MULTIMODAL COMPOSING IN MARINE BIOLOGY: MULTILINGUAL LEARNERS' STRENGTHS AND PARTICIPATION IN SCIENCE PRACTICES

By

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To my family

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Multilingual learners (MLs) bring numerous resources to science learning contexts. In classrooms, multilingual learners have expansive linguistic repertoires to draw upon for information-seeking (Gynne & Bagga-Gupta, 2015), collaboration (French, 2016; García & Sylvan, 2011), and learning (Vygotsky, 1978). However, within US secondary science classrooms, traditionally English-centric spaces, MLs' resources may go unrecognized for a number of reasons, including monolingual ideologies (Wiley & Lukes, 1996), assimilationist discourses (de Jong, 2013), and language-as-problem orientations (Ruiz, 1984).

Multimodal composing provides opportunities to engage with and learn through modes in addition to language (e.g., image, sound, realia). While composing through multiple modes in classrooms, MLs have access to a wide range of nonlinguistic resources for the learning of content (Goulah, 2017; Suárez, 2020; Zheng et al., 2014), language (Goulah, 2017; Gynne & Bagga-Gupta, 2015; Pacheco & Smith, 2015), and composing (Ajayi, 2015; D'warte, 2014; Dalton et al., 2015). Multimodal composing has been shown to hold benefits for MLs in other content areas (Baize, 2019; Kane, 2018;

Smith, 2019; Smith et al., 2019; Staurseth & Håland, 2018) but few studies have explored its affordances within secondary biology (notable exceptions Castek & Dwyer, 2018; Pierson et al., 2021).

This dissertation explored multilingual learners' use of various modes and participation in science practices within a secondary marine biology classroom through a comparative case study. Findings of this dissertation study demonstrate how multilingual learners used various modes while multimodal composing to: (1) interact with classmates, (2) position themselves, and (3) enact their vision of engaging in science. Further, findings also show how multilingual learners participated in science and engineering practices: (1) by leaning into their strengths, (2) in accordance with how they positioned themselves, (3) and in accordance with their understandings of science. Findings from this work have implications for current conversations in multimodal composing research, science education for multilingual learners, and language education.

CHAPTER 1
INTRODUCTION

This chapter provides an introduction to the dissertation. This work studied multilingual learners' (ML's) multimodal composing of three artifacts. Specifically, how they used various modes and participated in science and engineering practices (SEPs) while composing in a secondary marine biology classroom. Here, I describe the background, state the problem, present my research questions, and describe the significance of the study.

Research Background

Multilingual learners (MLs) bring numerous resources to science learning contexts. In classrooms, multilingual learners have expansive linguistic repertoires to draw upon for information seeking (Gynne & Bagga-Gupta, 2015), collaboration (French, 2016; García & Sylvan, 2011), and learning (Vygotsky, 1978). In addition to linguistic resources, MLs possess rich cultural resources that can be tapped into for meaningful participation (Clark, 2020), academic success (García et al., 2013), and mutual support of one another's academic learning (Kwon et al., 2019). Though MLs possess abundant resources, the reality is that they also face challenges in leveraging these resources for their learning within science classrooms (Lemmi et al., 2019).

Within US secondary science classrooms, traditionally English-centric spaces, MLs' resources may go unrecognized for a number of reasons. Broadly, US K-12 education has been influenced by monolingual ideologies (Wiley & Lukes, 1996), assimilationist discourses (de Jong, 2013), and language-as-problem orientations (Ruiz, 1984). Even within education research, MLs are often framed as challenges to be addressed, rather than students who are ready to learn (Gutiérrez and Orellana, 2006).

While many influences shape secondary classrooms and student experiences, this study is concerned with MLs in science classrooms and will, therefore, focus on challenges specific to science classrooms. In the sections below, I describe a sociocultural perspective of learning before classifying the challenges relating to MLs in science classrooms into two broad categories: those relating to language and those relating to participation. Later, I present multimodal composing as an opportune space where MLs can overcome these challenges while leveraging their strengths within secondary science classrooms.

Sociocultural Perspective of Learning

Central to research from a sociocultural perspective is the acknowledgement of the social formation of mind (Wertsch, 1985; Lantolf & Thorne, 2006; Hawkins, 2008). Social activity not only influences cognition, but "is the process through which human cognition is formed" (Lantolf, & Johnson, 2007, p. 878). Therefore, the role of social activities in learning and development cannot be overstated. This study explores MLs within a particular social activity, multimodal composing.

Sociocultural Theory (SCT) views learning as mediated through interactions between individuals and between individuals and their culturally constructed tools (Cole, 1996; Vygotsky, 1978) within the zone of proximal development (ZPD) (Mercer & Howe, 2012). Individuals' movement, or progress, within the ZPD is defined within SCT as development which is driven by learning. Learning can be evidenced by changes in a learner's participation (e.g., the ability to complete a particular assignment with less support than was previously necessary).

The ZPD is the invisible space between what individuals can do independently and what they can do with support from a more knowledgeable other or cultural artifacts

(tools) (Vygotsky, 1978). Work in sociocultural theory has presented an expanded notion of the ZPD; from a space for novice-expert interactions to a space for "collaborative construction of opportunities… for individuals to develop their mental abilities" (Lantolf, 2000, p. 17). Students do not simply take up and copy their teachers' strategies, they "transform what the experts offer them as they appropriate it" (Lantolf, 2000, p. 17). Rather than a place for production of copies of teachers' examples, the ZPD can be a communicative space for interaction not only with teachers as more knowledgeable others, but with peers as well, as students mediate one another's learning.

As learners participate in social activity, such as multimodal composing, their actions are mediated by tools and individuals within their setting. This mediation is the negotiation of learning through the use of physical or psychological tools (Martin-Beltrán, et al., 2017b). In other words, mediation is the work that takes place for the purpose of learning. In K-12 education, teachers mediate students' learning by leveraging tools and students also leverage tools to mediate their own learning and to co-construct understandings with other individuals. Over time, mediation moves from external to internal (internalization), as students become able to self-mediate rather than rely on external tools (Vygotsky, 1978).

In this study, SCT allows me to focus on important actions for learning. Students' composing moves, communications with peers, the tools they employ, and support provided by the teacher are all essential aspects of their participation. SCT emphasizes the importance of interactions and participation for learning, therefore this study will

explore how MLs use various modes and participate in science and engineering practices within the social activity of multimodal composing.

Science Classroom Challenges for Multilingual Learners

Within K-12 science classrooms in the US, particular challenges exist for multilingual learners. Though these challenges are numerous, this work is concerned with those relating to interaction and participation and are explored within the following sections.

Challenges relