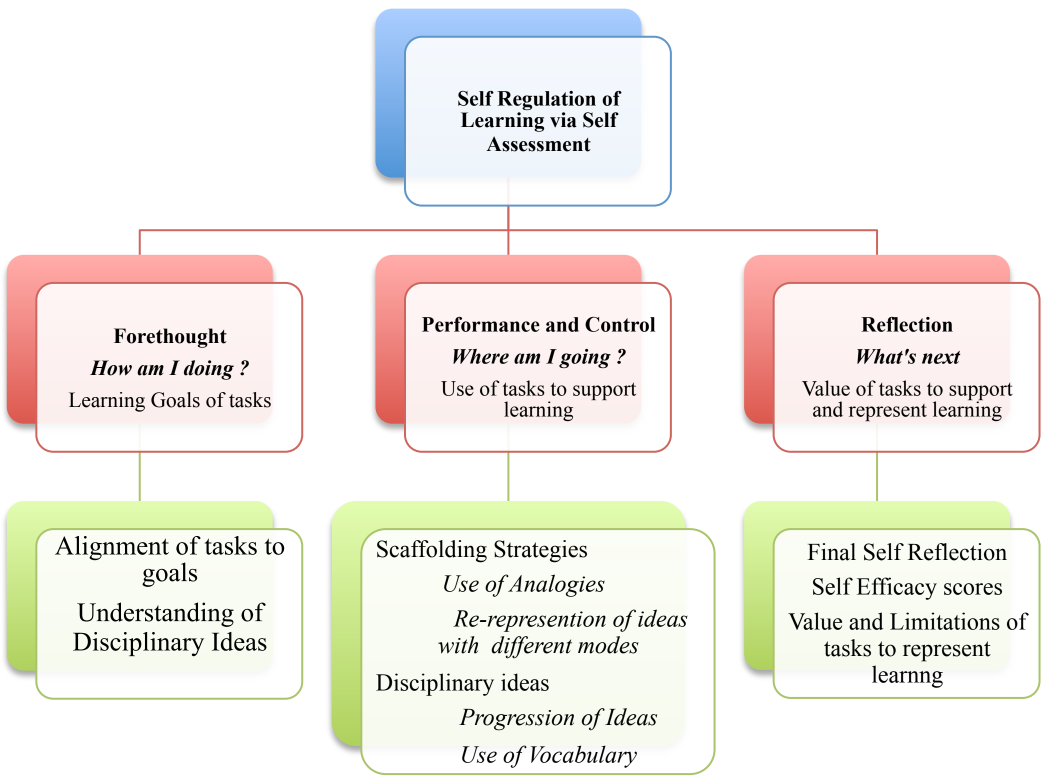

Figure 4. Summary of data analysis based on Andrade (2010) model of self-regulation of learning via self-assessment.

Affordances and Constraints of Multimodal Tasks—Students' Perspectives

According to most researchers, "self-assessment is formative—students assess works in progress to find ways to improve their performance" (Andrade, 2007, p. 60) and it is not having students determining their own grades. In this study, the interviews, self-assessment tasks and final self-reflection survey were analyzed to gain an insight into how the students viewed, used and reflected on the use of the tasks to support their learning process. The interviews offered an insight to how the students viewed the learning goals of the tasks. The open-ended self-assessment responses gave an insight as to how the students assessed their learning about the process of photosynthesis. Much as the open-ended responses were not provided for a grade, it gave a glimpse of how the students progressed in their learning. What could not be conducted in this study was using the self-assessment of the students to improve their performance, as the students did not reflect on their responses. Nevertheless, the responses demonstrated an increase in the level of conceptual understanding from the beginning of the unit, especially for the ELLs. The science attitude scores showed that the total sample increased in all the scores of interest, identity and affect except for self-efficacy. When the scores were disaggregated by ELL status, it showed that ELLs had a decrease in all scores and the redesignated had an increase in all scores, except for self-efficacy. This could be attributed to the fact that ELLs needed more modeling and scaffolds in some of the tasks especially the read-alouds, molecule model, and the comic strips. Even though the ELLs were fond of science, they did not "feel good about doing science." The redesignated students had an increase in all science attitude scores indicating that their experience during the science unit with the use of multimodal tasks in the classroom may have led to the increase in interest, affect and identity. The decrease in efficacy might also indicate that they did not "feel good about doing science" which could be attributed to the revisions of the comic strips several students had to do. There was a small gain or no gain in the scores for English only students, so they maybe more non-committal to the value of multimodal tasks or that the multimodal tasks did not influence their attitude towards science, compared to the other groups. Interestingly, the final self-reflection surveys show that majority of the students found most of the tasks useful. It is not clear, however, if the students' responses reflected how they felt about doing the task versus its utility to help them understand the process of photosynthesis.

To Assist Learning

In the previous sections, I have summarized how the students viewed the learning goals of each task, used scaffolding strategies while using the tasks and the reflected on the use of the tasks.   To conclude, I summarize the affordances and limitations of the multimodal tasks to assist the learning process and also represent their understanding of the process of photosynthesis based on the students' English Learner status. As Siegel et al. (2014) demonstrated in their study that scaffolding strategies used in assessment tasks supported both ELLs and non ELLs. Similarly, the scaffolding strategies outlined in this paper provided affordances to learn the process of photosynthesis for all the students. All the students found the interactive read-alouds "*Tree Is Like a Hungry Kid*," as it provided avenues to integrate multiple modes of reading, writing and talking along with scaffolding strategies of underlining and highlighting important core ideas. However, ELLs found the task of highlighting somewhat overwhelming, as they were not aware of what to underline or highlight.

They required further support and direction from the teachers as to what they should underline. Similarly while all students made the *molecule models*, a few students who were interviewed mentioned that they just followed the steps demonstrated by the teacher and were unsure of the reasons for making the molecule model. Finally when the teacher helped them individually, they understood some of the goals of the making the model. Interestingly, several students from all groups emphasized that specific aspects of making the model were helpful, like the cutting and making 2D paper models of the hydrogen, oxygen and carbon molecules.

Since the *videos* were shown at the beginning of the unit, most of the students interviewed did not remember the videos. Of the ELLs who remembered the videos, all of them found the content of the video rather confusing and not useful in helping them understand the process of photosynthesis. However, when asked about images or pictures which might have helped their understanding, they alluded to the images seen on one of the videos—oxygen molecules moving in pairs- being particularly useful as helping them understand that oxygen was a reactant. The students in the other groups stressed that the specific video, which showed the animated version of the process of photosynthesis was exceptionally helpful as it was a visual representation of the process of photosynthesis taking place in a plant.

The seed germination task was the only task which all the students found useful in understanding the role of sunlight in photosynthesis. The different steps namely placing bean seeds in Ziploc bags in sunlight and absence of sunlight, after the beans sprouted placing the seeds in pots, placed in sunlight and absence of sunlight. By observing the changes occurring every few days with the seeds and with the plants in the two conditions (with and without sunlight) provided affordances by which the students understood the process of photosynthesis.

To Represent Learning

The visual diagrams and comic strips were the multimodal tasks the students created to represent their understanding of the process of photosynthesis. The comic strips which the students created towards the end of the unit not only showed the integration of a narrative and science content but also their ability to combine their knowledge of photosynthesis from different resources and represent their understanding of the process of photosynthesis. As the student reflected on the utility of the two tasks assigned to represent their understanding of the process of photosynthesis, the comic strip was the task that was difficult to create, especially for ELLs. However, the comic strips proved to be challenging for most students. Comments like, "I went off topic of the plants first because I wanted to explain how they turn small and then how they did all this…" ; "That (comic strip) confused me a lot because it sort of based on more activity, more fun than learning about photosynthesis. Like the plants had to make jokes and they had to teach, so it kind of confused me." And finally for some students, " It made me confused a bit, but yeah it helped me and it got me confused at the same time."

It is important to note the immense value all the students found in the use of the visual diagrams. It was evident that almost all the students found value in the visual diagrams through the interviews, " I like drawing it and seeing how every step was made and how the plant…", "I could draw it in my own way that I understand it" and "I could go deep". In sum, the value of the visual diagrams through the students' perspectives include, (a) ability to use pictures or images to show their understanding, (b) drawing the visual representations three times during the unit helped in improving their understanding over time, (c) it also contributed to the in-depth understanding of the process of photosynthesis, (d) visual diagrams were also used by the teachers to explain the process of photosynthesis and provide feedback, and (e) the visual diagrams did not pose heavy language demands.

What makes the students' perspective distinctive is that while it showcases the students' opinions and attitudes, it also revealed how students, whether they were ELLs, redesignated or English only students, applied certain strategies for accomplishing different kinds of learning goals through the multimodal tasks.

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APPENDIX A

Science Attitudes Survey

(Adapted from Seeds of Science/Roots of Reading—Soil Habitats Assessment)

Fill in the bubble under the answer that best describes the way you feel.

Example	YES!!	Somewhat yes	Somewhat no	NO!!
My favorite flavor of ice cream is chocolate.				

	YES!!	Somewhat yes	Somewhat no	NO!!
1. I have a good feeling about science.				
2. Science is fascinating.				
3. I have a hard time understanding science ideas.				
4. I am a science-type person.				
5. If I knew I would never have science again I'd feel sad.				
6. Science just isn't interesting to me.				
7. I think I am able to learn science ideas.				
8. I am the type of person who could become a scientist.				

9. When I hear the word science I have a feeling of dislike.

10. Science is interesting to me and I enjoy it.

11. I think I will get a good grade in science.

12. Other people think of me as a science-type person.

13. Science makes me feel uncomfortable.

14. Learning about science is fun.

15. I will not do very well on scientific activities.

16. I cannot imagine myself as a scientist.

17. Science is boring.

18. I am usually interested in science class.

19. I will know a lot about science at the end of this year.

20. Science isn't for me.

21. I feel comfortable with science and I like it very much.

22. I enjoy studying science.

23. The science ideas taught this year have been hard

24. I would like to learn more about science.

25. I think I will do well on science tests and class work.

APPENDIX B

Open-ended self-assessment questions

Name:

Date:

Teacher:

Lesson—Photosynthesis ("Tree Is Like a Hungry Kid"/Molecule Model/Seed Germination Task/ Comic Strip)

- The thing I already knew (about photosynthesis) before this lesson…

- One thing I am not sure (about photosynthesis) after this lesson is…

- One thing I learned better (about photosynthesis) than I knew before this lesson is…

APPENDIX C

Student interview protocol

To be read: Thank you for participating in this interview. There are no right or wrong answers for these responses. Please be honest. If you need more clarification or need me to elaborate/expand/justify at anytime, just let me know. Please understand that your participation is voluntary and that you have the right to refuse to answer particular questions or discontinue this interview at any time without penalty. Your individual privacy will be maintained in all published documents resulting from this study. [how prompt and response]

1. What did you think about this assignment (show any multimodal task the student completed) and do you like doing these assignments /tasks ?
2. How did this help you understand photosynthesis ?
3. The teacher has provided you with some comments. Did you get a chance to read them and did it help you?
4. What part of the assignment was helpful for you to understand photosynthesis?
5. What part of the assignment was not easy to understand ?
6. What would you suggest to your friends who are going to come to middle school next year, about the assignments that helped you the best ?

APPENDIX D

Final Self-Reflection Survey

Name:

Date:

Teacher:

(A) Please check the box which best shows your opinion

Lessons/Activities to Understand Photosynthesis (by Teacher)

Lessons/ Activities	Helped me understand a lot	Somewhat helped me understand	Somewhat did not help me understand	Did not help me at all
Website & Videos				
Reading "Tree Is Like a Hungry Kid"				
Making Molecule Model				

Activities to Show How You Understand Photosynthesis (by Student)

	Helped me show my understanding a lot	Somewhat helped me show my understanding	Somewhat did not help me show my understanding	Did not help me at all
Diagram on the Process of photosynthesis				

Comic strip explaining process of photosynthesis				

(B) Which part of photosynthesis did you learn/understand best from each lesson/activity?

Please check only the most relevant responses.

Please add if you learned anything else.

Lessons/Activities	Process of Photosynthesis
Website/Videos/	(A) Please check the box which best shows your opinion
"Tree is like a Hungry Kid"	○ What Chlorophyll does ○ Sunlight as energy ○ Glucose is formed ○ Carbon-dioxide and Water are used ○ Oxygen is released
Molecule Model	○ What Chlorophyll does ○ Sunlight as energy ○ Glucose is formed ○ Carbon-dioxide and Water are used ○ Oxygen is released

(B) Which part of photosynthesis could you draw & explain well in the following activities?

Please check only the most relevant responses.

Please add if you explained anything else.

Lessons/Activities	Process of Photosynthesis
Diagram on the Process of Photosynthesis	◯ What Chlorophyll does ◯ Sunlight as energy ◯ Glucose is formed ◯ Carbon-dioxide and Water are used ◯ Oxygen is released
Comic Strip explaining Process of Photosynthesis	◯ What Chlorophyll does ◯ Sunlight as energy ◯ Glucose is formed ◯ Carbon-dioxide and Water are used ◯ Oxygen is released

APPENDIX E

Tree Is Like a Hungry Kid—Interactive Read Aloud

Name: ___________________________

A Tree is Like a Hungry Kid

By Mikki Sadil

What do you do when you are hungry? If you're like many people, you probably like something sweet for a snack. A tree is like a hungry kid because it needs food to grow, and it prefers sugar. It's not exactly the same sugar we find in candy and cookies, but it is a special kind called glucose that makes trees grow.

You might be thinking, *How does a tree eat the food (sugar)? It doesn't even have a mouth!* True, trees don't have mouths. They do have roots to take in water and minerals, but they don't really get food through their roots either. Trees make their sugar in their leaves. The sugar is sent from the leaves into the branches, trunk, and even the roots. When a tree "eats," it is moving sugar from the leaves to all its other parts.

When your mom makes cookies, she uses a recipe with certain ingredients. When a tree grows, it uses its own version of a recipe, which is a process called photosynthesis. This process also has to have certain ingredients to work. Do you know what a recipe for photosynthesis would look like?

Recipe Card for Photosynthesis

Makes 1 Batch of Sweet, Delicious Glucose for Trees

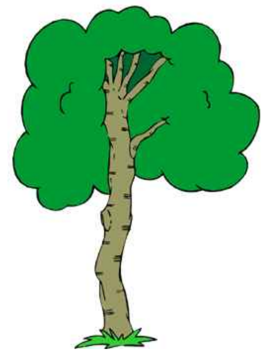
Ingredients:

- Light energy: comes from the sun.
- Water: comes from the soil, gathered by the tree's roots.
- Carbon dioxide: comes from the air.
- Chlorophyll: comes from the cells of green plants.

Directions:

Mix the chlorophyll, carbon dioxide, and water together. Bring in energy from the sun. Soon, glucose sugar and oxygen will form through a process called PHOTOSYNTHESIS.

Photosynthesis occurs when a tree uses the sunlight and chlorophyll to convert carbon dioxide and water into glucose. The tree needs to eat this glucose to grow, and we know it is eating because the leaves are turning green. It isn't the glucose which turns the leaves green, however, it is the chlorophyll.



Trees grow the most in the spring and summer, where there is a lot of sunshine every day. When fall begins, the days grow shorter and there is less sun. This alerts the tree to begin getting ready for winter. The leaves begin to turn red, orange, gold, and brown, because with less sunlight and water for photosynthesis, the green chlorophyll begins to disappear.

The leaf colors we see in the autumn have been in the leaves all along, but with so much green chlorophyll, we can't see them until the chlorophyll is gone. As winter begins to approach, the tree uses the food it has stored during the spring and summer, and goes into a rest period. Actually, the tree hibernates…just like bears do! The only difference is that bears lie down in a cave to sleep, and trees lose all their leaves and stand up to sleep.

Name: ___________________________

A Tree is Like a Hungry Kid

By Mikki Sadil

1. What substance does a tree use for food?

a. photosynthesis **b.** chlorophyll
c. glucose **d.** leaves

2. What four things does a tree need for photosynthesis?

____

____

3. What causes a tree's leaves to appear green?

____

4. What signals a tree to preparing for winter?

a. The days become colder.
b. The weather becomes dry.
c. There are more rainy days.
d. There are fewer hours of sunlight.

5. How does a tree get water?

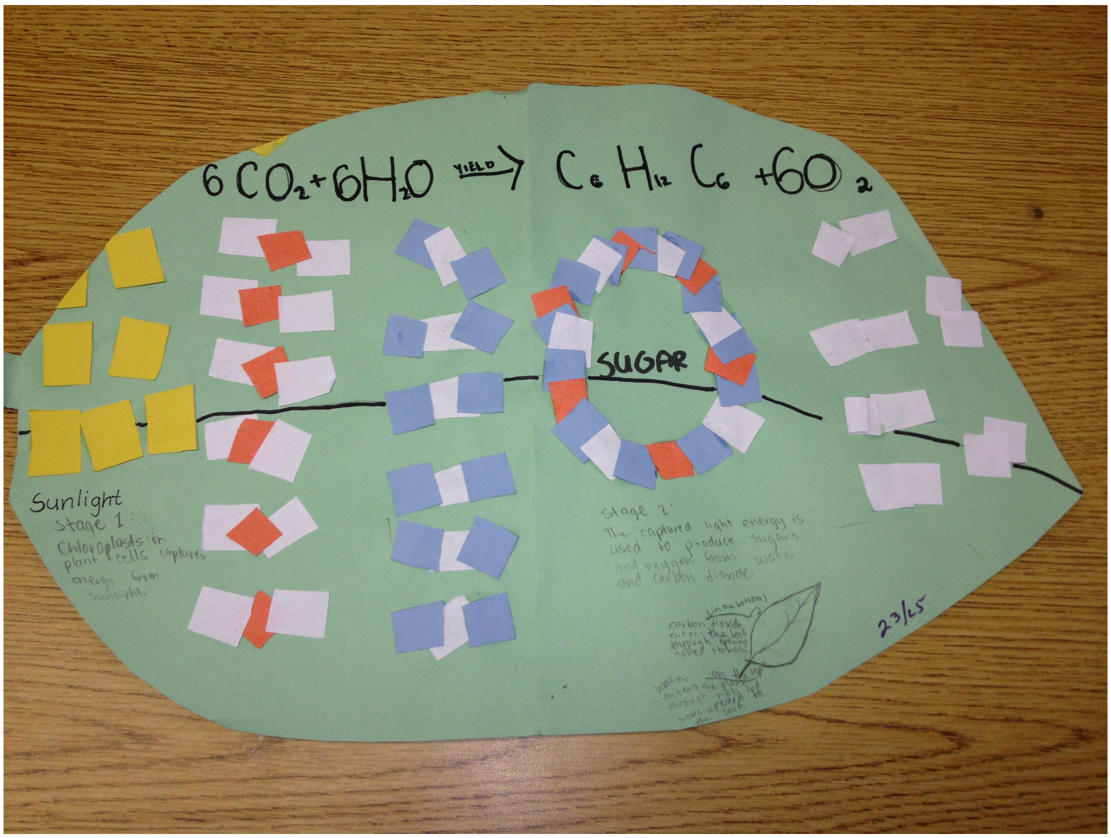
a. It makes water in its leaves.
b. It turns glucose into water.
c. It absorbs water through its roots.
d. It uses photosynthesis.

6. Why do a tree's leaves change color in the fall?

a. The tree has less chlorophyll.
b. The tree has less water.
c. The tree has no leaves.
d. The tree is growing quickly before the winter sets in.

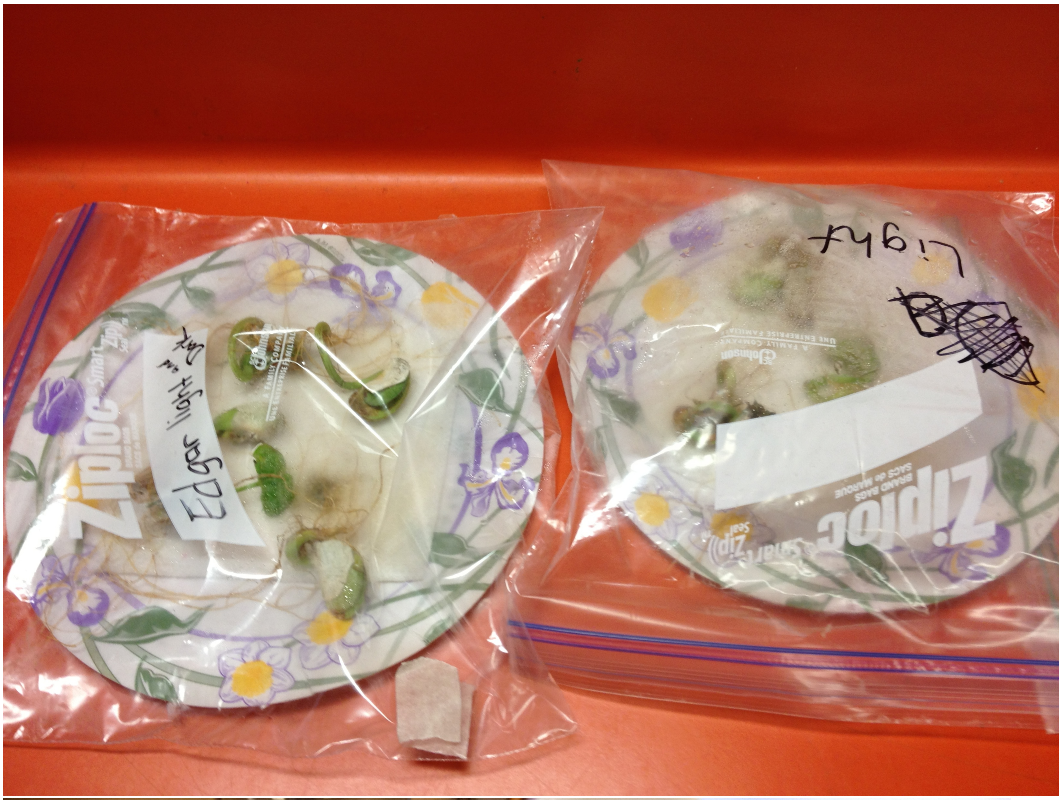
APPENDIX F

Molecule Model



APPENDIX G

Seed Germination Task


Ziploc
Light

Light

CHAPTER 4: MULTIMODAL TASKS TO SUPPORT STUDENTS' SCIENCE LEARNING IN LINGUISTICALLY DIVERSE CLASSROOMS: USING A SCIENCE AND LANGUAGE LEARNING RUBRIC

Assessing ELLs in Science Education

Who Are ELLs?

According to the U.S. Department of Education, about 49.7 million students are enrolled in the US public schools and more than 4.4 million children are English language learners (ELLs; National Center for Education Statistics [NCES], 2014). ELLs make up the fastest growing segment of the public school population. The number of ELL students has increased by 53.2 %—from 3.5 million to 4.4 million—from 1997-1998 to 2007-2008. It is predicted that by 2025, nearly one out of every four public school students will be an ELL (NCES, 2011, 2012). Nearly 70% of these students are being educated in just five states—California, New York, Illinois, Florida, and Texas (National Clearinghouse for English Language Acquisition [NCELA], 2007). This demographic issue is national in nature as the number of ELLs grows rapidly in other parts of the country (Meyer, Madden, & McGrath, 2000). In recent years, other parts of the US have also experienced a dramatic growth of ELL students. For example, South Carolina, Kentucky, Indiana, North Carolina, Tennessee, Alabama, and Nebraska have experienced a 300–700% increase in the ELL student population, whereas other states have seen at least a 100–300% increase in the ELL student population (National Academy of Sciences [NAS], 2010; NCELA, 2011). The ELL students in the United States are a heterogeneous population;

Spanish is the native language for the majority of ELL students (79%) and a substantial share of the entire United States. The ELL population are also native speakers of Asian, Southeast Asian (5.5%), and European languages (less than 1%).

The academic achievement of ELLs has lagged behind that of native English speakers in science and literacy (Lee & Luykx, 2006; NCES, 2011; Rodriguez, 2001, 2003). On the 2011 National Assessment for Educational Progress (NAEP) tests administered by the National Center for Education Statistics, the average scale score of ELLs for eighth-grade science was 106, and that of non-ELLs was 154. ELLs are also less likely to pursue advanced degrees in science (Commission on Professionals in Science and Technology, 2007; NAS, 2010; Tate, 2001). With regard to enrollment in science in California, the percentage of ELLs was considerably lower than their English-speaking counterparts in 2013. In 10th-grade life science, the enrollment of ELLs is around 12%, and that of non-ELLs is around 81%. In 11th-grade physics, the enrollment of ELLs is around 1.6%, and that of non-ELLs is around 11.4% (California Department of Education, 2015).

As science standards are translated into curricula, instruction, and assessment, particular attention has to be paid to inclusive strategies to engage students from culturally and linguistically diverse backgrounds. Pursuing the goal of supporting the science learning of students from different social and linguistic traditions, the Next Generation Science Standards (NGSS) Diversity and Equity Group focused on ensuring that they are accessible to all students. Identifying three main strategies, they posited that the implementation of and engagement in these strategies can support science learning for ELLs. They provide various strategies for literacy and language development, including an explicit discussion of reading and writing of scientific genres and use of academic language in science practices, and using realia (real objects or events) and multiple modes of representation (gestural, oral, pictorial, graphic, textual) in science.

This study incorporates some aspects of a design-based approach, wherein the research was conducted in real-time classroom settings. Both the teachers and I planned the science unit in photosynthesis jointly, and the data were collected and analyzed to promote the theory (sociocultural orientation of multimodality and formative assessment) and the practice of implementing multimodal tasks to support science learning in two middle school science classrooms. I explored how the use of some of these strategies through multimodal tasks created by the students supported their science learning in two sixth-grade linguistically diverse classrooms. With the help of a science and language learning rubric created, I aim to show the extent to which the multimodal tasks—namely the visual diagrams and comic strips—created by the students supported their learning of photosynthesis.

Guided Literature Review

Since the early 1990s, research has been conducted on the promotion of science learning and English language and literacy development among students from diverse linguistic and cultural backgrounds. The focus of most of the research has been the improvement of science learning among ELLs by addressing some of the challenges ELLs face. Researchers have examined the science learning of ELLs in the context of studying the impact of educational interventions or programs. Most of this research falls within three categories, namely (a) large scale standardized assessments—modifications and accommodations for ELLs and alternate assessments, (b) interventions through curriculum-based programs, and (c) notions of cultural validity. Most of these researchers evaluated the efficacy of their programs or interventions on student learning through summative assessments given to students after the program or intervention was completed. There are certain aspects of the interventions or assessments that focused on enhancing student learning of science content. Most of the interventions attended to the language and literacy needs of ELLs, the development of science concepts and vocabulary, and the cultural and linguistic backgrounds of the students. In this review, I highlighted how these studies addressed these key aspects to support student science learning.

Large-Scale Standardized Assessments and Alternate Assessments for ELLs

The criteria for deciding how ELLs are assessed in large-scale standardized assessments rely entirely on whether students are classified as ELL or not and do not take into account the heterogeneous nature of ELLs. Science assessments used in state-level accountability systems are typically developed for native speakers of English. The linguistic demands of tasks used to measure science knowledge and the abilities of science assessments are also high (Baxter, Shavelson, Goldman, & Pine, 1992; Solano-Flores & Trumbull, 2003). Hence, there is substantial concern whether these science assessments yield valid scores for the ELL population. Researchers have expressed concerns regarding the reliability, validity, and fairness of statemandated achievement tests (Abedi, 2001, 2004; Kieffer, Lesaux, & Snow, 2008), particularly in science, for ELLs (Penfield & Lee, 2010).

Accommodations and Modifications

Research has been conducted on ways and means of reducing the linguistic complexity of these tests through accommodations (Abedi, 2001) and modifications (Siegel, 2007). Accommodations affect a student's or group's performance in comparison to a peer group by providing unique and differential access to performance so they may complete the test and tasks without other confounding influences of test format or administration (Hollenbeck, Tindal, & Almond, 1998). Modifications result in a change in the test (how it is given, how it is completed, or what construct is being assessed) and tend to work across the board for all students with equal effect. Abedi (2001) investigated linguistic modification—modified or simplified English vocabulary of test items and glossary, wherein words or phrases identified as potentially difficult for ELL students to understand were defined or paraphrased, along with extra time and glossary—as a form of accommodation and its impact resulted in substantially higher test scores for ELL and non-ELL students. Most accommodations helped both ELL and non-ELL students, with modified English being the only type of accommodation that narrowed the score difference between ELL and non-ELL students. Siegel (2007) developed a framework for equitable classroom assessments that was used to refine and evaluate assessments for English learners in middle school life science courses in two California schools. Adding visual supports and dividing prompts into smaller units were some of the modifications introduced in the classroom assessments; Siegel noted that both English-only students and advanced ELLs scored significantly better on the modified assessments.

Alternative Assessments

In order to address equity in classroom-based assessments, researchers have explored the use of alternative assessments with ELLs. Performance assessment tests students using constructive responses and long-term engagement in project-like tasks. In this type of assessment, experts judge the quality of the student performances along with the products of their tasks, such as reports or works of art (Baker & O'Neil, 2008), in contrast with using standardized achievement measures consisting of objective test formats. Shaw (1997) used science performance assessments with ELLs and native English speakers in five high school science classes and investigated the face, construct, and consequential validity of this intersection. The results showed that students' English comprehension and expression skills were determining factors for certain items. The recommendations from this study included increasing the clarity of an assessment's design, allowing ELLs more time to complete assessments, and scoring by raters who are knowledgeable about typical patterns in written English for this student population. Later, Shaw, Bunch, and Geaney (2010) created a Science Assessment Language Demands (SALD) framework to document the wide range of functional and interactional language demands involved in science performance assessments. Their analyses demonstrated the wide range of language demands faced by ELLs during student interactions with the teacher, with each other, and with the texts that the students had to interpret and produce during science performance assessments. These studies revealed the potential challenges facing English learners during science performance assessments, as well as multiple opportunities afforded by such assessments for demonstrating their knowledge and skills and further developing language proficiency.

Cultural Validity

While assessing students from diverse cultural and linguistic backgrounds, the factors related to culture and language are often seen as sources of measurement errors (Solano-Flores, 2011). In order to address this issue, Solano-Flores and Nelson-Barber (2001) introduced the idea of *cultural validity,* i.e., “the effectiveness with which science assessment addresses the sociocultural influences that shape student thinking and the ways in which students make sense of science items and respond to them” (p. 555). They posit that to attain cultural validity, attention must be paid to the ways sociocultural influences and interactions determine student perceptions of what science assessment items are about, what they feel they are expected to do, and what strategies they use to solve them. Through the analysis of science items, it was shown that current approaches in standardized assessments do not focus on understanding the sociocultural influences that shape student thinking (Solano-Flores, 2011).

Several researchers have provided ideas on how to incorporate the notion of cultural validity in classrooms with ELLs. Duran (2011) argued that an important aspect is to have assessments for ELLs embedded in an ongoing classroom context so the students can draw on their understanding of “the everyday social and cultural characteristics of classroom life and its academic linguistic and task demands in responding to task" (p. 119). Lee, Santau, and Maerten-Rivera (2011) posited that to assess ELLs in science, separate criteria should be used to assess English Language proficiency and science knowledge, which will enable teachers to identify strengths and weaknesses of ELLs in each area and understand their learning needs. Kopriva and Sexton (2011) proposed using a variety of approaches by which different kinds of knowledge and skills can be assessed in an ongoing classroom with ELLs. Formative assessment tasks developed to capture information about student learning and provide feedback to students with strategies for improvement will be particularly useful for ELLs. As such, teachers should be viewed as the effective contributors who can provide accurate information about student learning in classroom settings (Fradd & Lee, 1999). Thus, new assessment systems embedded in classroom contexts have to be devised that allow for a more genuine participation of students to enable both teachers and students to support the learning of science.

Curriculum for Linguistically Diverse Students

In this section, I describe those studies that have implemented science curriculum designed for the purposes of teaching linguistically diverse students. The curriculum for these classrooms included using (a) students' ideas as intellectual resource in the materials designed for ELLs in their native language, (b) the use of narrative genres, and (c) an integration of science and literacy through multiple modes of representation like talking, read alouds, and visuals.

At the Chèche Konnen Center, science education research was conducted wherein the students' linguistic and cultural experiences were used as intellectual resources in science learning and teaching. Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes (2001) proposed alternative ways for understanding the everyday sense-making practices of students and offered their perspective on how the relationship between every day scientific knowledge and ways of knowing have been conceptualized in the field of science education research, especially for ELLs. All of their case studies elaborated on this point of view; they analyzed Haitian American and Latino students' talk and activity as they worked to understand Newton's laws of motion, heat transfer, metamorphosis, and experimentation in science (Rosebery & Warren, 2008; Rosebery, Warren & Conant, 1992; Rosebery, Ogonowski, DiSchino, & Warren, 2010). In their analysis, the researchers interpreted student talk with the view that the students' perspectives are quite complementary, rather than discontinuous, to scientific discourse. Warren et al. (2001) suggested that teachers and researchers should view students as capable possessors of "invaluable intellectual resources" (p. 548).

As science and literacy share highly complementary learning processes and discourse practices (Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012), there has been research on *science-literacy programs* that capitalized on potential synergies between science and literacy, where students can utilize skills such as posing questions, making predictions, or making inferences that can be used for both science inquiry and for reading comprehension. Some of these studies include the Seeds of

Science and Roots of Reading science-literacy curriculum programs. (Duesbery, Werblow, & Twyman, 2011). The particular nature of the Seeds of Science/Roots of Reading unit is that it strategically employs multiple learning modes through reading, writing, and drawing in the curriculum, which provides ample opportunities to support ELL learning. Similarly, other studies examined the implementation of curriculum kit inquiry-based science instruction in promoting science with predominantly Spanish-speaking elementary students (Amaral, Garrison & Klentschy, 2002) and instructional intervention for linguistically and culturally diverse students, utilizing household materials for conducting scientific inquiry activities, a medium for examining language and literacy, and collaborative interactions in the classroom (Bravo & Garcia, 2004).

In sum, the aforementioned studies focused on some key aspects in their curricula for culturally and linguistically diverse students that served to support their science learning. I have attempted to highlight the unique aspects in the curricula which may have contributed to ELLs' science learning. These include attention to students' primary language (Amaral et al., 2002); using the students' ideas as resources for learning (Rosebery et al., 1992, 2008, 2010); and the integration of science and literacy in inquiry-based curricula as a way to provide opportunities for ELLs to show their understanding of science through multiple learning modes like writing, reading, and drawing (Bravo & Garcia, 2004; Cervetti et al., 2011; Duesberry et al., 2011; Hanaeur, 2005). All these studies demonstrate the value of discourse in science through talking, reading, and writing as a support for science learning for ELLs (Moje et al., 2001).

Supporting Pre-Service and In-Service Teachers in Assessing ELLs

Stoddart, Solis, Tolbert, and Bravo (2010) created the Effective Science Teaching for English Language Learners (ESTELL) framework, which embodied the same principles of integrating science inquiry and literacy while simultaneously adopting the CREDE standards, where the science content provides a meaningful context for the learning of language structure and functions. To study the efficacy of the framework, pre-service teachers who were trained in the ESTELL framework during their student teaching were followed into their first year of teaching. In the preliminary analyses of the student achievement of these first-year teachers, Shaw, Lyon, Mosqueda, Stoddart and Menon (2014) found that student learning improved in science concepts, writing, and vocabulary, and ELL learning gains were on par with non-ELLs, with differences across proficiency levels for vocabulary gain scores. In their commitment to science education with elementary students from diverse languages and cultures, Lee and Fradd (1996, 1998, & 2002) developed the instructional congruence framework through extensive collaboration with a small group of volunteer teachers. As such, the work of Fradd and Lee (1998) viewed the diverse cultural behavior of their Haitian students as incongruent with the discourse of science. To assess the fidelity of the implementation of the instructional congruence framework, studies were conducted on the impact of student learning with science tests where ELL students showed statistically significant gains (Cuevas, Lee, Hart, & Deaktor, 2005; Lee et al., 2005; Lee, Maerten-Rivera, Penfield, LeRoy, & Secada, 2008). The intervention paid specific attention to the language and literacy strategies to address the needs of English language learners, which included student booklets to strengthen students' reading and writing comprehension, focus on language functions within the context of scientific inquiry, and using "multiple modes of communication and representation (e.g., verbal, gestural, written, and graphic) to enhance students' understanding" (Lee et al., 2008, p. 38).

In sum, special attention has to be placed on supporting ELLs in learning science through simultaneously supporting their language learning and science content learning. Some of the instructional strategies include use of questions, awareness of students' cultural and language backgrounds, and supporting science inquiry projects with an emphasis on language and science scaffolding through multiple ways—including visuals and graphic organizers.

Summary

The proposed ideas in the above studies can be summarized as an integration of science and literacy, instructional congruence, incorporation of student modes of discourse into classroom interaction, and explicit teaching of the discourses of science. I highlighted the knowledge of how science content is constructed linguistically and to be aware of the linguistic demands of science tasks. Even though knowledge of the discourse of science is important, what is exemplified in most studies is how to make that knowledge of the discourse of science accessible to students from differing cultural and linguistic practices. We must focus attention on the process of how ELLs engage in the reading, writing, and talking of science, and teachers need to provide scaffolds to support these students in performing and engaging in ways to integrate the knowledge of the discourse of science into the classroom (Amaral et al., 2002; Bravo & Garcia, 2004; Warren et al., 2001). To that extent, I examine how students demonstrate their understanding of the process of photosynthesis through two forms of multimodal tasks that were used in the classroom settings for the purpose of examining how the students used the feedback provided by the teacher and also represented their understanding of photosynthesis.

Research Questions

The overarching goal of this study is to address the problem of improving ELL science learning by addressing (a) instructional supports to concurrently develop English proficiency while learning science content and knowledge; (b) fair assessment for student science learning during the process of teaching and learning in the classroom; and (c) how the combined use of (a) and (b) can support science learning for ELLs. Hence, the main research question guiding this research is to what extent and how do the multimodal tasks (visual diagrams and comic strips) represent the science learning of students in linguistically diverse classrooms?

In this paper, I focused on analyzing the following research questions:

1. To what extent do the first two visual diagrams show the improvement of the science learning of linguistically diverse students using the science language rubric?

2. To what extent do the comic strips demonstrate the science learning of linguistically diverse students using the science language rubric?

3. To what extent do the third visual diagrams demonstrate the science learning of linguistically diverse students using the science language rubric?

Table 1
How Do the Multimodal Tasks (Visual Diagrams and Comic Strips) Represent the Science Learning of Linguistically Diverse Students?

Research Questions	Data Collected	Data Analysis
1. To what extent do the visual diagrams demonstrate the science learning of linguistically diverse students using the science language rubric?	Visual diagrams of all students collected at two different times during the unit: beginning (Visual Diagram A), end (Visual Diagram B)	Quantitative analysis of the differences in scores of each construct of the science language rubric between the two visual diagrams (using measures as defined earlier)
2. How do the comic strips demonstrate the science learning of linguistically diverse students using the science language rubric?	Comic strips of all students	Quantitative analysis of each comic strip using the science-language rubric to get a score on each construct of the rubric (using measures as defined earlier)
3. How do the final visual diagrams demonstrate the science learning of linguistically diverse classrooms?	Visual diagrams of all students: collected four weeks after the end of the unit (Visual Diagram C).	Quantitative analysis of each visual diagram using the science-language rubric to get a score on each construct of the rubric (using measures as defined earlier).

Context of the Study

Addressing Diversity in This Study

There are approximately 1.41 million English Language Learners in California public schools. Seventy three percent of the ELLs are enrolled in elementary grades K-6, and the rest are enrolled in secondary grades. In California, 84.24 % of ELLs speak Spanish, 2.3% Vietnamese, 1.4% Tagalog, and 2.7% Chinese. Currently, California public schools—the context of this study—educate over one third of the nation's ELLs (Legislative Analyst's Office, 2007).

The actual process of identifying ELLs varies from state to state. In most states, parents have to complete a home language survey when they enroll their children for the first time in school. If a child speaks a language other than English, then he or she is given an English language proficiency test. In California, where the current study is conducted, the California English Language Development Test (CELDT) was developed to identify students with limited English proficiency, determine the level of English language proficiency of those students, and assess the progress of limited English-proficient students in acquiring the skills of listening, speaking, reading, and writing in English (California Department of Education, 2015). Currently, students who are identified as ELLs continue to take the CELDT annually until they are reclassified as proficient in CELDT, deemed adequate by the teachers, and have parental approval.

An interesting conundrum faced by most school districts with large numbers of ELLs is their heterogeneous nature. Some English learners are immigrants who were born outside the United States and moved to this country at some point in their young lives, and who are often called first-generation English learners. The second or third generation English learners are those who were born in the United States and represent their families' second or third generation in this country. Incidentally, most

ELLs are US-born citizens, with 76% in the elementary level and 57% in the secondary level. Nationally, 57% of adolescent English learners are second or third generation, with California having 49% of the total number (Batalova, Fix, & Murray, 2007). In California, second and third generation students tend to not have well-developed literacy skills in their family language or in English (Francis, Rivera, Lesaux, Kieffer, & Rivera, 2006). As such, adolescent English learners in California middle and high schools do not fare well in school, socially or academically (Walqui et al., 2010). The middle school years are a critical transition period for all adolescents, as they help students in setting a course toward accomplishing the requirements for pursuing university options (Walqui et al., 2010). Furthermore, in middle school settings, there is more emphasis placed on disciplinary language development and subject matter knowledge and skills, which becomes more central to the success of all students (Moje, 2007). As such, for adolescent second language learners who have a limited proficiency in English, this period is complex (Walqui et al., 2010).

The academic achievement of ELLs has lagged behind that of native English speakers in science and literacy at the state level as well. In the 2013 California Standards Tests in English Language Arts, administered by the California Board of Education, 14 % of sixth-grade ELLs performed at the proficient level compared to 67% of non-ELLs. In the eighth grade, 8% of ELLs performed at the proficient level compared to 64% of non-ELLs and, in the 10th grade, 6% of ELLs performed at the proficient level compared to 59% of non-ELLs. In the 2013 California Standards

Tests in Science, administered by the California Board of Education, in the eighth grade, 23% of ELLs performed at the proficient level compared to 72% non-ELLs; and, in the 10th grade, 10 % of ELLs performed at the proficient level as compared to 61% of non-ELLs.

Statewide standardized testing has been one of the ways to evaluate educational impacts on students who have participated in reform efforts. Standardized tests have been referred to as distal measures, to distinguish them from close and proximal assessments, which are embedded in the curriculum or which examine curricular concepts in a new context (Ruiz-Primo, Shavelson, Hamilton, & Klein, 2002). In order to develop a complete understanding of the impacts of reform, it is important to address the impact of any reform on a full range of measures (Ruiz-Primo et al., 2002), whether the reforms help address gaps in achievement outcomes between subpopulations (Geier et al., 2008) and how well the reform efforts address issues of educational equity (Rodriguez, 2001). Some of the reforms aimed at improving the academic achievement of ELLs required "integrating knowledge of academic disciplines with knowledge of English language and literacy development" (Lee, 2004). In that regard, the purpose of this paper is to explore the potential of multimodal tasks to support science learning in linguistically diverse classrooms. In this study, I do not claim the use of multimodal tasks to be part of a reform effort, nor do I claim the tasks as part of an educational intervention. However, I have attempted to show the potential of multimodal tasks to support the science learning of linguistically diverse students. Using information about students' performances on standardized tests and analyzing disaggregated student data will provide insight into whether their proficiency levels on these standardized tests can influence their performance on the multimodal tasks.

Studies have shown the value of analyzing student learning in science in relation to their proficiencies in English language and science inquiry and reasoning skills. Torres and Zeidler (2002) examined the effects of English language proficiency, scientific reasoning skills, and students' classification as "English language learners" on scientific content knowledge. While whether the students were Hispanic ELLs or native English speakers did not have any statistically significant effect, students' level of English language proficiency and their scientific reasoning skills had significant effects, both independently and in interaction with each other. In the same vein, Cuevas et al. (2005) examined their intervention's impact on both the science and writing achievement of their participating students, and the results indicated that the intervention improved students' science achievement, literacy achievement, and inquiry abilities. In addition, gaps narrowed on measures of science and literacy among demographic subgroups in terms of home language and English proficiency. Shaw (1997) found that students' English proficiency level significantly affected their ability to parse the text included in science inquiry procedures and, conversely, their level of science knowledge significantly affected how they used graphs, calculations using an equation, and final summary questions. From the aforementioned studies, it is worthwhile to note how students' varying proficiencies in science, English literacy and ELL status determined their performance on the assessment tasks. *What is unique in this study* is the usage of the science-language rubric to determine the extent of student learning on the multimodal tasks and how their English Learner status, proficiencies in English language and literacy, and science determine the extent of their science learning.

Thus, for the analysis, the students were categorized into groups based on two criteria, namely (a) English language learner status and (b) proficiency levels in California standardized tests in English Language Arts and Science and in one diagnostic test of STAR reading. Incidentally, the teachers also used the proficiency levels in English Language Arts and Science to determine student grouping in their respective classrooms.

Sixth grade English language learner status. Students in this group were identified by their home language survey and their performance on the California English Language Development Test (CELDT). All those students identified as those who speak a language other than English at home also write the CELDT. If they are found proficient in all the categories of the CELDT test, they will be redesignated as English proficient. If they do not acquire a certain level of proficiency in the CELDT test, the students continue as English Learners. If the students identify English as their native language, they are identified as English only. There were three levels of English Learner status: English only and student reclassified in 2010 and earlier together (n = 25); currently ELL and those reclassified this year in one group (n = 20); and the third group had those who were reclassified in 2011 and 2012 (n = 18).

The reason I combined the students into three discrete groups was to increase the sample size of each group (based on CELDT and their first language).

Table 2
CELDT/English Language Learner Status of the Students in the Two Classrooms

Status	Number
CELDT status (designated in 2014)	
Advanced	1
Early Advanced	3
Intermediate	5
Early Intermediate	0
Beginning	5
Total	14
English Language Learner Status	
English only	25
Redesignated	18
English Learner	20
Total	63

Scores on standardized tests and diagnostic tests.

Scores on 5th grade standardized state test: English Language Arts. The California English–Language Arts Standards Test has two strands/reporting clusters: Writing Strategies and Written Conventions and Reading Comprehension (focus on informational materials). The students are assessed as to whether they can read and understand grade-level-appropriate material; describe and connect the essential ideas, arguments, and perspectives of the text; and read and respond to historically or culturally significant works of literature. Students are also assessed on whether they can write clear and coherent essays. Five groups are identified based on proficiency levels on the tests – Far below basic, Below basic, Basic, Proficient and Above proficiency. They were merged to make three groups. The below proficiency group consisted of Far below basic and Below basic proficiency levels; the at proficiency group consisted of Basic and Proficient levels; and the above proficiency group consisted of Above proficiency level. Three groups were identified as those who scored below proficiency (n = 11), at proficiency (n = 34) and above proficiency levels (n = 8) based on their scores on the standardized tests.

Scores on 5th Grade State Tests: Science. Students were assessed on how they understood the following ideas on the state tests: how elements and their combinations account for all the varied types of matter in the world, and how electricity and magnetism are related effects that have many useful applications in everyday life. Other ideas included how plants and animals have structures for respiration, digestion, waste disposal, and transport of materials, how all organisms need energy and matter to live and grow, how living organisms depend on one another and on their environment for survival, and how water on Earth moves between the oceans and land through the processes of evaporation and condensation. Five groups were identified based on proficiency levels on the tests – Far below basic, Below basic, Basic, Proficient and Above proficiency. These were also merged to make three groups. The below proficiency group consisted of Far below basic and Below basic proficiency levels; the at proficiency group consisted of Basic and Proficient levels; and the above proficiency group consisted of the Above proficient level. The three groups, those who scored above proficiency (n = 24), at proficiency (n = 15) and below proficiency levels (n = 14), were identified based on their scores on the standardized tests.

Scores on sixth grade STAR Student Diagnostic Report on Reading: Vocabulary Acquisition and Usage. The goal of STAR Reading was to give educators valid and reliable data for screening, benchmarking, measuring student growth, progress monitoring, and instructional planning. The teachers of these classrooms used these reports to gain insight into students' performances in language arts and reading. They used the data to identify those students who needed active intervention and followed the recommendations provided by the reports to improve student outcomes. Since this report was used to determine the students' progress in language arts, I used the students' proficiency benchmark ratings and percentages scored in the domain of Vocabulary Acquisition and Use to group the students. I used this domain to delineate between the groups, as one of the constructs of the rubric was the usage of curriculum-based vocabulary. The recommended benchmark levels identified for the students include, Urgent Intervention, Intervention, On Watch and At/Above Benchmark. The three levels I identified were Below Proficiency (included students identified as Urgent Intervention and Intervention, with below 60% in Vocabulary Acquisition and Use); Proficient (included students identified as On Watch, with scores between 60% and 80% in Vocabulary Acquisition and Use); and Above Proficient (At/Above Benchmark (> 80% Vocabulary Acquisition and Use).

Table 3
Summary of Student Sample Based on Proficiency in English, Science, and Vocabulary Acquisition and Use

	State tests in English language arts (5th grade)	State tests in science (5th grade)	Diagnostic tests in vocabulary acquisition & use (6th grade)

Below Proficiency	11	14	20
At Proficiency	34	15	13
Above Proficiency	8	24	30
Total	53*	53*	63

* = Missing student information on standardized tests

Creating and Using the Science and Language Learning Rubric (See Appendix A)

A rubric informs both instructor and student what is considered important and what to look for when assessing (Arter & McTighe, 2001), and this idea holds assessment for learning or formative assessment as well (Brookhart, 2013). Research has shown the benefits of using rubrics, one of which is the increased consistency of judgment when assessing authentic tasks. It is assumed that rubrics enhance the consistency of scoring across students and assignments, as well as between different raters (Jonsson & Svingby, 2007). Another benefit is to provide valid judgment of assessments that cannot be achieved by other means. In addition, an important effect of a rubric is the promotion of learning, often focused in research on formative, self, and peer assessments. It is assumed that the explicitness of criteria and standards are fundamental in providing the students with quality feedback, and rubrics can in this way promote student learning (Arter & McTighe, 2001; Wiggins, 1998).

The *Science Content and Language Learning Rubric* was designed to assess each student-created multimodal task (visual diagrams and comic strips) for the learning of science content and language. Researchers have posited that it is important to assess ELLs' understanding of science content by assessing science content and language content separately and to align embedded tasks with instructional objectives (Kopriva & Sexton, 2012; Lee et al., 2010). Science content includes the disciplinary core ideas of science as specified by NGSS standards and modified by the teacher for their classes. I have drawn the language—also referred to as the language of the science content—from the notion of the language of the science classroom also identified in the ELDP standards (Lee, Quinn, & Valdes, 2013). The *science content* is determined by the disciplinary core ideas as identified by the NGSS. The *language of the science content* is determined by how the students "communicate (orally and in writing) ideas, concepts, and information related to a phenomenon or system (natural or designed)" (Pimental et al., 2012, p. 35). The purpose of this rubric is to capture the students' science content understanding (disciplinary core ideas) and language functions (use of symbols, images and disciplinary terminology). The science and language learning on the visual drawing tasks and comic strips were measured using two main constructs: (a) *Productive Language Function:* Includes how students use *symbols, images and curriculum-based words and terms* to describe the process of photosynthesis, and (b) *Science Disciplinary Core Ideas*: Includes understanding the process of photosynthesis, including the reactants and products and the use of the sun's energy. These constructs were measured using the *Science and Language Learning Rubric* I designed and aligned to the science content and the language learning objectives of the unit. As the teachers identified the disciplinary core ideas of photosynthesis, the purpose of the rubric was to assess to what extent they have demonstrated their understanding through these multimodal tasks, and if the students have increased their understanding of these disciplinary ideas.

Productive Language Function

Information in science is often conveyed not just through oral or textual forms but also through visual representations, including pictures, diagrams, graphs, charts, tables, maps, and equations (Jewitt & Kress, 2013; Kress, Charalampos, Jewitt, & Ogborn, 2006). In order to gain knowledge in science, students need to understand nonlinguistic modes of representation as well (Prain & Waldrip, 2006). In addition, they need to comprehend "information presented through the various modes into a single coherent understanding of the material being presented or a coherent presentation of their own ideas" (Lee et al., 2013, p. 6). For ELLs, the coordination of these multiple representations provides an additional path to science and language learning.

To enhance science learning, NGSS recommends that students engage in science practices, namely, how to develop explanations in science and obtain, evaluate, and communicate scientific information. The language functions—productive and receptive functions—that will help ELLs engage in these practices include a) comprehending explanations offered by texts and coordinating texts and representations, b) reading or listening to obtain scientific information from diverse sources, and c) providing information needed by listeners or readers and responding to questions by amplifying explanations (Lee et al, 2013). In this study, the main idea of productive language function was determined using three constructs: symbols, images, and curriculum-based vocabulary.

Symbols. Most researchers in science education have invoked Peirce's (1931–1958) triadic model, using social semiotic theory to examine multimodality in science classrooms. Wu and Shah (2004) have described how each mode has various affordances, where students use (a) a "verbal mode" to describe the entities and their relationships in written form; (b) a "symbolic mode," which makes use of chemical symbols and formulae and chemical equations; and (c) a "visual mode," which makes use of graphs, diagrams, and drawings (Christopherson, 1997; Gilbert, 2004). In their study, Hubber, Tytler, and Haslam (2010), using the triadic model, describe how we come to know what force means, and its causes and effects, through *interaction*—the relationship between a concept (e.g., the idea of force), its representation in a sign or signifier (verbal and diagrammatic accounts of force and motion), and its referent, or the phenomena to which both concept and signifier refer (the movement of objects that interact with each other). For example, a diagram representing forces on interacting objects has material features such as the shape, size and location of arrows, size and simplification of the objects, and indicators of movement arising out of interactions. Understanding ideas by using visual codes and communicating their learning through representational modes is critical for students' learning experience (Gilbert, 2004).

The *symbols* identified for the tasks in this study are (a) arrows or lines (correct direction and connecting the right sources) and (b) symbols for the compounds CO_2, H_2O, O_2, $C_6H_{12}O_6$ (the writing of any of these symbols).

Images. A significant aspect of multimodality is that different modes have different functions with a specific mode partial to a specific aspect of representation or communication (Kress & van Leeuwen, 2006). For instance, the use of both images and text in a schematic representation to describe a process like cell division provides more affordances to the meaning-making process than if either text or image was used alone. Ainsworth, Prain, and Tytler (2011) argued that in the science class, learners are encouraged to focus mainly on interpreting others' visualizations, teacher-produced or textbook. The Role of Representation in Learning Science (RiLS) project (Ainsworth et al., 2011) provides exemplars revealing how, through hands-on activities and a variety of multi-modal representations in which drawing was central, learners aged ten to thirteen were guided to generate, justify, and refine representations in science. Although the interpretation of visualizations and other information is clearly critical to learning, becoming proficient in science also requires learners to develop many representational skills. Unsworth and Chan (2009) outlined the practical ways in which students learning English as a second language in this classroom were taught about image construction and images complementing the meaning-making resources of language in multimodal texts. Van Meter (2001) found that drawing was most helpful in learning from science texts when students were prompted with guidance questions while creating diagrams.

As there is no simple relationship between the interpretation and construction of a representation, a finer-grain size that examines the smaller elements (as signs) of a representation may enable researchers to analyze how the various compositions and configurations thematically give rise to different meanings (as interpretation). Paying explicit attention to the role of integrating words, gestures, shapes and arrows in furthering students' conceptual understanding can amplify ways in which they can express concepts (van Lier & Walqui, 2012).

The *images* used in this study include leaves, roots, stems, sun/sunlight/sunrays, chloroplast, and carbon-dioxide molecule/oxygen molecule/water molecule.

Curriculum-based vocabulary. Science and literacy share highly complementary learning processes and discourse practices (Cervetti, Pearson, Barber, Hiebert, & Bravo, 2007). As language development and conceptual development are inextricably linked (Vygotsky, 1978), an effective science instructional program recognizes and uses instructional strategies in vocabulary where students are taught the technical and specialist vocabulary of science and how to use and spell these words (Wellington & Osborne, 2010). Further, these strategies should connect word meanings to conceptual learning to enable and expand students' knowledge specific to science and build a science vocabulary that is accurate to that knowledge base (Rupley & Slough, 2010).

The best way to help ELLs learn both English and the knowledge of school subjects is to teach language through content (National Council of Teachers of

English, 2006). An insightful study by Cowie, Moreland, and Otrel-Cass (2013) highlighted the *multimodal nature* of the interactions, where both teachers and students used verbal and written resources to enhance meaning-making in ELL classrooms. Varelasand Pappas (2013) demonstrated a different way of engaging ELL students with multimodality by having them create illustrated science books in the units of matter and forests; the books included both writing and drawings, wherein the students had used typical features of science text-relational verbs (has, resembles) and process verbs (changed, grew; Halliday & Martin, 1994; Schleppegrell, 2004). Lee et al. (2008) paid specific attention to language and literacy strategies through the instructional congruence framework to address the needs of ELLs, which included student booklets using "multiple modes of communication and representation (e.g., verbal, gestural, written, and graphic) to enhance students' understanding" (p. 38).

The *curriculum-based vocabulary* identified in this study includes: Oxygen (air): by-product of photosynthesis; carbon-dioxide (air): absorbed by stoma in leaves and used as reactant in photosynthesis; stoma (holes): CO_2 enters and O_2 leaves; chloroplast or chlorophyll (leaves/green pigment) (leaves): traps sunlight; carbohydrate/glucose or starch (sugars, food): product of photosynthesis; carbohydrates stored as food/starch; sunlight (sun): used as energy in photosynthesis; water: absorbed by roots, used as reactant in photosynthesis; xylem: transporting minerals and water; phloem: transporting food or glucose or food.

Science Learning: Understanding of Disciplinary Core Ideas

In the topic of photosynthesis, there are two disciplinary core ideas—(1) *organization of matter and energy flow in organisms.* "Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) with carbon-dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use" (NGSS Lead States, 2013, p. 68). (2) *Energy in chemical processes and everyday life.* "The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (from sunlight) to occur. In this reaction, carbon-dioxide and water combine to form carbon-based organic molecules and release oxygen" (NGSS Lead States, 2013, p. 69).

The ultimate goal is to have a science and language rubric that can be applied to most science units and not target a specific science idea or concept in a unit. To that end, it is important to identify the science content and language objectives of the multimodal tasks. Science content will include the disciplinary core ideas of science as specified by the teacher or NGSS standards, and the language function objectives will include the use of colloquial and disciplinary terminology to express science understanding. The rubric exhibits how the students use symbols, images, and curriculum-based vocabulary or terms to explain and communicate their understanding of the process of photosynthesis.

Method

Data Collected

Multimodal Tasks to Represent Learning. The multimodal tasks used by the students to represent their learning include a) drawing a visual diagram–a schematic using images, symbols and text, and b) creating a comic strip–a narrative using images, symbols and text, thus enabling the students to engage in more than one mode (Alvermann & Wilson, 2011; Jewitt & Kress, 2003; Prain & Waldrip, 2006). In the following multimodal tasks, the students will respond to prompts (administered by the teacher), which will helped them communicate their learning through their multimodal tasks.

The visual drawing tasks A, B and C (writing and drawing) (See Appendix B). The students drew and labeled a schematic representation of the process of photosynthesis using words, symbols and images (Ainsworth, 2006). The visual diagrams had to be completed without any support or help from peers or other sources and were created by the students entirely by themselves in response to a prompt.

The comic strip (reading, writing and drawing) (See Appendix C). The students created a comic story about the process of photosynthesis. An example shown by the teacher was the story of the "Magic School Bus," where the narrator of the story travels inside the plant to explain the process of photosynthesis. In this task, the students had to write a narrative explaining the process of photosynthesis by drawing pictures to illustrate the process and explain each step of the process. The comic strip was created over a week with support through peer and teacher discussions and use of resources from books, the web and the science textbook.

For this study, I collected and included the visual diagrams and comic strips created by the students. Three visual diagrams and one comic strip were collected from each student. The first two visual diagrams, A and B, were completed and collected at the beginning and toward the end of the unit. The comic strip was completed and collected at the end of the unit, and Visual Diagram C was completed and collected 4 weeks after the unit.

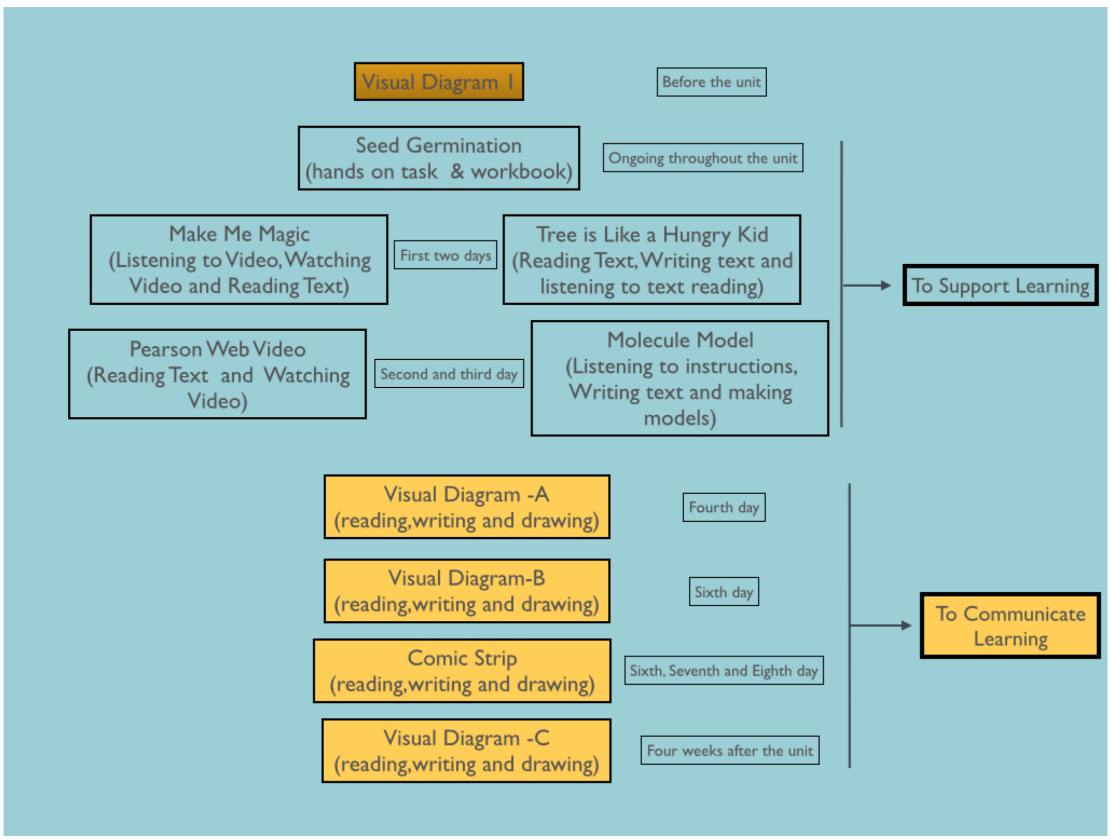


Figure 1. Schematic of Time Frame of Representational Tasks

Setting and Participants in This Study

This study was conducted in a school located in an urban district in Northern California. The school district has 49.9% ELLs and 33% fluent English proficient and 19.5% students redesignated. The school district has 83% of students on free and reduced lunch, 62% are Hispanic and 30% are Asian. In the school used in this study, Garden Brooks School (pseudonym), 40.7% of the students are Hispanic, 49.1% are Vietnamese and are 58.5% are on free and reduced lunch; 41.4% are ELLs and 55.86% of the ELLs speak Vietnamese; 35.55% of the ELLs speak Spanish.

In the two sixth grade classrooms combined, there are 63 students, with 32 males and 31 females. Thirty-six students are on free and reduced lunch, 24 students speak Vietnamese, 17 speak Spanish, two speak Mandarin and two Cantonese, seven speak other languages like Urdu, Somali, and Cambodian, and 13 declared English as their primary language.

Table 4
Demographic Data

Teacher	Male/Female	Vietnamese	Spanish	Chinese	Others	English
Total	32/31	24	17	4	5	13

Data Analysis

As the study has design-based research components, I approached my research with an outcome-oriented perspective that accepts the validity of both experimental and interpretive methods, suggesting that the researcher "choose the combination or mixture of methods and procedures that works best for answering your research questions" (Johnson & Onwuegbuzie, 2004). A sociocultural perspective on learning emphasizes the role of interactions and participation; hence, in a classroom setting the role of the teachers and students is crucial, as are the ways and means they use to mediate the learning processes. While my theoretical orientation is within a sociocultural perspective, I see the value of having a pragmatic approach for both data collection and analysis. A pragmatic approach can provide insight into how research approaches can be mixed, such that it offers the best opportunities for answering important research questions. The result is a mixed-methods design (Creswell, 2013), where qualitative and quantitative data collection occurs concurrently to address my research goals. For this paper, I have focused on the analysis of the quantitative data, which I collected based on scoring the visual diagrams and comic strips using the science and language learning rubric.

Method of Analysis

Prior research has shown that formative assessment improves learning. Since I approached this study with same hypothesis, it is important to examine whether the multimodal tasks created by the students demonstrate that they have learned the process of photosynthesis. The relationship between the formative and summative functions of an assessment task can be considered as a continuum; at the formative end, assessment tasks are evaluated by the extent to which they provide the foundation for creating shared meanings amongst the students, while at the summative end the shared meanings are important for creating consistency of interpretations (Cizek, 2010). Significant tensions often arise when the same assessments are required to serve both formative and summative functions.

However, in this study the purpose of each multimodal task was clearly delineated. For this paper, I created a science and -language rubric with the purpose of assessing whether the multimodal tasks (visual diagrams and comic strips) can demonstrate learning through the different constructs often seen in multimodal tasks. The representational tasks were designed to link to specific learning outcomes/objectives of the unit (photosynthesis), determined by the teachers and researcher, and the criteria for the tasks were made explicit to the students. Therefore, I used the rubric created for this study to examine the student learning of photosynthesis. It is also important to note that only I (researcher) used the science and language learning rubric to analyze the visual diagrams and comic strips for this paper. The analysis was done in two phases:

Phase 1 consisted of

- scoring all the Visual Diagrams A, B, and C and the comic strips in all the constructs using the science and language learning rubric independently by me and two science education researchers as raters; and
- establishing the reliability and validity of the rubric.

Phase 2 consisted of

- identifying the mean scores in all constructs in the Visual Diagrams A, B, and C and the comic strips;
- identifying the gains between all the constructs between Visual Diagram A and Visual Diagram B (to see the effects of the feedback); and

- identifying the mean scores within different student groups (as defined by English Leaner status, proficiency in English Language Arts, Science and Vocabulary Acquisition and Usage.

Phase 1: Establishing Reliability and Validity of the Science and Language Rubric (See Appendix A)

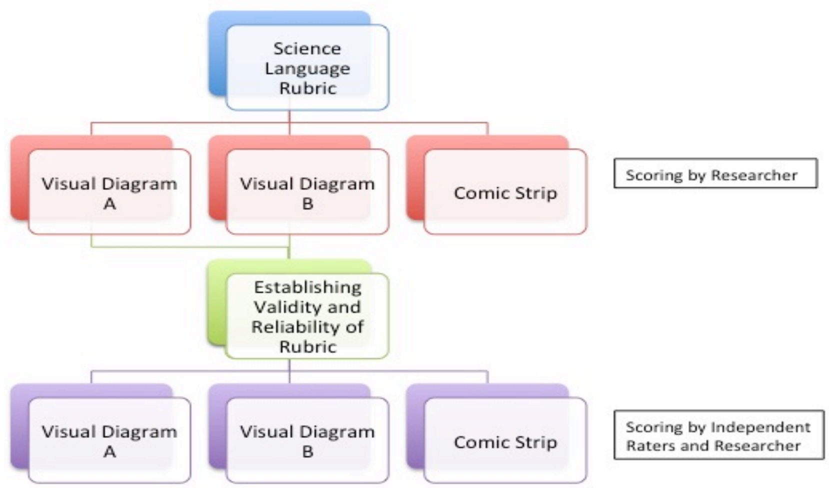


Figure 2. Schematic flow chart showing how the reliability and validity of the science and language learning rubric was established.

Scoring of the Rubric (See Appendix A)

Each construct on the rubric, namely, Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, and Understanding of Disciplinary Core ideas has a minimum score of 1 (Novice) to a maximum of 5 (Advanced). The construct of Productive Language Function was calculated by adding the average scores of all the constructs of Use of Symbols, Use of Images, and Use of Curriculum-based Vocabulary. The construct of composite Science and Language Learning was calculated by adding the average scores of the Productive Language Function and Understanding of Core ideas.

Inter-rater and intra-rater reliability. *Reliability* is the extent to which a rubric yields consistent results when used repeatedly under the same conditions. The reliability of the rubric was assessed through inter-rater and intra-rater reliability scores. When two different raters use the rubric on the same performance, and they give similar scores, this is called inter-rater reliability. The rubric should also yield consistent results if one rater uses the same rubric to judge the same task at different times. This is called intra-rater reliability. The more consistent the scores are over different raters and occasions, the more reliable the assessment instrument is thought to be (Moskal & Leydens, 2000).

Table 5
Inter-Rater Reliability of Constructs of Rubric

Category	Symbols	Images	Vocabulary	Disciplinary core ideas
Comic Strip	.45	.42	.47	.43
Visual Diagram A	.74	.31	.41	.38
Visual Diagram B	.64	.61	.71	.65
Visual Diagram C	.90	.77	.83	.77

Table 6
Intra-Rater Reliability of Constructs of Rubric

	Symbols	Images	Vocabulary	Disciplinary core ideas
Visual Diagram A	.55	.94	.83	.83
Visual Diagram B	.70	.74	.67	.89

I was the expert scorer and scored Visual Diagrams A, B, and C and the comic strip using the science and language learning rubric. Two independent science education researchers scored about one third of Visual Diagrams A, B, and C and the comic strip using the science and language learning rubric. Inter-rater agreement was calculated and those visual diagrams and comic strips where the kappa scores were not significant were identified. Another round of scoring took place and those specific tasks were scored again. Inter-rater agreement was calculated again till all the tasks had a significant kappa scores. Since I was the expert scorer, my scores were used to reach a single consensus score. Prior to determining consensus scores, inter-rater agreement using Cohen's kappa ranged from .42 (Use of Images in Comic Strip) to .90 (Use of Symbols in Visual Diagram C). Landis and Koch (1977) suggest the following guidelines for interpreting the kappa coefficient: 0 = poor, .01–.20 = slight, .21–.40 = fair, .41–.60 = moderate, .61–.80 = substantial, and .81–1 = almost perfect (see Table 7). Inter-rater agreement for all the constructs in Visual Diagrams A, B, and C and the comic strip ranges from moderate to almost perfect agreements.

Internal consistency reliability. Internal consistency reliability is an estimate based on how highly parts of a rubric correlate with each other. Coefficient alpha is an internal consistency reliability estimate based on correlations among all items on a test. Cronbach's alpha is not a statistical test; it is a coefficient of reliability or consistency and a measure of scale reliability. Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group. The following guidelines for interpreting alpha coefficients are: below .5 = unacceptable,

.5–.6 = poor, .6–.7 = questionable, .7–.8 = acceptable, .8–.9 = good, above .9 = excellent (George & Mallery, 2003).

The science language rubric consisted of four items, namely, Symbols, Images, Curriculum-based Vocabulary and Disciplinary Core Ideas. Cronbach's alpha for the four items was .86. The constructs of the rubric were found to be highly reliable. The following table shows how, even if one item is deleted, the internal consistency (Cronbach's alpha) remains high with a value of α = .88–.89.

Table 7
Internal Consistency Cronbach's Alpha of Rubric Constructs

	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's αif item deleted
Symb_VDR_A	27.176	65.868	.767	.885
Img_VDR_A	26.784	69.373	.811	.893
Vocab_VDR_A	27.020	66.100	.853	.882
CI_VDR_A	26.961	65.518	.865	.880

Validity of the rubric. *Validity* of the rubric measures whether the rubric measures what we want it to measure. Validity is seen as a property of the test, or as test score interpretations (Borsboom, Mellenbergh, & van Heerden, 2004). The first perspective is most widely used in natural sciences and psychological testing; instead, validity in educational research is often seen to involve evaluative judgment, and is therefore not seen as a property of the test as such, but rather as an interpretation of the results (Borsboom et al., 2004; McMillan, 2007; Messick, 1998).

The rubric designed in this study was used to assess how the students responded to the prompts to create the multimodal tasks (visual diagrams and comic strips) for science content and language content. The science content and language rubric I designed was aligned to the science content and the language learning objectives determined by the teachers, the NGSS standards and ELDP standards (Brookhart, 2013; NGSS Lead States, 2013; Pimental et al., 2012).

Construct validity. To establish construct validity, I measured whether the rubric measures the constructs I aimed to measure. For this purpose, to say that a rubric exhibits validity means that it measures the underlying variable of interest. In this case, the variable of interest is science and language learning determined by four main constructs: symbols, images, curriculum based vocabulary and disciplinary ideas. One way to demonstrate validity is to provide evidence that different measures of the same variable are correlated with one another, or convergent validity (Crocker & Algina, 1986). Convergent validity refers to the degree to which two measures of constructs that theoretically should be related are in fact related. In this study, I assessed convergent validity by comparing measures of science and language learning obtained with the rubric to judgments of science and language learning made by an independent evaluator. In this study, two science teachers who have taught and graded the student-created visual diagrams, but who did not use the rubric, provided evaluations.

A *Pearson product-moment correlation coefficient* was computed to assess the relationship between the cumulative scores on the visual drawing task based on the rubric I created and the teachers' scores on the same tasks based on an independent rubric, which they created for their interim assessment purposes. The scores they assigned to the students' tasks were used to categorize the students to provide adequate feedback. There was a *strong positive correlation* between the researcher's composite rubric scores and teachers' scores, $r = 0.86$, $n = 53$, $p = 0.0001$, showing *converging validity.*

Content validity. To establish content validity, I checked to see whether the rubric tested the knowledge and skills of the larger domain of biology and to see whether a content expert would agree with the criteria chosen in the rubric. I asked science education experts, my advisors, who are experts in science and language, as they have worked in the field of science education with ELLs. I also consulted with a scientist (a PhD biology graduate who is doing research in ecology and informal science learning) to align the criteria of the rubric with what scientists do and learn.

Face validity. To establish face validity, I checked to see if the rubric appeared to be valid to its users. The rubric was created with the idea of having a tool for teachers to assess multimodal tasks for science and language learning. Before scoring the tasks using the rubrics, I consulted the two participating teachers to align the science and language learning criteria of the rubric with what was expected of the students who created the visual diagrams and comic strips.

Phase 2 Analysis

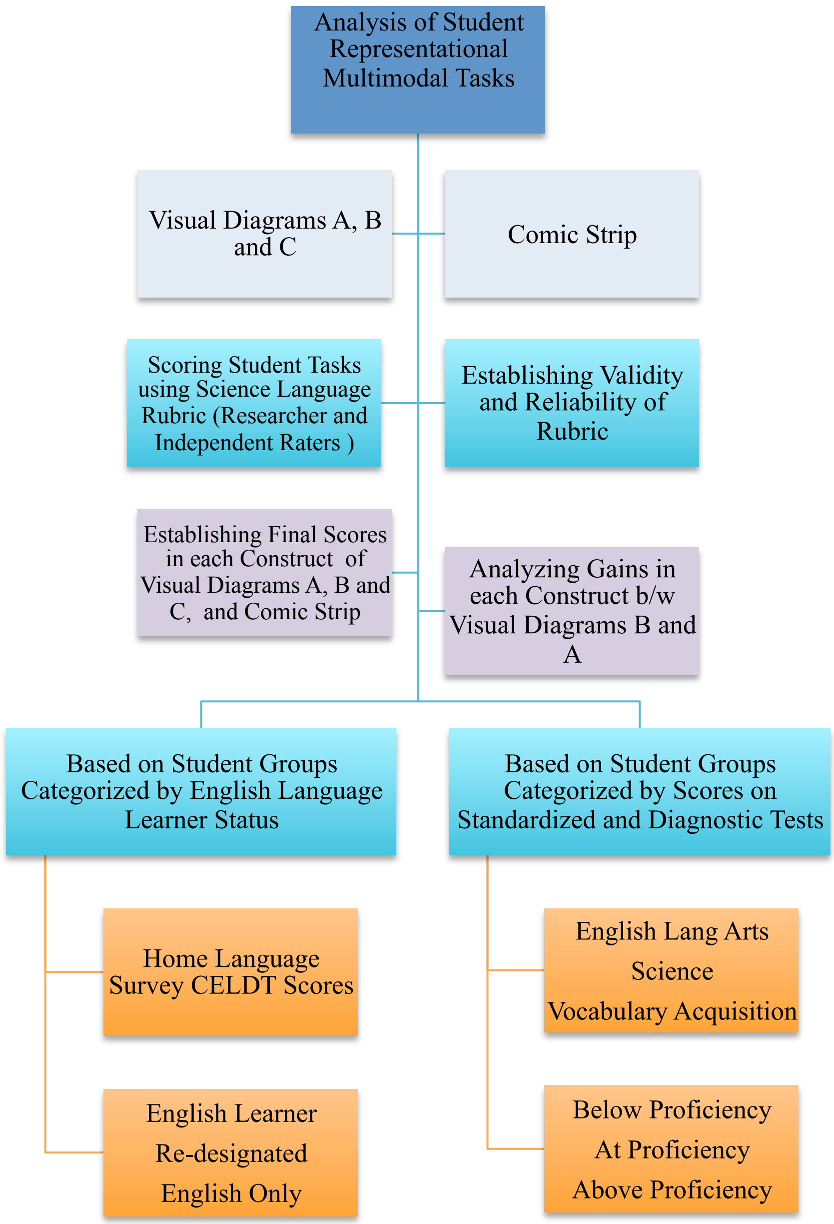


Figure 3. Model of analysis of the visual diagrams and comic strips using the science and language learning rubric based on ELL status and proficiencies in English Language Arts and Science and Vocabulary Acquisition and Use.

In order to gain better insight on how the students of these two sixth grade classrooms demonstrated their learning, it was essential to understand how not only their English Learner status but also their varying proficiencies in English Language Arts, Science and Vocabulary Acquisition and Usage contributed their ability to demonstrate their understanding of photosynthesis through the comic strips. Further the teachers grouped their students in their classrooms based on their proficiencies in the standardized tests in English Language Arts and Science, and diagnostic tests in Language Arts Vocabulary Acquisition and Usage, so as to identify those who needed extra assistance or support in the class. So, it was also prudent to explore how their proficiencies in these subjects and English Learner status influenced their performance in the visual diagrams and comic strips.

RQ 1: To What Extent Do the Visual Diagrams Demonstrate the Science Learning of Linguistically Diverse Students Using the Science and Language Learning Rubric?

Data collected. For this analysis, the visual diagrams created at the beginning of the unit (Visual Diagram A) and at the end of the unit (Visual Diagram B) were collected from all students. The science and language rubric was used to score each visual diagram on each construct, namely, Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary and Undersyanding of Disciplinary Core Ideas. A productive language function construct was created by calculating the average mean scores on the total of symbol, image and curriculum-based vocabulary. Similarly, a total composite in science and language learning construct was created calculating a mean score on the total of the constructs of productive language function and the disciplinary core ideas. As explained earlier, the students were divided into four categories based on their English Language Learner status and proficiency levels on state-based standardized tests in English Language Arts, Science and Vocabulary Acquisition and Usage. All the students' visual diagrams were scored, but only those that had a complete set of either visual diagram A and visual diagram B (n= 51) were analyzed.

Visual Diagrams A and B. The teachers used the Visual Diagram A to assess the students' understanding of photosynthesis and to provide feedback. The scores of each Visual Diagram A were calculated. Visual Diagram B was used for a class grade and to assess if there was a progression in the understanding of photosynthesis compared to Visual Diagram B. I evaluated to see if the mean gain scores between Visual Diagrams B and A in each construct were affected by the respective scores in each construct in the first visual diagram (Visual Diagram A). This was to determine if the mean gain scores between Visual Diagrams B and A were significant for each construct and each category.

Data analysis.

Gains between Visual Diagrams A and B in total sample. For this analysis, the gains between Visual Diagrams B and A were calculated. This analysis was done to gain insight on the use of feedback by the students to improve their understanding of photosynthesis and represent it in the form of a visual diagram. So, the purpose of this analysis was to explore gains of learning following feedback (Visual Diagram B – Visual Diagram A)

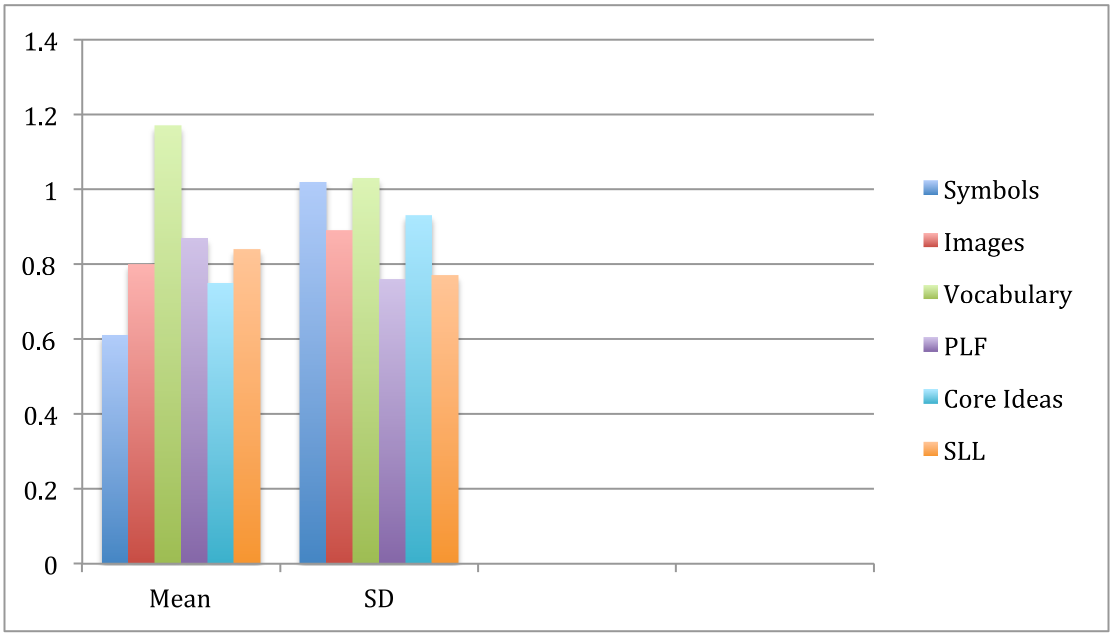


Figure 4. Gains in mean scores between Visual Diagrams B and A in the total sample (*N* = 51).

Total sample. In the following table, it can be seen that the highest gains were in the construct of the use of curriculum-based vocabulary (M = 1.18, SD = 1.03) and the lowest gain was in the construct of the use of symbols (M =.61, SD = 1.02). The effect size was highest in the use of curriculum-based vocabulary and the lowest for the use of symbols. This shows that following feedback, the students had a gain in all constructs, and the feedback was particularly helpful in the students' increased usage of curriculum-based vocabulary.

Table 8
Gains in Mean Scores Between Visual Diagrams B and A in the Total Sample

Gains b/w	Gains in Use of	Gains in Use	Gains in Use of	Gains in Prod	Gains in Disciplinary	Gains in Science

Visual Diagram B and Visual Diagram A	Symbols *M (SD)*	of Images *M (SD)*	Curriculum-based Vocab *M (SD)*	Lang Function *M (SD)*	Core Ideas *M (SD)*	Language Learning *M (SD)*
Total (*N* = 51)	0.61 (1.02)	0.80 (0.89)	1.18 (1.03)	0.87 (0.76)	0.75 (0.93)	0.84 (0.77)
Effect size	0.28	0.45	0.53	0.37	0.48	0.47
Cohen's	0.58	1.00	1.24	0.79	1.09	1.06

Cohen (1988) defined effect sizes as "small, d =.2," "medium, d =.5," and "large, d =.8," stating that "there is a certain risk inherent in offering conventional operational definitions for those terms for use in power analysis in as diverse a field of inquiry as behavioral science" (p. 25). With that said, the effect size was small for the gains in the use of symbols and images, medium for the gains in the use of vocabulary, and large for the gains in understanding of core ideas, productive language function, and science and language learning.

Analysis by each student category.

Table 9
Significant Differences in Gains in Mean Scores Between Visual Diagrams B and A by ELL Status

Construct	ELL (1) (*N* = 15)	Redesignated (2)(*N* = 16)	English only (3) (*N* = 19)	*F*	*p*	Tukey's
Disciplinary Core Ideas	1.1 (0.70)	0.87 (1.1)	0.32 (0.82)	3.61	.03	1 > 3

Gains between Visual Diagrams A and B by English learner status. A one-way between-subjects ANOVA was conducted to compare the effect of *English Learner Status* on the mean scores of the Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, Productive Language Function, Understanding of Disciplinary Core Ideas and Cumulative Science Language Score in the gains between Visual Diagrams B and A in those students who were English Learners, Redesignated two years ago, and English Only statuses. There was a significant effect of the English Learner status for the three conditions at the $p < .05$ level for the Understanding of Disciplinary Core Ideas [$F(2, 44) = 3.61$, $p = 0.03$].

Post hoc comparisons using the Tukey HSD test indicated that the mean score gain is significantly higher in the *English Learner Status* for the Understanding of Disciplinary Core Ideas ($M = 1.06$, $SD = .70$) than the *English Only* group ($M = .32$, $SD = .82$).

To determine if the mean scores in Understanding of Disciplinary Core Ideas in Visual Diagram A did not influence the gain in Understanding of Disciplinary Core Ideas, the Understanding of Disciplinary Core Ideas in Visual Diagram A was identified as a covariate. Then the interaction between the mean scores in Understanding of Disciplinary Core Ideas in Visual Diagram A (covariate) and the English Learner Status (independent variable) was evaluated in the prediction of the gain in scores in Understanding of Disciplinary Core Ideas (dependent variable). A significant interaction between the covariate and the factor suggests that the differences on the dependent variable among groups vary as a function of the covariate. My results suggest the interaction is not significant $F(2,41) = .96$, $p = .39$, suggesting that the differences in the gain in scores in Understanding of Disciplinary Core Ideas is not a function of the covariate Understanding of Disciplinary Core Ideas in Visual Diagram A.

This indicates that the English Learners had significant gains in their understanding of core ideas following feedback, compared to the redesignated and English Only groups, which were not influenced by the mean scores in Visual Diagram A.

Gains between Visual Diagrams A and B by English Language Arts Proficiency. A one-way between-subjects analysis of variance (ANOVA) was conducted to compare the effect of *English Language Arts Proficiency* on the mean scores of the Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, Productive Language Function, Understanding of Disciplinary Core Ideas and Cumulative Science Language Score in the gains between Visual Diagrams B and A in those students who were Below Proficiency, At Proficiency and Above Proficiency. There was a significant effect of the proficiency in English Language Arts for the three conditions at the $p < .05$ level for the Use of Symbols [$F(2, 48) = 3.14$, $p = 0.05$], Use of Images [$F(2, 48) = 4.22$, $p = 0.02$], Understanding of Disciplinary Core Ideas [$F(2, 48) = 61.8$, $p = 0.04$], Productive Language Function [$F(2, 48) = 5.62$, $p = 0.007$], and Cumulative Science Language Learning [$F(2, 48) = 6.39$, $p = 0.004$].

Table 10
Significant Differences in Gains in Mean Scores and Standard Deviations Between

Visual Diagrams B and A by ELA Proficiency

Construct	Below proficient (1) (*N* = 11)	At Proficient (2) (*N* = 29)	Above Proficient (3) (*N* = 7)	*F*	*p*	Tukey's
Symbols	0.55 (1.21)	0.83 (0.76)	−0.14 (1.06)	3.14	.05	2 > 3
Images	1.09 (0.70)	0.72 (0.79)	0.00 (0.82)	4.22	.02	1 > 3
Productive Language Function	1.00 (0.65)	0.94 (0.66)	0.05 (0.71)	5.62	.007	1 > 3 2 > 3
Disciplinary Core Ideas	1.09 (0.70)	0.79 (0.90)	−0.28 (0.76)	6.18	.004	1 > 3 2 > 3
Science Language Learning	1.02 (0.64)	0.91 (0.68)	−0.3 (0.69)	6.39	.004	1 > 3 2 > 3

Post hoc comparisons using the Tukey HSD test indicated that the mean gain score is significantly higher in the *Below proficiency group* for the Use of Images (M = 1.098, SD = .70), the Understanding of Disciplinary Core Ideas (M = 1.09, SD = .7), the Productive Language Function (M = 1.00, SD = .65), and Cumulative Science Language Score (M = 1.02, SD = .64) than the *Above proficiency group*. Post hoc comparisons using the Tukey HSD test also indicated that the mean score for the *At Proficiency group,* the Understanding of Disciplinary Core Ideas (M = 1.63, SD =.92), Productive Language Function (M= .94, SD= .66) and Cumulative Science-Language Function (M= .91, SD= .68) *was significantly higher than the Above Proficiency group*. Post hoc comparisons using the Tukey HSD test also indicated that the mean score was significantly higher in the *At Proficiency group* for the Use of Symbols (M = .83, SD = .76), Productive Language Function (M = .94, SD = .66), Understanding of Disciplinary Core Ideas (M = .79, SD = .90) and Cumulative Science and Language Learning (M = .91, SD = .68) than the *Above proficiency* group.

To determine if the mean scores in Use of Images and Understanding of Disciplinary Core Ideas in Visual Diagram A did not influence the gain in Use of Images and Understanding of Disciplinary Core Ideas, respectively, the Use of Images and the Understanding of Disciplinary Core Ideas in Visual Diagram A were identified as covariates. Then, the interaction between the mean scores in Use of Images and Understanding of Disciplinary Core Ideas in Visual Diagram A (covariates) and the English Language Arts Proficiency (independent variable) was evaluated in the prediction of the gain in scores in Use of Images and Understanding of Disciplinary Core Ideas (dependent variables). A significant interaction between the covariate and the factor suggests that the differences in the dependent variable among groups vary as a function of the covariates. Results show the interaction is not significant—$F(2, 41) = .42$, $p = .66$—suggesting that the differences in the gain in scores in Use of Images is not a function of the covariate Use of Images in Visual Diagram A. My results suggest the interaction is not significant—$F(2, 41) = 1.98$, $p = .15$—suggesting that the differences in the gain in scores in Understanding of Disciplinary Core ideas is not a function of the covariate Understanding of Disciplinary Core Ideas in Visual Diagram A.

This indicates that proficiency in English Language Arts had a significant effect on how the students used the visual diagrams to represent their understanding of the process of photosynthesis following feedback. The students who were in the Below proficiency group had an increase in their Use of Images and Understanding of Disciplinary Core Ideas and subsequently an increase in Productive Language Function and Science and Language Learning, following feedback. Students in the At proficiency group had an increase in the Use of Symbols and Understanding of Disciplinary Core Ideas and subsequently an increase in Productive Language Function and Science and Language Learning, following feedback. Interestingly, the students in the Above proficiency group had a loss in the gain scores in the Use of Symbols and Science and Language Learning.

Gains between Visual Diagrams A and B by science proficiency. A one-way between-subjects ANOVA was conducted to compare the effect of *Science Proficiency* on the mean scores of the Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, Productive Language Function, Understanding of Disciplinary Core Ideas and Cumulative Science Language Score in the gains between Visual Diagrams B and A in those students who were Below proficiency, At proficiency and Above proficiency. There was a significant effect of the proficiency in English Language Arts for the three conditions at the $p < .05$ level for the Use of Curriculum-based Vocabulary [$F(2, 41) = 4.81$, $p = 0.01$], Understanding of Disciplinary Core Ideas [$F(2, 41) = 4.39$, $p = 0.02$], Productive Language Function [$F(2, 41) = 4.79$, $p = 0.01$], and Cumulative Science Language Learning [$F(2, 41) = 5.17$, $p = 0.01$].

Table 11
Significant Differences in Gains in Mean Scores and Standard Deviations Between

Visual Diagrams B and A by Science Proficiency

Construct	Below Proficient (1) (*N* = 10)	At Proficient (2) (*N* = 26)	Above Proficient (3) (*N* = 8)	*F*	*p*	Tukey's
Curriculum Vocab	1.50 (0.85)	1.31 (1.05)	0.25(0.46)	4.82	.01	1,2 > 3
Productive Language Function	0.93 (0.44)	0.96 (0.73)	0.17 (0.56)	4.79	.01	1,2 > 3
Disciplinary Core Ideas	1.00 (0.67)	0.81 (0.98)	−0.13 (0.64)	4.40	.02	1,2 > 3
Science Language Learning	0.95 (0.46)	0.92 (0.75)	0.09 (0.57)	5.17	.01	1,2 > 3

Post hoc comparisons using the Tukey HSD test indicated that the mean gain score is significantly higher in the *Below proficiency* group for the Use of Curriculum-based Vocabulary (M = 1.50, SD = 1.31), the Understanding of Disciplinary Core Ideas (M = 1.00, SD = .67), the Productive Language Function (M = .93, SD = .44), and Cumulative Science Language Score (M = .95, SD = .46) than the *Above proficiency* group. Post hoc comparisons using the Tukey HSD test also indicated that the mean gain score for the *At proficiency* group for the Understanding of Disciplinary Core Ideas (M = .81, SD =.98), Productive Language Function (M= .96, SD= .73) and Cumulative Science-Language Learning (M= .92, SD= .75) *was significantly higher than the Above proficiency group*.

The interaction between the mean scores in Use of Curriculum-based Vocabulary and Understanding of Disciplinary Core Ideas in Visual Diagram A (covariates) and the Science Proficiency (independent variable) was evaluated in the prediction of the gain in scores in Use of Curriculum-based Vocabulary and Understanding of Disciplinary Core Ideas (dependent variables). Results suggest the interaction is not significant—$F(2, 38) = 2.74$, $p = .08$—suggesting that the differences in the gain in scores in Use of Curriculum-based Vocabulary is not a function of the covariate-Use of Curriculum based Vocabulary in Visual Diagram A. My results suggest the interaction is not significant—$F(2, 38) = 1.62$, $p = .21$—suggesting that the differences in the gain in scores in Understanding of Disciplinary Core ideas is not a function of the covariate Understanding of Disciplinary Core Ideas in Visual Diagram A.

This indicates that proficiency in science had a significant effect on how the students used the visual diagrams to represent their understanding of the process of photosynthesis following feedback. The students who were in the *Below proficiency* group and *At proficiency* group had an increase in their Use of Curriculum-based Vocabulary and Understanding of Disciplinary Core Ideas and subsequently an increase in Productive Language Function and Science and Language Learning, following feedback.

Gains between Visual Diagrams A and B by vocabulary acquisition and usage proficiency. A one-way between subjects ANOVA was conducted to compare the effect of *Vocabulary Acquisition and Usage Proficiency* on the mean scores of the Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, Productive Language Function, Understanding of Disciplinary Core Ideas, and Cumulative

Science Language Score in the gains between Visual Diagrams B and A in those students who were Below proficiency, At proficiency and Above proficiency. There was a significant effect of the proficiency in Vocabulary Acquisition and Usage Proficiency for the three conditions at the $p < .05$ level for the Use of Symbols [$F(2, 43) = 5.02$, $p = 0.01$] and Use of Images [$F(2, 43) = 3.09$, $p = 0.05$].

Table 12
Significant Differences in Gains in Mean Scores Between Visual Diagrams B and A by Vocabulary Acquisition and Usage Proficiency

Construct	Below proficient (1) (*N* = 9)	At proficient (2) (*N* = 18)	Above proficient (3) (*N* = 17)	*F*	*p*	Tukey's
Symbols	0.22 (0.97)	1.06 (0.80)	0.23 (0.83)	5.02	.01	2 > 3
Images	1.22 (0.44)	0.67 (0.97)	0.41 (0.71)	3.09	.05	1 > 3

Post hoc comparisons using the Tukey HSD test indicated that the mean gain score was significantly higher in the *At proficiency* group for the Use of Symbols (M = .22, SD = .97), and significantly higher in the *Below proficiency* group for the Use of Images (M = 1.06, SD = .80) than the *Above proficiency* group.

The interaction between the mean scores in Use of Symbols and Images in Visual Diagram A (covariates) and the Science Proficiency (independent variable) was evaluated in the prediction of the gain in scores in Use of Symbols and Images (dependent variables). Results suggest the interaction was not significant—$F(2, 38) = .34$, $p = .71$—suggesting that the differences in the gain in scores in Use of Symbols is not a function of the covariate Use of Symbols in Visual Diagram A. My results suggest the interaction is not significant—$F(2, 38) = .32$, $p = .73$—suggesting that the differences on the gain in scores in Use of Images is not a function of the covariate Use of Images in Visual Diagram A.

Summary of results for gains between Visual Diagrams A and B. This analysis was done to provide insight on the gains in learning of the understanding of the process of photosynthesis, following feedback by the teachers in the form of the gains mean scores of the constructs between the first Visual Diagram A and second Visual Diagram B. The gains in each construct were identified and the effects of English Language Learner status and Proficiencies in English Language Arts and Science and Vocabulary Acquisition and Usage on the gains of each construct were analyzed.

English Learner Status. *English Learner Status* influenced how the students used the visual diagrams to demonstrate their understanding of photosynthesis. Even though English Learners had the highest mean gain scores in all constructs, their gain in Understanding of Disciplinary Core disciplinary ideas ($M = 1.06$, $SD = .70$) was most significant, where they showed an increase in understanding of core disciplinary ideas compared to the English Only group in their visual diagrams.

Proficiencies in English Language Arts and Science and Vocabulary Acquisition and Usage. Those students designated as *Below Proficient in English Language Arts* demonstrated an increase in the Use of Images and Use of Curriculum-based Vocabulary in their visual diagrams, thus showing an increase in their Productive Language Function and Cumulative Science-Language Learning, following feedback. Those students designated as *At Proficiency in English Language Arts* demonstrated an increase in the Use of Symbols and Use of Curriculum-based Vocabulary in their visual diagrams, thus showing an increase in their Productive Language Function and Cumulative Science-Language Learning, following feedback. Those students designated as *Below Proficiency in Science* and *At Proficiency in Science* demonstrated an increase in Use of Curriculum-based Vocabulary in their visual diagrams, and Understanding of Disciplinary Core Ideas, thus showing an increase in their Productive Language Function and Cumulative Science-Language Learning. Those students who were *Below Proficient in Vocabulary Acquisition and Use* showed an increase in the Use of Images and an increase in Understanding of Disciplinary Core Ideas compared to the Above proficiency group.

RQ 2: How Do the Comic Strips Demonstrate the Science Learning of Linguistically Diverse Students Using the Science and Language Learning Rubric?

Data collected. Comic strips of all students: The comic strip was a representational task collected toward the end of the unit. This was used primarily by the teachers for the purpose of a grade and to engage the students in an activity that would *integrate the skills of storytelling of language arts and representing knowledge of photosynthesis*.

Data analysis.

Comic strip. The comic strip was a representational task used primarily by the teachers for the purpose of a grade and to engage the students in an activity that would integrate the skills of storytelling of language arts and science.

Total sample. Each comic strip was analyzed using the science and language rubric to get a score on each construct of the rubric, where the score for each construct ranged from 0 – 5. The purpose of this analysis was to explore evidence of consolidation of learning about the process of photosynthesis from different contexts, including the other multimodal tasks used in the unit and the ability to integrate science and language learning.

Table 13

Mean Scores in Comic Strip in Total Sample

Comic Strip (*N* = 47)	Use of Symbols *M (SD)*	Use of Images *M (SD)*	Use of Curriculum based Vocab *M (SD)*	Productive Language Function *M (SD)*	Disciplinary Core Ideas *M (SD)*	Science Language Learning *M (SD)*
Total	2.79 (1.18)	3.89 (0.76)	3.79 (0.81)	3.49 (0.81)	3.52 (0.78)	3.49 (0.77)

For the comic strip, in the total sample, the students' mean scores of the Use of Images (M= 3.89, SD = .76) was the highest, and the mean score for the Use of Symbols (M= 2.79, SD = 1.18) was the lowest to represent their understanding of photosynthesis (see Table 4.12).

Analysis by Each Student Category

English Learner Status.

Table 14
Mean Scores in Comic Strip in Total Sample and by Each Student Category

Construct (*N* = 47)	Use of Symbols *M (SD)*	Use of Images *M (SD)*	Use of Curriculum based Vocab *M (SD)*	Prod Lang Function *M (SD)*	Disciplinary Core Ideas *M (SD)*	Science Language Learning *M (SD)*
ELL status (47)	2.79 (1.18)	3.89 (0.76)	3.78 (0.81)	3.49 (0.80)	3.52 (0.78)	3.49 (0.77)

The students classified as *redesignated* had the highest scores in all constructs, Use of Symbols (M =3.85, SD = 1.28), Use of Images (M = 4.39, SD = .77), Use of Vocabulary (M = 4.31, SD = .85), Productive Language Function (M = 4.15, SD = .80), Disciplinary Core Ideas (M = 4.15, SD = .80) and Cumulative Science and Language Score (M = 4.17, SD = .82). The *ELL* group had the lowest scores in the construct of Use of Symbols (M = 2.35, SD = .93), Use of Images (M = 3.64, SD = .63), Curriculum-based Vocabulary (M = 3.36, SD = .74), and Disciplinary Core Ideas (M = 3.14, SD = .66). They had the lowest score in Productive Language Function (M = 3.12, SD = .66) and Science-Language Learning (M = 2.98, SD =.35). The *English Only* group showed the second highest scores on the Use of Symbols (M =2.40, SD = .28), Use of Images (M = 3.75, SD = .72), Curriculum-based Vocabulary (M = 3.75, SD = .64), Disciplinary Core Ideas (M = 3.35, SD = .59), Productive Language Function (M = 3.30, SD = .52), and Cumulative Science and Language Score (M = 4.17, SD = .82).

A one-way between-subjects ANOVA was conducted to compare the effect of English Learner status on the scores of the Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, Productive Language Function, Understanding of Disciplinary Core Ideas and Cumulative Science Language Score, in the comic strips in those students who were English Learners, Redesignated two years ago, and English Only status. There was a significant effect of *English Learner* status on at the $p < .05$ level for the three groups for the Use of Symbols [$F(2, 46) = 10.51$, $p = .000$], Use of Images [$F(2, 47) = 4.42$, $p = .02$], Curriculum-based Vocabulary [$F(2, 46) = 5.69$, $p = .006$], Disciplinary Core Ideas [$F(2, 46) = 8.59$, $p = .001$], Productive Language Function [$F(2, 46) = 9.39$, $p = .000$], and Science-Language Learning [$F(2, 46) = 14.92$, $p = .000$].

Table 15
Significant Mean Scores in Comic Strip by ELL Status

Construct	English Learner 1 (*N* = 14) *M (SD)*	Re-Designated2 (*N* = 13) *M (SD)*	English Only 3 (*N* = 20) M (SD)	*F* (2, 44)	*p*	Tukey's
Symbols	2.35 (0.93)	3.85 (1.28)	2.40 (0.28)	10.15	.00	2 > 1,3
Images	3.64 (0.63)	4.39 (0.77)	3.75 (0.72)	4.42	.02	2 > 1,3
Curriculum Vocab	3.36 (0.74)	4.31 (0.85)	3.75 (0.64)	5.69	.006	2 > 1
Productive Language Function	3.12 (0.66)	4.18 (0.88)	3.30 (0.52)	9.39	.000	2 > 1,3
Disciplinary Core Ideas	3.14 (0.66)	4.15 (0.80)	3.35 (0.59)	8.59	.001	2 > 1,3

Science Language Learning	2.98 (0.35)	4.17 0.82	3.30 (0.52)	10.38	.000	2 > 1,3

Post hoc comparisons using the Tukey HSD test indicated that the score for the Use of Symbols was significantly different for the *redesignated* group (M = 3.85, SD = 1.28) from the English *Learner* group (M = 2.36, SD = .93) and the English Only group (M = 2.40, SD = .82). Post hoc comparisons using the Tukey HSD test indicated that the score for the Use of Images was significantly different for the redesignated group (M = 4.39, SD = .77) from the English Learner group (M = 3.64, SD = .63) and English Only group (M = 3.79, SD = .72). Similarly, the score for the Curriculum-based Vocabulary was significantly different for the redesignated group (M = 4.31, SD = .85) than the English Learner group (M = 3.36, SD = .74). Post hoc comparisons using the Tukey HSD test also indicated that the score for the Productive Language Function was significantly different for the redesignated group (M = 4.18, SD = .88) than the English Learner group (M = 3.12, SD = .66) and the English Only group (M = 3.30, SD = .52). Post hoc comparisons using the Tukey HSD test indicated that the score for the Understanding of Disciplinary Core Ideas was significantly different for the redesignated group (M = 4.15, SD = .80) than the English Learner group (M = 3.14, SD = .66) and English Only group (M = 3.35, SD = .59). Post hoc comparisons using the Tukey HSD test indicated that the score for Science-Language Learning was significantly different for the redesignated group (M = 4.17, SD = .82) than the English Learner group (M = 2.98, SD = .35) and the English Only group (M = 3.30, SD = .52).

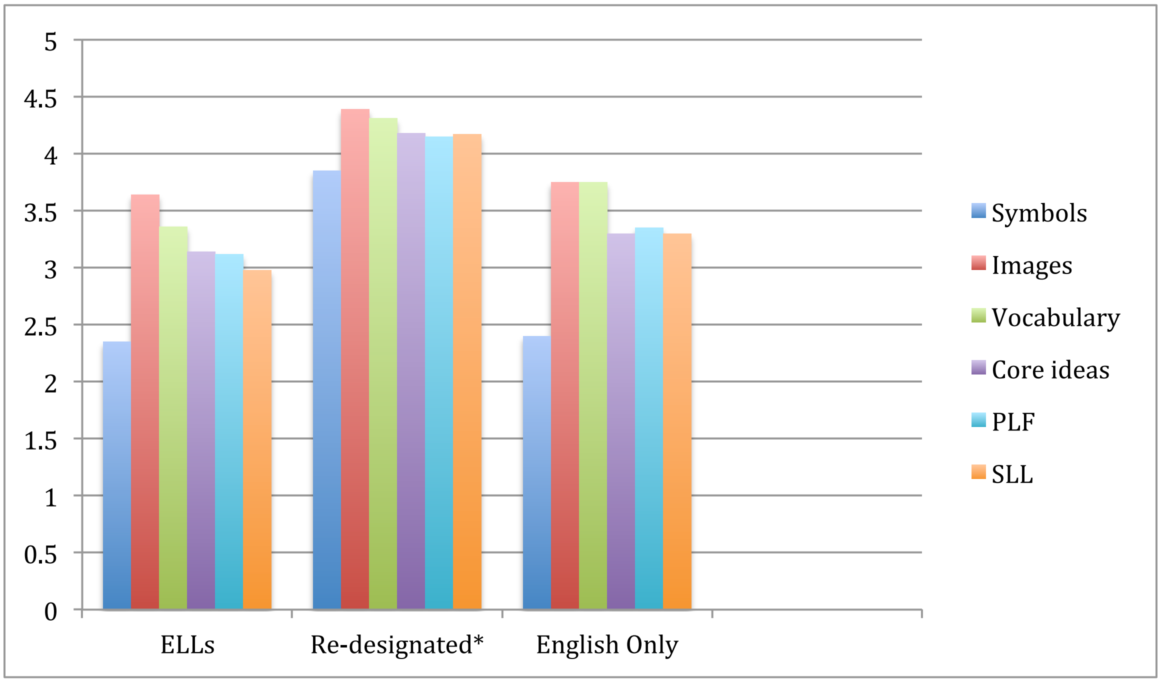


Figure 5. Summary of mean scores in each construct by ELL status in the comic strips. * = significant $p < .05$.

Science Proficiency.

Table 16

Mean Scores in Comic Strip in Science Proficiency Category

Construct (*N*)	Use of Symbols *M (SD)*	Use of Images *M (SD)*	Use of Curriculum-based Vocab *M (SD)*	Prod Lang Function *M (SD)*	Disciplinary Core Ideas *M (SD)*	Science Language Learning *M (SD)*
Science Prof (40)	2.90 (1.24)	4.00 (0.75)	3.87 (0.82)	3.59 (0.82)	3.60 (0.78)	3.59 (0.78)

A one-way between-subjects ANOVA was conducted to compare the effect of Science Proficiency on the scores of the Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, Productive Language Function, Understanding of Disciplinary Core Ideas and Cumulative Science Language Score in the comic strips in those students who were Below proficiency, At proficiency and Above proficiency. There was no significant effect of Science Proficiency at the $p < .05$ level for all three groups.

ELA Proficiency.

Table 17
Mean Scores in Comic Strip in ELA Proficiency Category

Construct (*N*)	Use of Symbols *M (SD)*	Use of Images *M (SD)*	Use of Curriculum-based Vocab *M (SD)*	Prod Lang Function *M (SD)*	Disciplinary Core Ideas *M (SD)*	Science Language Learning *M (SD)*
ELA Prof (44)	2.82 (1.21)	3.95 (0.75)	3.82 (0.81)	3.53 (0.81)	3.54 (0.79)	3.53 (0.77)

A one-way between-subjects ANOVA was conducted to compare the effect of English Language Arts Proficiency on the scores of the Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, Productive Language Function, Understanding of Disciplinary Core Ideas and Cumulative Science Language Score in the comic strips in those students who were Below proficiency, At proficiency and Above proficiency. There was no significant effect of English Language Arts Proficiency at the $p < .05$ level for all three groups.

Vocabulary Acquisition and Usage.

Table 18
Mean Scores in Comic Strip in Vocabulary Acquisition and Use Proficiency Category

Construct (*N*)	Use of Symbols *M (SD)*	Use of Images *M (SD)*	Use of Curriculum-based Vocab *M (SD)*	Prod Lang Function *M (SD)*	Disciplinary Core Ideas *M (SD)*	Science Language Learning *M (SD)*
Vocab Acq and Use	2.79 (1.18)	3.89 (0.76)	3.79 (0.81)	3.49 (0.80)	3.51 (0.78)	3.49 (0.77)

Diagnostic (47)

A one-way between subjects ANOVA was conducted to compare the effect of Vocabulary Acquisition and Usage Proficiency on the scores of the Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, Productive Language Function, Understanding of Disciplinary Core Ideas and Cumulative Science Language Score in the comic strips in those students who were Below proficiency, At proficiency and Above proficiency. There was no significant effect of Vocabulary Acquisition and Usage Proficiency at the $p < .05$ level for all three groups.

Summary. Taken together, these results suggest that *English Language Learner* status does have an effect on Use of Symbols and Understanding of Disciplinary Core Ideas. Specifically, these results suggest that students redesignated as English Learners within the last two years used Symbols, Images and Curriculum-based Vocabulary to show and demonstrate their understanding of Disciplinary core ideas in the comic strips. This group also had higher Productive Language Function and Science Language Learning. The English Learner group had the lowest scores in all the constructs and demonstrated that their English Learner status affected their performance in comic strips.

It can be seen that the linguistic diversity of the students helped to explain how the students created the comic strips to represent their understanding. English Learner status influenced how students performed on the comic strips, as they had the lowest scores in all constructs of the comic strips. Redesignated students had the highest scores in all constructs. What is observed is that ELLs were not successful in using the comic strips to represent their learning, whereas the redesignated students were most successful in doing so. It also can be seen that in the Vocabulary Acquisitions and Use category, the students who were proficient had the highest scores in Science-Language Learning, whereas Proficiencies in Science, English Language Arts and Vocabulary Acquisition and Usage did not play any role in how the students created the comic strips to represent their understanding of photosynthesis.

RQ 3. How Do the Final Visual Diagrams (Visual Diagram C) Demonstrate the Science Learning of Linguistically Diverse Students Using the Science and Language Learning Rubric?

Data collected. The students created Visual Diagram C about four weeks after completion of the unit, the purpose being to gauge how much understanding of photosynthesis the students could retain. In this section, I analyzed the final visual diagram (Visual Diagram C), which was collected four weeks after the completion of the unit. The intent was to engage the students in a representational activity that they were familiar with and had created during the unit.

Data analysis.

Visual Diagram C. The Visual Diagram C was a representational task that the students created four weeks after the completion of the unit of photosynthesis. The purpose of having the students create a third visual diagram was twofold: (a) to see if the students could still represent their understanding of photosynthesis in a visual diagram and (b) to see if the students could still retain their understanding of the process of photosynthesis.

Total sample.

Table 19
Mean Scores in Visual Diagram C in Total Sample

Visual Diagram C (51)	Use of Symbols *M (SD)*	Use of Images *M (SD)*	Use of Curriculum-based Vocab *M (SD)*	Prod Lang Function *M (SD)*	Disciplinary Core Ideas *M (SD)*	Science Language Learning *M (SD)*
Total	2.29 (1.14)	2.93 (0.85)	2.96 (0.86)	3.06 (1.08)	3.14 (1.00)	3.35 (0.89)

Further, in order to gain better insights on how the students of these two sixth grade classrooms demonstrated their learning, it was important to understand how not only their English learner status but also their varying proficiencies in English Language Arts, Science and Vocabulary Acquisition and Usage contributed their ability to demonstrate their understanding of photosynthesis through the different multimodal tasks. The teachers also grouped their students in their classrooms based on their proficiencies in the standardized tests in English Language Arts and Science and diagnostic tests in Language Arts – Vocabulary Acquisition and Usage so as to identify those who needed extra assistance or support in the class. Hence it is important to explore how their proficiencies in these subjects and English learner status influenced their performance in these tasks.

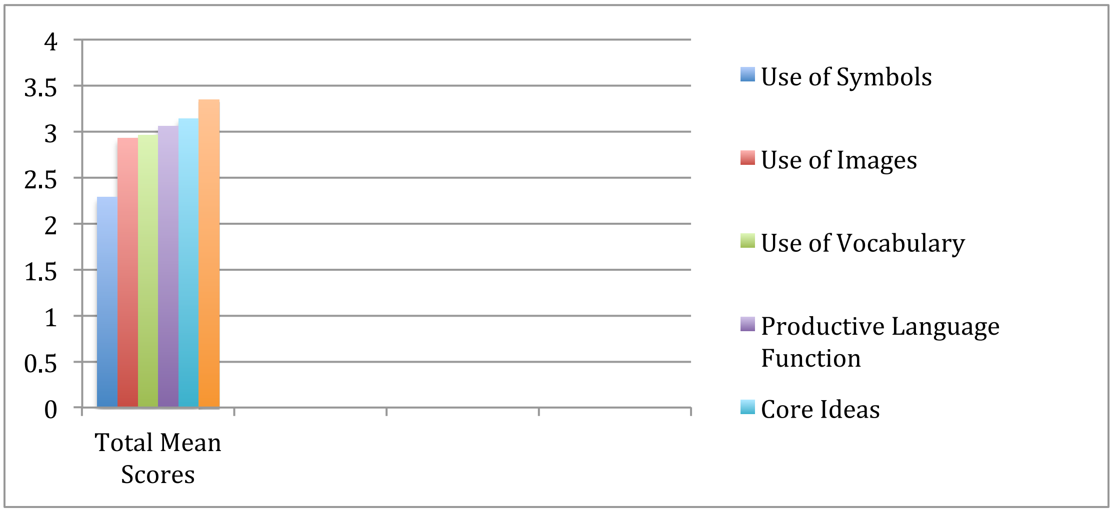


Figure 6. Mean scores in Visual Diagram C in total sample.

Analysis by student category for the mean scores in Visual Diagram C.

Table 20
Mean Scores in Visual Diagram C by English Learner Status

Construct (*N*)	Use of Symbols *M (SD)*	Use of Images *M (SD)*	Use of Curriculum-based Vocab *M (SD)*	Prod Lang Function *M (SD)*	Disciplinary Core Ideas *M (SD)*	Science Language Learning *M (SD)*
English Learner Status (51)	2.29 (1.13)	3.35 (0.89)	3.14 (1.00)	2.93 (0.85)	3.08 (1.08)	2.98 (0.85)

A one-way between-subjects ANOVA was conducted to compare the effect of English Language Learner status on the scores of the Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, Productive Language Function, Understanding of Disciplinary Core Ideas and Cumulative Science Language Score, in those students who were Below proficiency, At proficiency and Above proficiency. There was no significant effect of ELL status at the p < .05 level for all three groups.

ELA proficiency.

Table 21
Mean Scores in Visual Diagram C by ELA Proficiency

Construct (*N*)	Use of Symbols *M (SD)*	Use of Images *M (SD)*	Use of Curriculum-based Vocab *M (SD)*	Prod Lang Function *M (SD)*	Disciplinary Core Ideas *M (SD)*	Science Language Learning *M (SD)*
ELA Proficiency (47)	2.36 (1.15)	3.40 (0.88)	3.23 (0.98)	3.00 (0.83)	3.19 (1.05)	3.07 (0.82)

A one-way between-subjects ANOVA was conducted to compare the effect of English Language Proficiency on the scores of the Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, Productive Language Function, Understanding of Disciplinary Core Ideas and Cumulative Science Language Score, in the third Visual Diagram C in those students who were Below proficiency, At proficiency and Above proficiency. There was a significant effect of the proficiency in English Language Arts for the three conditions at the p < .05 level for the Use of Vocabulary [F(2, 44) = 4.52, p = 0.05], Productive Language Function [F(2, 44) = 3.36, p = 0.007], Understanding of Core Ideas [F(2, 44) = 3.72, p = 0.03],and Cumulative Science Language Learning [F(2, 44) = 6.39, p = 0.03].

Table 22
Significant Mean Scores in Visual Diagram C by ELA Proficiency

Construct	Below Proficiency	At Proficiency	Above Proficiency	*F* (2,	*p*	Tukey's

	(N = 10) *M (SD)*	(*N* = 29) *M (SD)*	(*N* = 8) *M (SD)*	44)		
Vocabulary	2.70 (1.25)	3.21 (0.82)	4.00 (0.76)	4.52	.02	3 > 1
Productive Language Function	2.50 (0.79)	3.24 (0.91)	3.46 (1.02)	3.36	.04	3 > 1
Core Ideas	2.50 (1.35)	3.24 (0.91)	3.75 (0.71)	3.72	.03	3 > 1
Science Language Learning	2.50 (0.88)	3.90 (0.73)	3.53 (0.89)	3.97	.03	3 > 1

Post hoc comparisons using the Tukey HSD test indicated that the score for the Use of Vocabulary was significantly different for the *Above proficiency* group (M = 4.00, SD = .76) than the *Below proficiency* group (M = 2.70, SD = 1.25). Post hoc comparisons using the Tukey HSD test also indicated that the score for the Productive Language Function was significantly different for the *Above proficiency* group (M = 3.46, SD = 1.02) than the *Below proficiency* group (M = 2.50, SD = .79). Post hoc comparisons using the Tukey HSD test indicated that the score for the Understanding of Disciplinary Core Ideas was significantly different for the *Above proficiency* group (M = 3.75, SD = .71) than the *Below proficiency* group (M = 2.50, SD = 1.35). Post hoc comparisons using the Tukey HSD test indicated that the score for the Science-Language Learning was significantly different for the *Above proficiency* group (M = 2.50, SD = 1.35) than the *Below proficiency* group (M = 2.50, SD = .88).

Science Proficiency.

Table 23
Mean Scores in Visual Diagram C by Science Proficiency

Construct (*N* = 45)	Use of Symbols *M (SD)*	Use of Images *M (SD)*	Use of Curriculum-based Vocab *M (SD)*	Productive Language Function *M (SD)*	Disciplinary Core Ideas *M (SD)*	Science Language Learning *M (SD)*
Science Proficiency	2.38 (1.17)	3.42 (0.89)	4.00 (0.87)	3.00 (0.85)	3.13 (1.03)	3.04 (0.85)

A one-way between-subjects ANOVA was conducted to compare the effect of Science Proficiency on the scores of the Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, Productive Language Function, Understanding of Disciplinary Core Ideas and Cumulative Science Language Score, in the third Visual Diagram C in those students who were Below proficient, At proficiency and Above proficiency. There was a significant effect of the proficiency in Science for the three conditions at the $p < .05$ level for the Use of Vocabulary [$F(2, 42) = 4.52$, $p = 0.05$], Productive Language Function [$F(2, 42) = 3.36$, $p = 0.007$], Understanding of Disciplinary Core Ideas [$F(2, 42) = 3.72$, $p = 0.03$] and Cumulative Science Language Learning [$F(2, 42) = 6.39$, $p = 0.03$].

Table 24
Significant Mean Scores in Visual Diagram C by Science Proficiency

Construct	Below Proficiency (*N* = 11) *M (SD)*	At Proficiency (*N* = 25) *M (SD)*	Above Proficiency (*N* = 9) *M (SD)*	*F* (2, 42)	*p*	Tukey's
Symbols	1.64 (0.67)	2.44 (1.04)	3.11 (1.54)	4.65	.02	3>1
Vocabulary	2.70 (1.25)	3.21 (0.82)	4.00 (0.76)	4.87	.01	3 > 1
Productive Language Function	2.50 (0.79)	3.24 (0.91)	3.46 (1.02)	5.37	.008	3 > 1

Core Ideas	2.50 (1.35)	3.24 (0.91)	3.75 (0.71)	6.82	.003	3 > 1
Science Language Learning	2.50 (0.88)	3.90 (0.73)	3.53 (0.89)	6.27	.004	3 > 1

Post hoc comparisons using the Tukey HSD test indicated that the score for the Use of Vocabulary was significantly higher for the *Above proficiency* group (M = 4.00, SD = .76) than the Below proficiency group (M = 2.70, SD = 1.25). Post hoc comparisons using the Tukey HSD test also indicated that the score for the Productive Language Function was significantly higher for the *Above proficiency* group (M = 3.46, SD = 1.02) than the *Below proficiency* group (M = 2.50, SD = .79). Post hoc comparisons using the Tukey HSD test indicated that the score for the Understanding of Disciplinary Core Ideas was significantly higher in the *Above proficiency* group (M = 3.75, SD = .71) than the *Below proficiency* group (M = 2.50, SD = 1.35). Post hoc comparisons using the Tukey HSD test indicated that the score for the Science-Language Learning was significantly higher for the *Above proficiency* group (M = 2.50, SD = 1.35) than the *Below proficiency* group (M = 2.50, SD = .88).

Vocabulary Acquisition and Usage.

Table 25
Total Mean Scores of each Construct in Visual Diagram C by Vocabulary Acquisition and Usage

Construct (*N*)	Use of Symbols *M (SD)*	Use of Images *M (SD)*	Use of Curriculum-based Vocab *M (SD)*	Productive Language Function *M (SD)*	Disciplinary Core Ideas *M (SD)*	Science Language Learning *M (SD)*
Vocabulary Acquisition	2.38 (1.17)	3.42 (0.89)	3.22 (0.99)	3.01 (0.85)	3.13 (1.04)	3.03 (0.85)

and Usage

A one-way between subjects ANOVA was conducted to compare the effect of Proficiency in Vocabulary Acquisition and Usage on the scores of the Use of Symbols, Use of Images, Use of Curriculum-based Vocabulary, Productive Language Function, Understanding of Disciplinary Core Ideas and Cumulative Science Language Score, in Visual Diagram C in those students who were Below proficiency, At proficiency and Above proficiency. There was a significant effect of the proficiency in Vocabulary Acquisition and Usage for the three conditions at the $p < .05$ level for the Understanding of Disciplinary Core Ideas [$F(2, 42) = 3.81$, $p = 0.03$].

Table 26
Significant Mean Scores in Visual Diagram C by Vocabulary Acquisition and Usage

Construct	Below Proficiency (*N* = 11) *M (SD)*	At Proficiency (*N* = 25) *M (SD)*	Above Proficiency (*N* = 9) *M (SD)*	*F* (2, 42)	*p*	Tukey's
Understanding of core ideas	1.64 (0.67)	2.44 (1.04)	3.11 (1.54)	3.81	.03	2 >1

Post hoc comparisons using the Tukey HSD test indicated that the score for the Understanding of Disciplinary Core Ideas was significantly higher for the *At proficiency* group (M = 2.44, SD = 1.04) than the *Below proficiency* group (M = 1.64, SD = .67).

Summary. In this analysis, it can be seen that in the final visual diagrams, ELL status had no significant influence on the use of different constructs to retain their understanding of photosynthesis and still express it in the form of a visual diagram. Students who were *Above Proficiency in English Language Arts* showed the highest use of curriculum-based vocabulary in representing their understanding of photosynthesis. The students who were classified as *Above Proficient in Science* showed the highest score in the Use of Symbols and Use of Curriculum-based Vocabulary, and the highest score in Understanding of Disciplinary Core Ideas. This group consequently also had the highest score in Productive Language Function and Science Language Learning compared to the students who were Below proficiency. Those students classified as *At Proficiency in Vocabulary Acquisition and Use* had the highest scores in Understanding of Disciplinary Core Ideas. This shows that P*roficiency in Science* and P*roficiency in English Language Arts* has a significant influence on how students were able to retain their understanding of photosynthesis and still express it in the form of a visual diagram.

Summary of Science and Language Learning Using the Rubric by Constructs of Symbols, Images, Curriculum-based Vocabulary, Disciplinary Core Ideas, Productive Language Function and Science and Language Learning

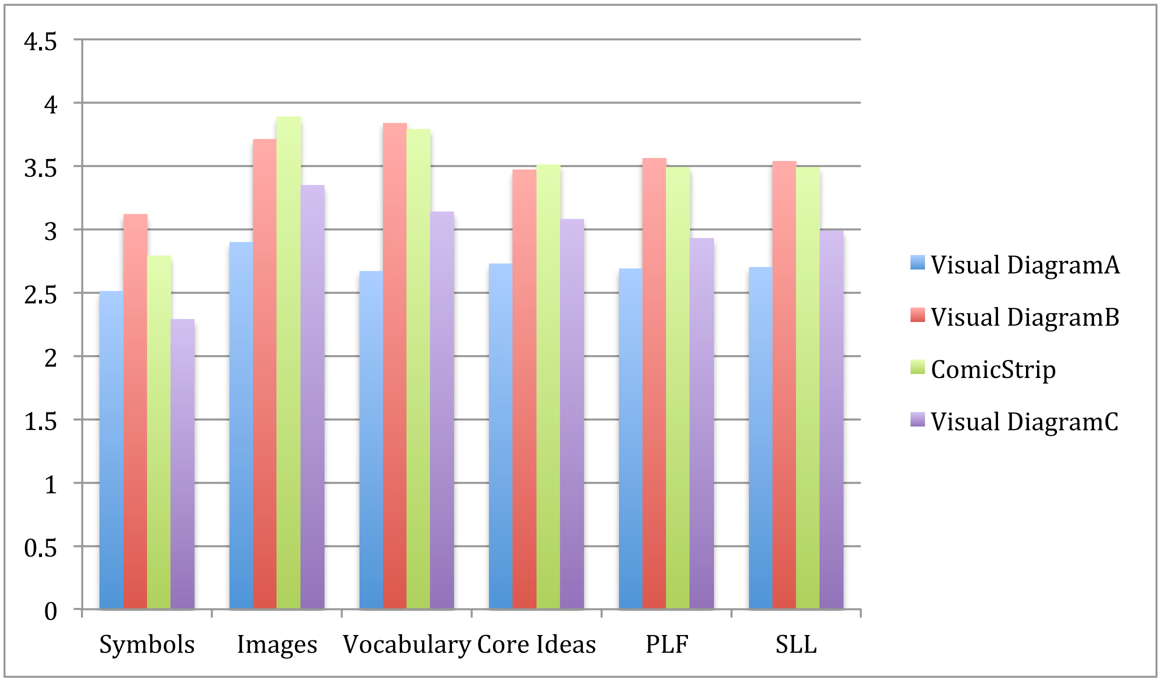


Figure 7. Mean scores in total sample in each construct for each multimodal task.

In order to gain insight into the how all the students performed in each construct in Visual Diagrams A and B, the comic strip and Visual Diagram C, I calculated the mean scores in each construct for each multimodal task. During the unit, the students created all these tasks in a sequential manner, where Visual Diagram A was created first, followed by Visual Diagram B, and then the comic strip. Finally, four weeks after the unit, the students completed Visual Diagram C. By analyzing how all the students performed in each construct, it can be seen how the students performed as they created each multimodal task during the unit. The *highest scores in symbols* was seen in Visual Diagram B (M = 3.12), *vocabulary* (M = 3.84), *productive language function* (M = 3.56) and *science language learning* (M = 3.54), thus showing that all the students had the highest use of symbols and curriculum-based vocabulary to represent their learning in the visual diagram after receiving feedback. The lowest scores in the use of curriculum-based vocabulary, productive language function, understanding of core ideas and science language learning were in Visual Diagram A. In the use of symbols, Visual Diagram C had the lowest scores. In the comic strip, the students showed the highest use of images (M = 3.49) and highest understanding of core ideas (M= 3.08).

Representational Tasks: Visual Diagrams and Comic Strips

In order to gain insight into the how all the students performed in each construct in Visual Diagrams A and B, the comic strip and Visual Diagram C, I calculated the mean scores in each construct for each multimodal task.

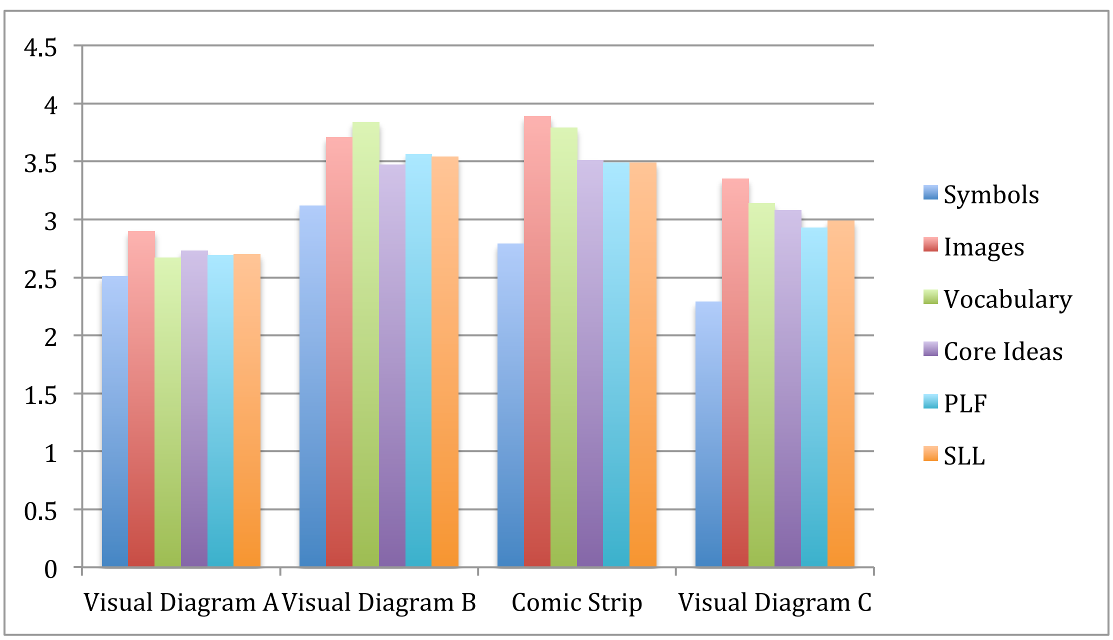


Figure 8. Mean scores in total sample for each multimodal task in each construct.

As shown in the figure above, all students had the highest scores in each construct for Visual Diagram B (Symbols = 3.12; Images = 3.71; Vocabulary = 3.84; Core Ideas = 3.47; Productive Language Function = 3.56 and Science Language Learning = 3.54) and the comic strip (Symbols = 2.79; Images = 3.89; Vocabulary = 3.79; Core Ideas = 3.51; Productive Language Function = 3.49 and Science Language Learning = 3.49). The lowest scores were seen in Visual Diagram A (Symbols = 2.51; Images = 2.9; Vocabulary = 2.67; Core Ideas = 2.73; Productive Language Function = 2.69 and Science Language Learning = 2.7) created by the students. Even though there is a drop in the scores in all the constructs in Visual Diagram C, (Symbols = 2.29; Images = 3.35; Vocabulary = 3.14; Core Ideas = 3.08; Productive Language Function = 2.93 and Science Language Learning = 2.99) as compared to that scored in the comic strip and Visual Diagram B, they are still higher than the mean scores of Visual Diagram A. This figure gives a clear representation of how the students performed in each multimodal task in a sequential manner with the students having the lowest scores in Visual Diagram A and higher scores in Visual Diagram B and the comic strip.

ELL Status

ELL status determined students' performance when they created Visual Diagram B and the comic strip. ELLs showed an increase in their understanding of disciplinary core ideas compared to redesignated and English Only students between Visual Diagrams B and A. In the comic strip, redesignated students used symbols, images and curriculum-based vocabulary to represent their learning more than ELLs and English Only students. There was no significant effect of ELL status in Visual Diagram C.

ELA Proficiency

Proficiency levels in English Language Arts determined students' performance when they created Visual Diagrams A and B, the comic strip and Visual Diagram C. *In gains between Visual Diagrams B and A,* students designated as Below proficiency and At proficiency had a higher score in the understanding of disciplinary core ideas compared to those students who are above proficiency in English Language Arts. Also, the students Below proficiency and At proficiency had higher gains in Productive Language Function and Science Language Learning. *In the comic strip*, proficiency levels in English Language Arts had no significant effect to represent their learning in all three groups. *In Visual Diagram C*, proficiency levels in English Language Arts had a significant effect on the use of curriculum-based vocabulary and understanding of disciplinary core ideas with the group designated as Above proficiency, with higher scores than the Below proficiency group. Students designated as Above proficiency also had higher gains in Productive Language Function and Science Language Learning.

Science Proficiency

Proficiency levels in science determined students' performance when they created Visual Diagrams A and B, the comic strip and Visual Diagram C. *In the gains between Visual Diagrams B and A*, students designated as Below proficient and At proficiency used curriculum-based vocabulary to represent their learning compared to the Above proficiency group. *In the comic strip*, proficiency levels in science had no significant effect in all three groups. *In Visual Diagram C*, proficiency levels in science had a significant effect on the use of curriculum-based vocabulary and understanding of disciplinary core ideas with the group designated as Above proficiency, with higher scores than the Below proficiency group. Students designated as Above proficiency also had higher gains in Productive Language Function and Science Language Learning.

Vocabulary Acquisition and Usage

Proficiency levels in Vocabulary Acquisition and Usage determined students' performance when they created Visual Diagrams A and B, the comic strip and Visual Diagram C. *In the gains between Visual Diagrams B and A*, students designated as Below proficiency used images to represent their learning compared to At proficiency and Above proficiency level students. This group also had an increase in the understanding of disciplinary core ideas. *In the comic strip*, proficiency levels in Vocabulary Acquisition and Usage had no significant effect to represent their learning in all three groups. *In Visual Diagram C*, students designated as Above proficiency had higher scores in their understanding of core ideas to represent their learning compared to Below proficiency and At proficiency groups.

Conclusion

Visual Diagrams as Representational Tasks

The visual diagrams were a representational multimodal task created by the students to show their understanding of the process of photosynthesis through a single representative diagram with the use of images, symbols and text. All the visual diagrams were created in a similar manner by most students (with the same prompt); what differed among the diagrams was the varying use of images, chemical symbols and curriculum-based vocabulary. The differences can be accounted for by the students' ELL status, proficiencies in English Language Arts, Science and Vocabulary Acquisition and Usage. For this paper, I analyzed the progress of science language learning by examining the gains made in all the constructs of the use of symbols, images and curriculum-based vocabulary between Visual Diagram B and A following feedback provided by the teacher. I also analyzed the students' performance on the third visual diagram to get insight on the students' retention of learning and how they could represent their learning.

The overall results show that ELLs had a higher gain in understanding of disciplinary core ideas than the English Only and redesignated groups, following feedback. Also, the students belonging to Below proficiency groups for English Language Arts and Vocabulary Acquisition and Use, following feedback, showed an increased use of images. The students belonging to Below proficiency groups for English Language Arts and Science showed an increased use of curriculum-based vocabulary and understanding of disciplinary core ideas. The students belonging to Below proficiency groups for Science and Vocabulary Acquisition and Use, following feedback, showed an increase in scores of understanding of disciplinary core ideas. What is noteworthy is how students who were Below proficient in English Language Arts tended to use images more than the other groups, and if a student group had an increase in curriculum-based vocabulary, they also had an increase in understanding of disciplinary core ideas.

For Visual Diagram C, it was noted that ELL status had no significant effect on the performance, whereas the proficiency in English Language Arts, Science and Vocabulary Acquisition and Use had a significant effect on the performance on Visual Diagram C, where the students who were in the Above proficiency group in English Language Arts and Science had the highest scores in curriculum-based vocabulary. Interestingly, the students who were Above proficiency in science had the highest scores in the use of symbols.

These results reveal the intricate relationship between proficiencies in English Language Arts, science and vocabulary acquisition and use. They also reveal that how the students used the visual diagrams to represent their understanding of the process of photosynthesis at various times of the unit. Those students who belonged to the Above proficiency groups in English Language Arts, Science and Vocabulary Use definitely were able to retain their understanding of the process of photosynthesis compared to the other groups. While those belonging to the Below proficiency groups had the highest gains in most constructs, thus showing they not only improved the most following feedback from the teacher, these students were also able to show an increase in their learning through the diagrams through the use of images and curriculum-based vocabulary.

Comic Strips as Representational Tasks

The comic strip was a representational multimodal task created by the students to show their understanding of the process of photosynthesis, which included images, text and use of a storyline. The purpose of the comic strip was to explore evidence of consolidation of learning from different contexts. The students could create the comic strip using any storyline, but the teachers insisted that they write it in a sequential manner. Some illustrated books, like the Magic School Bus series, were used as examples for the students. The teachers gave the list of vocabulary words, which they expected the students to incorporate into the comic strip. It can be seen that *ELL status* has a significant influence on the performance of the students on the comic strip. Redesignated students had the highest scores in all the constructs, while ELLs had the lowest scores. This could be attributed to the fact that the ELLs may not be familiar with the genre of writing a narrative task in science, hence had the lowest scores in the comic strip. There existed some dissonance between the art of story-telling and writing science ideas, especially for ELLs. The redesignated group had about fifteen students who were proficient in the English Language Arts and no students who were below proficiency. The redesignated group was able to create both the narrative part and incorporate the science knowledge in the comic strip through the use of symbols, images and curriculum-based vocabulary. Research has shown that redesignated students with their more focused English language and literacy support compared to the typical English Only students perform better on assessments (Shaw, 2014; Shaw, 2009 & Lee & Lukyx, 2006). The same reasons could have contributed to the increased scores of redesignated students in this study.

English Language Learners had the lowest scores in the comic strip, showing that a representational task that includes a narrative component, requires a certain amount of proficiency in English. The English only group consisted of students who were classified as Below proficient in English, which could explain their significantly lower scores in all constructs than the redesignated groups. Allen, Bernhardt, Berry, and Demel (1988) have illustrated how the nature of the language used may influence the production of a task. Research has also shown how redesignated students perform better than most students on assessment tasks as the support they receive

By claiming that a "multimodal approach assumes that the different modes have different affordances," it will be useful to examine how the different modes afford learning, which mode supports the best form of communication, or whether particular combinations of modes afford learning (Kress et al., 2006, p. 175). Varelas and Pappas (2013) demonstrated how their students prepared their own illustrated science books in the units of matter and forests and the students had used typical features of science text-relational verbs (has, resembles) and process verbs (changed, grew; Halliday & Martin, 1994; Schleppegrell, 2004). However, in their research project designed to address the quality of air and water of the river in the community, Moje et al. (2001) described the dissonance in students' production of texts and those required by the science curriculum. This could be attributed to the fact that the students were not aware of how to incorporate particular features of the science register while writing a narrative text (Anderson, 2007). The ELLs in this study too had the same difficulty with comic strips. Despite these contrasting views, most researchers in the field of multimodality have a consensus that students need to understand the necessity of modal diversity in representations of science concepts and processes and be able to translate different modes, as well as understand their integrated use in representing scientific knowledge (Prain & Waldrip, 2006). The gains made by most students, especially the ELLs, between the two visual diagrams not only demonstrates how the feedback provided by the teachers was helpful in improving their learning but also in how to integrate the use of different modes to express their understanding of photosynthesis.

Lemke (1989) stated that it is important to understand the lexical and grammatical combinations of words, clauses, and sentences, which, when configured, can lead to the understanding of science concepts. It is therefore, useful to understand how students and teachers make meaning from the various multimodal elements (including spoken words, images and symbols) of their representations, which the visual diagrams and the comic strips afforded. Kress et al. (2006) posited that learning and knowledge are shaped and transformed by the mode or modes in which they are represented or communicated; hence, it would be important to assess if the learning process is mode or content specific, or both. The assessment of the visual diagrams in the form of gains made in each construct and the scores in each construct of the diagram completed four weeks after the unit showed how the students improved in their understanding through the use of symbols, images or through curriculum-based vocabulary. However, creating the comic strips, which involved creating a narrative with images and using text, was challenging for most ELLs.

The current theorization of in multimodality in social semiotics does not address the important details of how students are able to articulate "thematic patterns" in a science lesson (Lemke, 1989, p. 137) with less focus on the fine-grain analysis of the textual practices and on the practical ways in which everyday text production can be linked precisely to science learning (Moje, 2007). This paper has demonstrated certain aspects of "grains of analysis" of the multimodal tasks—visual diagrams and comic strips—through the science and language learning rubric, which examined how the students represented their understanding of disciplinary core ideas photosynthesis through the use of symbols, images, curriculum-based vocabulary. Further, the findings reveal how the ELL status and proficiencies in English Language Arts, science and vocabulary acquisition and usage of the students influenced their representations of their understanding of content learning through the visual diagrams and comic strips. This study provides insight to an integrated view of assessing and learning science and language in science classrooms through the notion of multimodality. The findings offer a useful reminder of ways of enhancing students' ability to understand and construct knowledge in science, to use and understand its verbal, mathematical, and visual-graphical aspects (Lemke, 2001), to apply whichever is most appropriate in the moment, and being able to understand the relation among these aspects to science learning.

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Appendix A
Science and Language Learning Rubric of Multimodal tasks

In the topic of photosynthesis, there are two disciplinary core ideas- *organization of matter and energy flow in organisms* –(1) "Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon-dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or store for growth or later use (NGSS Lead State, 2013, p. 68)". (2) *Energy in chemical processes and everyday life*- "The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (from sunlight) to occur. In this reaction, carbon-dioxide and water combine to form carbon-based organic molecules and release oxygen (NGSS Lead State, 2013, p.69)".

Productive Language Function

Symbols (Appropriate use/Incorrect symbol/Missing symbols)

- Arrows or Lines (correct direction and connecting right sources)
- Symbols for the compounds- CO_2, H_2O, O_2, $C_6H_{12}O_6$ (writing of any of these symbols)

Images (Presence of image Or Missing images)

- Leaves
- Roots
- Stem
- Sun/Sunlight/Sunrays
- Chloroplast
- Carbon-dioxide molecule/ Oxygen molecule/Water molecule (circle or squares)

Curriculum-based Terms (Vernacular Terms): Appropriate use of terms

- Oxygen (air): By-product of photosynthesis
- Carbon-dioxide air): Absorbed by stoma in leaves; Used as reactant in photosynthesis
- Stoma (holes): CO_2 enters and O_2 leaves
- Chloroplast (leaves) : Traps sunlight
  OR Chlorophyll (leaves/green pigment) : Traps sunlight
- Carbohydrate/Glucose (sugars, food) : Product of photosynthesis

OR Starch (food) : Product of photosynthesis; Carbohydrates stored as food/starch

- Sunlight (sun): Used as energy in photosynthesis
- Water : Absorbed by roots; Used as reactant in photosynthesis
- Xylem: Transporting/carrying mineral and water (for comic strip)
- Phloem: Transporting/carrying food or glucose or food (for comic strip)

Science Understanding

Core Ideas

- Making carbohydrate/sugar/glucose from carbon-dioxide and water
- Use of carbon-dioxide and water as reactants
- Photosynthesis requires energy/ sunlight
- Releases oxygen
- Starch/Food is used for growth or storage

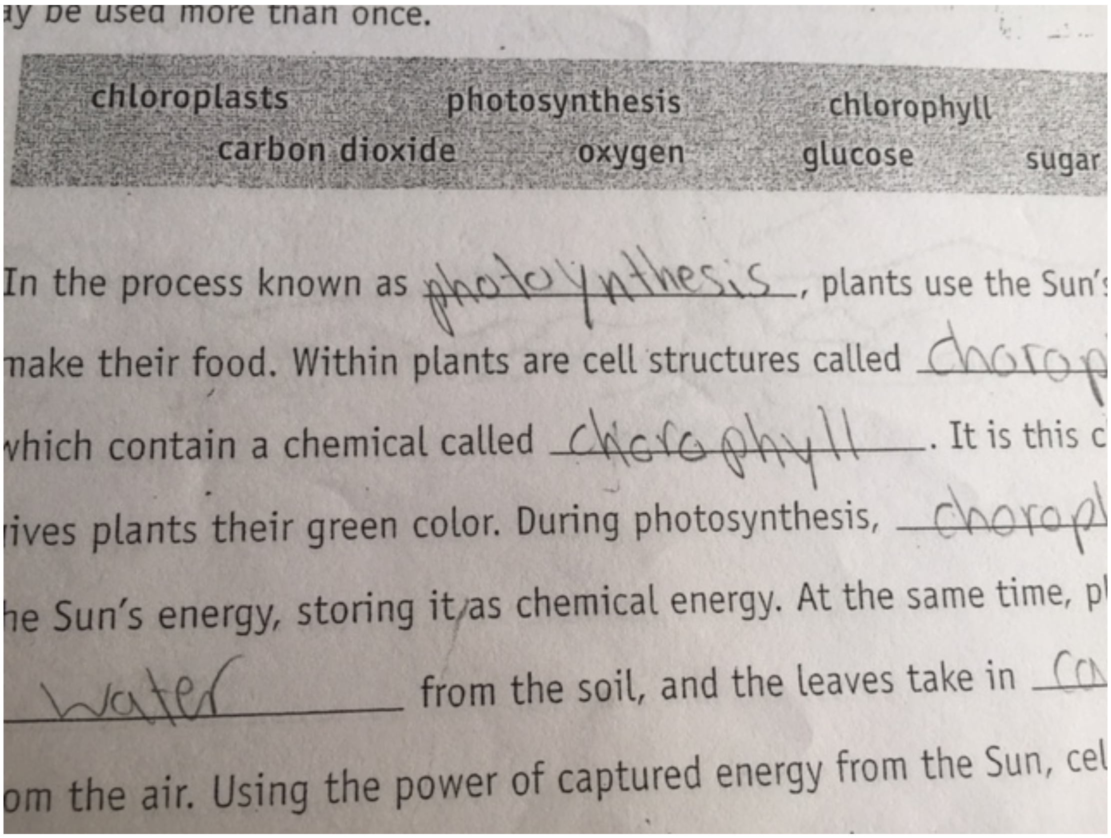
$$6C0_2 + 6H_2O + \text{energy from sunlight} \longrightarrow C_6H_{12}O_6 + 6O_2$$

		Advanced 5	**Proficient 4**	**Apprentice 3**	**Emerging 2**	**Novice 1**
Productive Language Function	Symbols	Most symbols present All used appropriately (incorrect)	Most symbols Uses most of them appropriately (incorrect)	Uses more symbols Uses only some of them appropriately (incorrect)	Uses a few symbols Does not use any symbol appropriately (incorrect)	Does not use any symbol.
	Images	All images present	Most images present	More images present	Very few images present	Does not use any image
	Curriculum Based Vocabulary	Uses almost all Curriculum-based science terms.	Uses most Curriculum-based science terms. Uses some	Uses more Curriculum-based science terms Use few vernacular terms. Uses only	Uses few curriculum -based science terms (>2) Uses mostly vernacular and.	Uses very few curriculum based terms (1 or 2) Uses mostly vernacular terms (holes, air, food).

		Uses terms appropriately (both C &V)	of them appropriately (both C & V	some of the terms appropriately (both C & V)	Does not use terms appropriately (both C & V)	Does not use any term appropriately (both C & V) No response
Science Understanding	Disciplinary Core Ideas (Combined use of symbols, images and terms)	Appropriate understanding of all core ideas	Appropriate understanding of more than one core idea. Partial understanding of other ideas.	Appropriate understanding of one core idea. Partial understanding of other core ideas	Partial understanding of core ideas No appropriate understanding of any core idea.	No understanding of core ideas (4). No response

Appendix B
Visual Diagram Sample

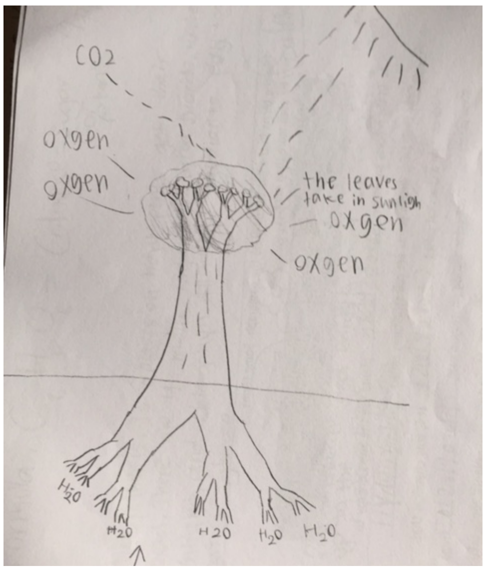
Cloze test and vocabulary words on one side

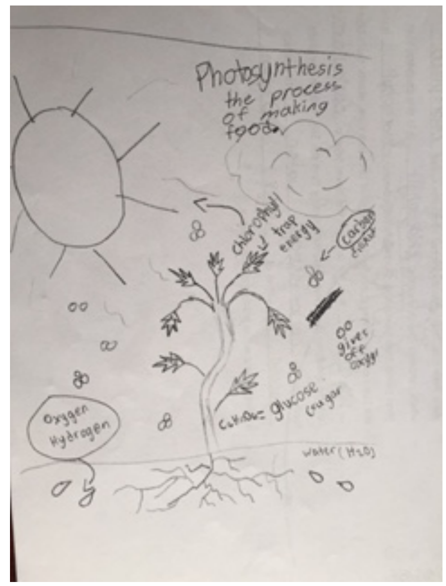

ay be used more than once.

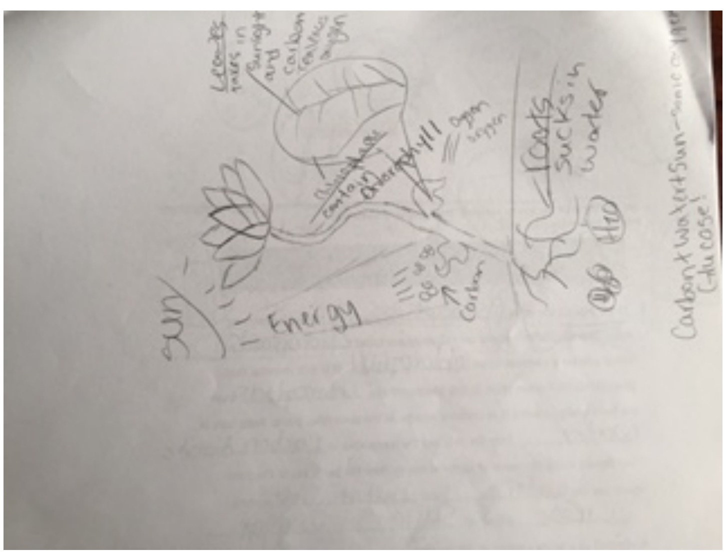
chloroplasts photosynthesis chlorophyll
carbon dioxide oxygen glucose sugar

In the process known as photoynthesis, plants use the Sun's
make their food. Within plants are cell structures called chorop
which contain a chemical called chorophyll. It is this c
ives plants their green color. During photosynthesis, chorop
he Sun's energy, storing it as chemical energy. At the same time, pl
water from the soil, and the leaves take in Ca
om the air. Using the power of captured energy from the Sun, cel

Sample Visual Diagrams of three students drawn on other side of cloze test

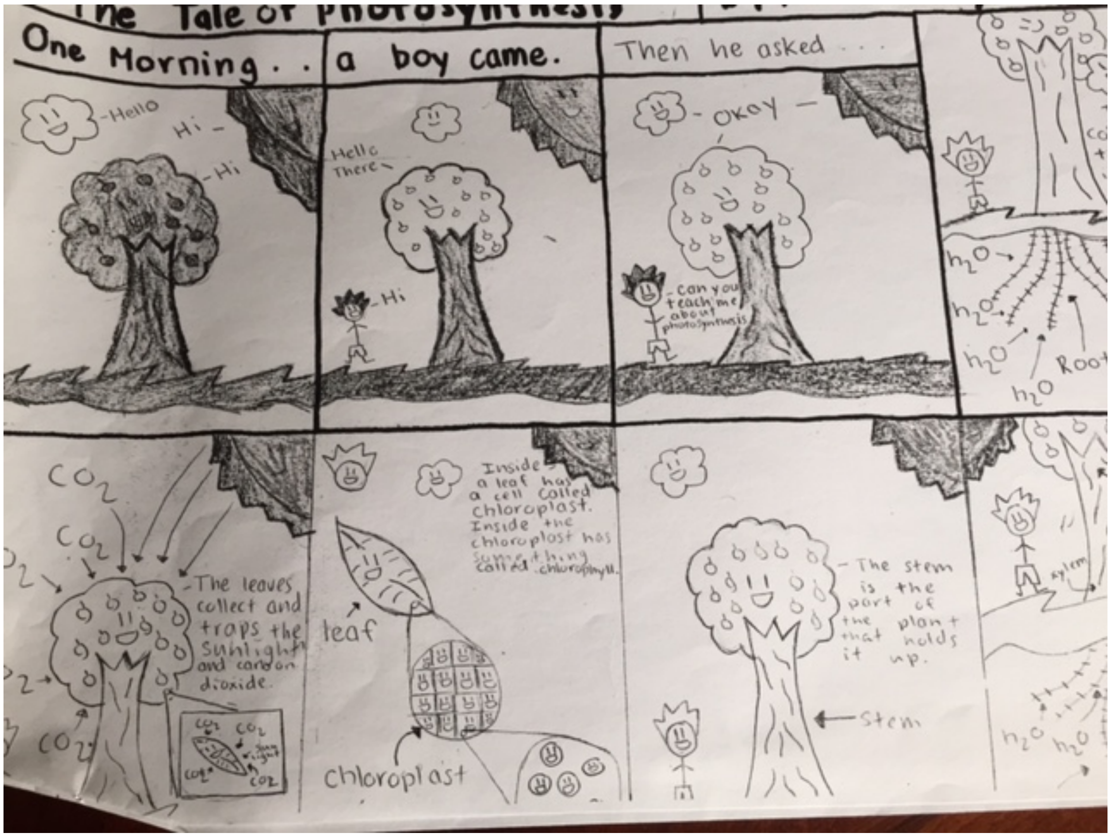






Appendix C

Sample Comic Strip of one Student



CHAPTER 5: CONCLUSION: SUMMARY, IMPLICATIONS, LIMITATIONS AND RECOMMENDATIONS

In the conclusion to my dissertation, I begin by summarizing my results. I then discuss implications for instruction and assessment and describe the limitations of the study. Finally, I provide recommendations for the use of multimodal tasks based on my results. In the previous three chapters, I looked at the role of multimodal tasks for assessment and learning in two linguistically diverse science classrooms from three perspectives: (a) exploring teachers' perspectives on the use of multimodal tasks to support science learning; (b) exploring students' perspectives on the use of multimodal tasks to support science learning and (c) exploring linguistically diverse students' learning through multimodal tasks using a science and language learning rubric.

Summary

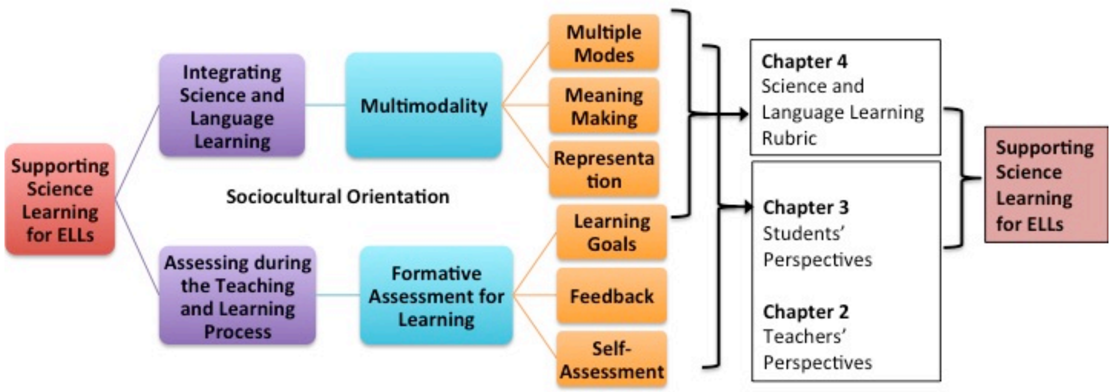


Figure 1. Framework of the dissertation study within a sociocultural theoretical orientation.

This study is located in the social milieu of a classroom setting, where the role of multimodal tasks was to support science learning with linguistically diverse students. This study takes place in an urban school in Northern California, Garden Brooks School in two sixth grade classrooms. Contrary to traditional educational research in which theories are tested in controlled environments, this study incorporates some aspects of design-based research and examines the confluence of the potential of multimodal tasks from a sociocultural perspective through the theory of integrating science and language learning and assessing during the process of teaching to support the science learning of linguistically diverse students.

In Chapter 1, I have outlined how a sociocultural orientation in this study which integrates the use of science and language and assessment for learning, engenders participation in discourse as a primary characterization of learning and knowing (Lemke, 2001; Vygotsky, 1978) with the support of knowledgeable others like teachers (Lave & Wenger, 1991; Vygotsky, 1978), and scaffolds that provide support and guidance to help students achieve what they cannot do alone (Wood, Bruner, & Ross, 1976). As integrating the notion of multimodality means studying the world as scientists and "learning the kinds of discourses and representations that are useful and how to use them" (Lemke, 2001, p. 298), in this study, the teachers and students engage in and create multimodal tasks to support their understanding of the process of photosynthesis. A sociocultural perspective of assessment involves having a "dynamic and distributed view" of assessment (Gipps, 1999, p. 273). The assessment tasks, in this study being the multimodal tasks, were used to support learning where both the task and the process of using the task were assessed. This aligns with the dynamic view of assessment. The distributed notion of assessment enables both teachers and students to use these tasks as scaffolds and as guides for the next steps of in both teaching and learning (Wood et al., 1976).

In Chapter 2, I have described how the teachers through their existing views and beliefs planned and implemented multimodal tasks to assist the students' learning process and used the tasks formatively to inform instructional decisions and provide feedback. Finally, I analyzed through the cyclic process of planning and decision-making, how the teachers' beliefs changed and further influence their future decision-making. The teachers had planned the tasks in such a way such that some were used to communicate the ideas of photosynthesis and others were used solely for representing students' ideas. Incidentally the teachers designed none of the tasks used to communicate learning, other web sources and teacher resources were modified and used. The teachers scaffold the appropriation of ideas within the tasks through the use of analogies; incorporated modes like symbols or images used in one task and used them in other tasks, thus re-representing the modes. Finally, the teachers also contextualized the use of both curriculum-based and non-curriculum based vocabulary in the unit within each task. The teachers used the tasks created by the students namely the visual diagrams and comic strips to assess "How the students are doing?" "Where are they going?" and "How to get them there?" – A model of formative assessment (Wiliam & Thompson, 2007). Through the three iterations of the students' visual diagrams the teachers could not only analyze how the students utilized what was taught through the various multimodal tasks and represent their learning but also assess their progress in understanding of the process of photosynthesis. As the teachers felt that multimodal tasks in the form of the narrative tasks like 'the comic strip' represented challenges for "language use for academic purposes", they underscored the importance of providing more scaffolds and modeling for ELLs and students who were classified as below proficiency in Language Arts and Science.

In Chapter 3, I have described how students in the two linguistically diverse classrooms used the multimodal tasks to support their learning during the unit of photosynthesis. I have examined the students' understanding of the process of photosynthesis before the use of the multimodal tasks and how they viewed the learning goals of the multimodal tasks they used during the unit. Next I analyzed how the students used the multimodal tasks provided by the teachers to assist their learning and finally how the students reflect on the use of the multimodal tasks used to represent their understanding of the process of photosynthesis. Results revealed that initially the students had a basic or first level of understanding of photosynthesis – Phenomenal Knowledge (Lin & Hu, 2003), especially those students belonging to the ELL group and English only group. Only one of the students in redesignated group had an advanced level of understanding at the beginning of the unit. During the unit the students appropriated the use of analogies put forth by the teachers, engaged in highlighting and underlining the read louds, and used the curriculum –based vocabulary in other contexts besides their representational tasks. I also examined their progression of disciplinary ideas as the unit continued, culminating in examining the students' views on how the multimodal tasks supported their learning and their views on those tasks (visual diagrams and comic strips) used to represent their learning. Most students had progressed to the second level of understanding of photosynthesis – Mechanical Knowledge with a few students demonstrating understanding within the category of Physical Knowledge (Lin & Hu, 2003). While majority of the students found the visual diagrams extremely useful, the comic strip proved to be challenging to some students specifically the ELLs. To add an affective lens in this study, I also analyzed the students' science attitude scores, in which all the students showed a gain in science interest, identity and but showed a decrease in efficacy. The ELLs had a reduction in the scores in all the constructs which could be attributed to the difficulties experienced by some students while creating the comic strip, as the post science attitude survey was completed by all the students after the comic strip. The English only students did not have any increase or a very slight increase in science attitude scores, whereas the redesignated students had an increase in all the science attitude scores, except for efficacy. The positive change in scores may indicate that the multimodal tasks supported the redesignated students in their science attitudes, whereas they did not have much influence on the English only students.

In Chapter 4, I used a science and language learning rubric to examine the science learning of the students through the multimodal tasks—visual diagrams and comic strips—used to represent their learning. The rubric focused on four main constructs—use of symbols, use of images, use of curriculum-based vocabulary and understanding of disciplinary core ideas—to assess the science and language learning of the students. During the unit the students created all these tasks in a sequential manner, where the visual diagram A was created first, followed by visual diagram B and then the comic strip. Finally four weeks after the unit the students complete the visual diagram C. The inter-rater reliability and construct validity of the rubric showed medium to high range of scores. By analyzing the tasks using the rubric for each construct, it can be seen how the students performed in each construct as they created each multimodal task. In the total sample, the students had the highest use of symbols and curriculum-based vocabulary to represent their learning in the second visual diagram (visual diagram B) after receiving feedback. The lowest scores in the use of curriculum based vocabulary, productive language function and knowledge of core ideas and science language learning was in first visual diagram (visual diagram A). In the use of symbols, the visual diagram C has the lowest scores. The students showed the highest use of images and highest understanding of core ideas in the comic strip.

Results also reveal the intricate relationship between proficiencies in English language arts, science, and vocabulary acquisition and use and how the students used the visual diagrams to represent their understanding of the process of photosynthesis at various times of the unit. While those belonging to the Below proficiency groups in English Language Arts, Science and Vocabulary Use had the highest gains (difference between Visual Diagram B and Visual Diagram A) in most constructs, thus showing they benefitted the most with the teacher feedback, these students were also able to show an increase in their learning through the diagrams through the use of images and curriculum-based vocabulary. Those students who were belonged to the Above proficiency groups in English Language Arts, Science and Vocabulary use definitely were able to retain their understanding of the process of photosynthesis in Visual diagram C, compared to the other groups. Results also reveal the intricate relationship between English Learner status and performance on these multimodal tasks. English Language Learners had the highest gains in most constructs especially in the Understanding of disciplinary core ideas, following feedback. English Learner status had a significant influence on the performance of the students on the comic strip where redesignated students had the highest scores in all the constructs while English Learners had the lowest scores. Not being familiar with the genre of writing a narrative task in science may have contributed to the low scores in the comic strip of the ELLs. ELL status had no significant influence on how the students performed on the third visual diagram. Research has shown that redesignated students receive more focused English language and literacy support compared to the typical English Only student, which could be the reason for their increased scores.

Implications for the Use of Multimodal Tasks for Teaching, Learning, and Assessment of Linguistically Diverse Students

With the implementation of the Next Generation Science Standards (NGSS Lead States, 2013) in thirteen states in the United States (Achieve Inc., 2013) and fast growing ELLs public school population, where it is predicted that by 2025, nearly one out of every four public school students will be an ELL (National Center for Education Statistics [NCES], 2011, 2012), the results of this study can provide insights into how NGSS can be implemented in linguistically diverse classrooms. The NGSS Diversity and Equity Group have focused on ensuring that the NGSS are accessible to all students by identifying strategies, which they posit can support the science learning for ELLs, including various strategies for literacy and language development including explicit discussion of reading and writing of scientific genres and use of academic language in science practices, using realia (real objects or events) and multiple modes of representation (gestural, oral, pictorial, graphic, textual) in science (NGSS Lead States, 2013). Researchers have suggested that an effective assessment system of NGSS aligned science content should target specific disciplinary core ideas, provide avenues to engage in science practices and should assess some aspects of performance expectations within a certain unit in science (NRC, 2014). Through the integrated model of Clark and Peterson (1986) and Ruiz-Primo & Li (2013), Andrade's (2010) model of self-regulation and learning through formative assessment and finally through the science and language learning rubric, I have highlighted the affordances and constraints of the multimodal tasks and how they can contribute to such an assessment system during the unit of photosynthesis.

Some of the characteristics of the assessment tasks suggested by the researchers (National Research Council [NRC], 2014) include, having multiple components, providing a progressive understanding of student learning and providing the teachers with a range of student responses so as to facilitate further instructional decision-making and curricular modifications. The different multimodal tasks planned and implemented by the teachers had multiple components, including videos, reading aloud tasks, making the molecule model and seed germination tasks. Most of these tasks assisted in the teaching and learning process while also incorporating the use of multiple modalities, like talking, reading and drawing. By providing the array of multimodal activities in the form of specific tasks aligned to learning goals, which corresponded to disciplinary core ideas, the students had a range of opportunities by which they could learn within the unit of photosynthesis. Furthermore, having both the teachers' and students' perspectives about the multimodal assessment system provides a unique perspective about the use of multimodal tasks in this study.

Pitoniak et al. (2009) have posited the need to provide ELLs with multiple opportunities to show what they know and can do. The seed germination task gave the students chance to record and observe the growth of a plant from seeds and learn the importance of light in photosynthesis. The students represented their understanding of photosynthesis through a single static representation – visual diagram. The comic strip completed at the end of the unit also provided an interesting perspective of how the students could synthesize all the information they knew about photosynthesis and present in the form of a narrative with images. While the teachers had planned this task with the intention of having a representational multimodal task, which represents the process of photosynthesis in a sequential manner, the task of integrating science knowledge and the language to write a narrative proved to be a challenge to most ELLs.

Another notion posited was that assessment tasks should "provide information about where students fall on a continuum between expected beginning and ending points in a given unit" (NRC, 2014, p. 3). This embedded assessment as such represents a type of formative assessment - intended to provide important information regarding learners' or learning that can be used for subsequent instructional decisions or curriculum modifications. Kopriva and Sexton (2011) proposed using a variety of approaches by which different kinds of knowledge and skills can be assessed in an ongoing manner with ELLs in a classroom. The data analyzed in the chapter two and three provide information of how both teachers and students assess learning about the process of photosynthesis through three main questions, “Where are the students now?”; Where are they going?”; “Where to next?” Through the three iterations of the students’ visual diagrams the teachers could not only analyze how the students utilized what was taught through the various multimodal tasks and represent their learning but also assess their progress in understanding of the process of photosynthesis. The visual diagram tasks provided insights as to how the students responded to the feedback provided by the teachers and improved on the visual diagram. Through the self-assessment surveys given to the students after the completion of various tasks, I was able to distinguish the progression of students’ ideas of photosynthesis, by comparing the surveys done at different intervals of the unit.

Duran (2011) posited that an important aspect is to have assessments for ELLs embedded in ongoing classroom context so the students can draw on their understanding of “the everyday social and cultural characteristics of classroom life and its academic linguistic and task demands in responding to task” (p. 119). In order to develop expertise needed to teach culturally and linguistically diverse students, many researchers have urged the need for teachers to develop competencies in linguistically responsive pedagogical practices (Banks et al., 2005; Lucas & Villegas, 2013; Stoddart, Luis, Tolbart, & Bravo, 2010). It requires the building of *pedagogical language knowledge* – development of understanding of “language as action” (Bunch, 2013; Galguera, 2011; van Lier & Walqui , 2012, p. 47). They posit that, as part of the process of developing this foundation to support ELLs is to engage them in challenging and meaningful academic tasks, where the language demands of such tasks have to be taken into account. Several instances of “language as action” can be seen in this study wherein, the teachers planned multimodal tasks and addressed the language demands through instructional scaffolds through the use of analogies, contextualizing the use of vocabulary, re-representation of ideas in one task in another task and re-representation of modes of one task into another.

Interestingly, through the students’ perspectives it was evident that the students also appropriated the “language as action”, by using the curriculum-based vocabulary, use of the analogies and re-representing the modes of one task into other tasks. Not many research studies have examined how students respond or reflect on the use of multiple opportunities given to them to support their learning. This study has also highlighted the students’ views through the interviews, self-attitude surveys and self-reflection surveys on the use of the multimodal tasks, which they used to assist and show their understanding of the process of photosynthesis. Majority of the students appreciated the use of the various multimodal tasks to support their learning and found the representational tasks very helpful. However, the science attitude surveys reveal that the self-efficacy scores of all the students had decreased by the end of the unit, while most of the other science attitude scores had increased in the total sample. This could be attributed to the difficulty experienced by the ELLs to create the comic strip and to a number of incomplete comic strips, which had to be modified by the students again.

While assessing students from diverse cultural and linguistic backgrounds, often seen as sources of measurement errors are those related to culture and language factors (Solano-Flores, 2011). To address this issue, Solano-Flores and Nelson-Barber (2001) introduced the idea of *cultural validity* described as "the effectiveness with which science assessment addresses the sociocultural influences that shape student thinking and the ways in which students make sense of science items and respond to them" (p. 555). To attain cultural validity, attention must be paid to the ways sociocultural influences and interactions determine student perceptions of what science assessments are about, what they feel they are expected to do, and what strategies they use to solve them. Some of the scaffolding strategies used by the students provide an insight to how the students perceived the usefulness of the tasks, like the highlighting and underlining of the read aloud tasks, cutting and making the molecule model and re-representing the modes of one task into their own representational tasks. These strategies used by the students in the classrooms can also address some of the issues of cultural validity of the multimodal tasks.

Lee, Santau, and Maerten-Rivera (2011) suggested that to assess ELLs in science, separate criteria should be used to assess English Language proficiency and another to assess science knowledge. This separation will enable teachers to identify strengths and weaknesses of ELLs in each area and understand their learning needs. The science and language learning rubric provides a good exemplar of how equal importance was given to all the modes of representation of learning. In this study, the science and language learning rubric was designed in an attempt to identify how students represented their understanding of photosynthesis through various modes without relying on their proficiency in English language. By disaggregating the scores on each visual diagram and comic strip, not only based on English Learner status but also on students' proficiencies determined by scores in English Language arts, Science and Vocabulary acquisition and use on standardized tests, provided ways to show that being an ELL or not only does not entirely determine the students' ability to create multimodal tasks.

It is interesting to note that the students' perspectives mirrored the teachers' perspectives in the use of most of the multimodal tasks. What is worthwhile noting is that specific scaffolding strategies used by the teachers during the implementation of the tasks, like analogies, metaphors, contextualization of vocabulary use, re-representation of ideas through different modes were also appropriated by the students. There existed a certain level of alignment between the teachers' ideas of supporting learning and appropriation of those ideas of learning by the students. Where there was dissonance was in the perceived value of the comic strips. While planning, the teachers asserted the simplicity of the task and were confident that the students could create a comic strip. However, in the interviews some students in the English only category and most of the ELLs clearly articulated that it was difficult to create a story and incorporate the science ideas, whereas, the redesignated students expressed an interest in creating the comic strips. Subsequently, in the post unit interviews, the teachers described how they realized that the students struggled with the creation of the comic strips, especially the ELLs and felt that they should have modeled the story-making process and the way it can be integrated with the science content. The results from the science-language rubric too mirrored the views of the teachers and students. The gains in the scores in the visual diagrams for the ELLs demonstrated that the ELLs gained the most from the feedback from the teachers – a fact reiterated by the teachers while they assessed the two visual diagrams created by the students. Similarly, the teachers noted that some of the students struggled during the process of creating the comic strip, echoed by the students, and also evident by the low scores of ELLs in the comic strip. The redesignated students had the highest scores in the comic strips, showing that the additional supports they received to improve their English language proficiency may have contributed to their success (Shaw, 2009). The teachers reflected on the fact that most students need more scaffolding and modeling to create representations to show their understanding. In the final visual diagram, ELL status did not reflect on the performance on the tasks, however, students who were designated as below proficiency in English Language Arts, Science and Vocabulary acquisition and usage, had the lowest scores in the third visual diagram. The low performance of these groups indicate that these students also need more scaffolds and modeling while using multimodal tasks to support and help them represent their learning.

Kress, Charalampos, Jewitt, and Ogborn (2006) posited "assessment needs to be seen and rethought in the context of multimodality" (p. 176). In most schools, there are severe time constraints to teaching science, especially in schools where there is a high percentage of low- income students (Blank, 2013). Low priority is often given to science in classrooms, as it is a subject that is not tested every year (Anderson, 2012). The teachers in these two classrooms also experienced similar constraints. Despite these impedances, the teachers were able to teach a unit of photosynthesis preceded by a couple of lessons in plant parts and their function in order to prepare their students to succeed the following academic year. Noting the affordances and constraints provided by the multimodal tasks (see Table below) will serve to better support teachers in linguistically diverse classrooms.

Table 1
Affordances and Constraints of Multimodal Tasks Used in the Two 6th Grade Science Classrooms

Multimodal Tasks	Affordances	Constraints
To Assist Learning (Support Learning)	Using scaffolding strategies (highlighting, underlining, use of metaphors and analogies) Contextualizing the use of curriculum-based vocabulary Incorporating modes of one task while using another task Using different iterations of a representational task to assist learning	The use of analogies and metaphors (to be contextualized) Use of certain scaffolding strategies (ELLs need more support)
To Communicate Learning (Representational)	Using different iterations of a multimodal task to communicate learning Using different modes to communicate learning	Modeling of the representational tasks (frequent modeling required)

Limitations of the Use of Multimodal Tasks for Teaching, Learning, and Assessment of Linguistically Diverse Students

The primary limitation of the study is that it is situated in a setting with a small sample size of 63 students and two teachers within one unit of photosynthesis in two sixth grade classrooms. Even though there was triangulation of data for the analysis of teachers' views and beliefs, planning and implementation and teacher decision- making, the teachers' perspectives were limited to the model I used for analysis (Clark & Peterson, 1986; Ruiz-Primo & Li, 2013). I used the model to best capture of how and why teachers used multimodal tasks to support science learning. Nevertheless, the teachers' use of multimodal tasks was limited to the unit of photosynthesis and not examined within other science content or domains. Due to time limitations, instructional or curricular modifications to the multimodal tasks could not be examined. Unique to this study is the elaboration of the students' perspectives of the use of multimodal tasks to support their learning. While I was able to capture their understanding of the process of photosynthesis through the interviews and self-assessment surveys, the science attitude surveys and self-reflection surveys focused on their feelings of efficacy and which task they perceived helped them the most. I administered the science attitude surveys before the unit and the teachers administered the science attitude surveys after the unit. The teachers had complained that there was very little compliance shown by the students to complete the survey and felt that they may not have written the apt responses. Therefore, the results from the science attitude survey may have given a glimpse of the students' attitudes before and after the unit and the scores may have been affected by other factors and not necessarily by their experience with the multimodal tasks in the unit.

Despite the fact that the goal of the final self-reflection survey was to capture how the students felt each task supported their understanding of photosynthesis, the questions may not have been adequate in separating the affective aspect towards a task versus the learning aspect of a task. Chances are that the students' responses reflected their feelings towards a task or the purpose of the task rather than the extent of its use in showing their understanding of the process of photosynthesis. That is why most students claimed that both the visual diagrams and comic strips helped them in understanding the process of photosynthesis. Another delimiting factor was the timing of the students' interviews as they could be interviewed only after class hours or during recess. Hence the interviews were conducted at different time intervals during the unit where the students had not completed similar multimodal tasks. As the interview questions had to be tailored to suit each student's timing of the interview, a wide variety of responses could not be elicited.

Although this study was conducted within certain time constraints, examining the teachers' perspectives and the students' perspectives provided insights on the use of multimodal tasks. However, the following could not be done, namely, (a) the examination of self-assessment surveys of the students by the teachers, (b) student discussion of their self-assessment surveys, and (c) further examination of the surveys by the students to assess their own progress in understanding the process of photosynthesis. In sum, even though this study invokes the notion of self-assessment through the self-assessment surveys, it was mostly done through my analysis and not entirely through the students' viewpoints.

Finally, the validity and reliability of the science and language learning rubric were established, albeit more rigorous analysis has to be done to examine the validity of constructs of the rubric in the form of principal component analysis. This analysis can be done in further research and can be implemented as next steps in this research study.

Recommendations for the Use of Multimodal Tasks for Teaching, Learning, and Assessment of Linguistically Diverse Students

This paper has identified research findings that could inform approaches of immense pedagogical value to ELLs in science which include explicit focus on constructing and interpreting multimodal texts by the students (Meltzer & Hamann, 2005). In science education for ELLs, the limited success of the sociocultural approach could be attributed to its "cultural navigation perspective," which tends to critique mainstream academic knowledge and provide a hybrid space for students to engage in everyday knowledge and linking it with science (Moje, 2007, p. 28). While this has been very useful in supporting the knowledge students bring with them, the disciplinary practices as explained by the new standards are often not attended to. The common rhetoric ascribed by educational reformers is that all students in science classrooms should be engaged in the activities or practices of scientists, rather than just learning about the results of those practices. Ford and Forman (2006) explicate the importance of "a grasp of practice," which can be considered as a sort of road map that highlights the relationships among facts, methods, and values and a set of abilities for reasoning coherently across these dimensions, which is key to learning informational content in science (p. 3).

The increasing population of ELLs in the United States coupled with the lack of instructional resources and academic support to assist their science learning pose challenges. Considering the heterogeneity of the ELL population and their varying proficiencies in English Language (Wright, 2010), using the term "English Language Learner"—an all-encompassing demographic term—as a reference point for teaching or assessing practices is problematic (Galguera, 2011). Instead we should examine how students of different linguistic backgrounds can apprentice into the "language use for academic purposes" (Galguera, 2011, p. 86). One of the ways to accomplish the academic discourse of science is through the integrated use of multiple modalities in classroom settings like reading, talking, gestures, writing and drawing. Bunch (2013) has described the notion of pedagogical language knowledge—"purposefully enact opportunities for the development of language and literacy in and through teaching the core curricular content" (p. 298). In this study, using multimodal tasks has provided several avenues for the teachers to develop both English language and the language of science while teaching the core curricular content of photosynthesis. Most of these opportunities were also utilized by the students through those multimodal tasks which were used to assist in the learning process, namely the videos, read louds, making the molecule model and the seed germination task. The visual diagrams and comic strips created by the students to represent their understanding of the process of photosynthesis provided students the opportunity to represent their understanding through the use of symbols, images and curriculum-based vocabulary.

As seen in this study, other facets of academic proficiencies based on standardized tests proved to determine how students use multimodal tasks in science, such as proficiency in English Language Arts, Science and Vocabulary acquisition and usage. Even though I do not claim proficiencies in the state standardized tests to be adequate measures of learning, the proficiency levels demonstrate a trend of how the students perform based on a certain standards determined at the state level. What is noteworthy is that ELL status only determined the students' creation and demonstration of learning on the comic strips. However, proficiencies in the representational tasks in English Language Arts, Science and Vocabulary acquisition and use had a more profound influence on how the students performed on the tasks. What is noteworthy is how students who were below proficient in English language arts tended to use images more than the other groups, and if a student group had an increase in curriculum-based vocabulary, they also had an increase in knowledge of disciplinary core ideas.

Based on the findings of this study, the recommendations for the use of multimodal tasks can be seen at three levels: applications for teachers in science classrooms; applications for ELLs for science; and impact on further research in science education.

Applications for Teachers in Science Classrooms

While planning and implementing multimodal tasks in linguistically diverse science classrooms, teachers should pay attention to (a) aligning the multimodal tasks learning goals and having separate multimodal tasks for both communicative (to assist learning) and representational (to represent learning) purposes; (b) contextualizing the use of curriculum based vocabulary by using metaphors and analogies familiar to students; (c) using of multimodal tasks to assess student learning over time; (d) providing more scaffolds by modeling the representational tasks for ELLs and (e) connecting and synthesizing ways and means on how the multimodal tasks are viewed, planned, implemented and influenced further curricular planning and instructional steps.

Applications for ELLs for Science

Multimodal tasks provide the ability to interact with different modes namely visual, verbal, tactile, gestural without an exclusive focus on written text. A key aspect to multimodal perspectives on learning is the assumption that meanings are made through many representational and communicational resources, of which language is but one (Kress & Van Leeuwen, 2001). Therefore, while implementing multimodal tasks for ELLs, (a) use several scaffolding strategies like highlighting and underlining of text and use metaphors to describe vocabulary words to assist the learning process; (b) integrate understanding of science content and language, re-represent modes by incorporating modes used in one task into others thus weaving common and connecting links amongst all the multimodal tasks; (c) model the use of representational tasks for ELLs - another crucial aspect of integrating the understanding of science content and language (d) provide opportunities for students to represent their learning in a similar type of multimodal representation (with both visuals and text) at various times in a unit will be effective in not only assessing students' learning over time but also deepening their understanding of the process of the disciplinary core science ideas.

Impact of Further Research in Science Education

This study focuses on research in classroom settings. For future research this study can provide insights to expanding design-based research in multimodal tasks in science classrooms for linguistically diverse settings "to include development and testing of innovations that foster alignment and coordination of supports for improving what takes place in classrooms" (Penuel, Fishman, Cheng, & Sabelli, 2011, p. 331).

The findings of the teachers' perspectives can inform some of the tenets of "*pedagogical language knowledge*" (Bunch, 2013) where the teachers demonstrated the use of language as action (van Lier and Walqui, 2012). Using the multimodal tasks for teaching, assessing and learning in science classrooms and assessing their learning through the science and language learning rubric can inform ways of adhering to the notion of *cultural validity* of assessing linguistically diverse learners. Assessing student learning over time and examining students' perspectives of learning adheres to the notion of *formative assessment*. The findings from examining the multimodal tasks through the teachers' and students' perspectives can inform how a sociocultural orientation of using the multimodal tasks through both dynamic and distributed notions of assessment can support science learning.

Moje (2008) sums the value of multimodality aptly as:

> A person who has learned deeply in a discipline can use a variety of representational forms—most notably the reading and writing of written texts, but also oral language, visual images, music or artistic representations—to communicate their learning, to synthesize readings across texts and groups of people, to express new ideas, and to question and challenge ideas dear in the discipline and in broader spheres. (p. 99)

The *complementary approach* of examining the alignment of the teachers' and students' perspectives and using the science and language learning rubric to examine the potential of the multimodal tasks to support learning provides us with a nuanced understanding of how teachers and students develop content area understanding. Multimodal tasks have the potential to provide linguistically diverse learners the exposure to complex scientific content, without requiring them to be fluent in the English language and the language of science. As such when multimodal tasks are used in linguistically diverse science classrooms they can open avenues to participation in classroom and expanding knowledge in science.

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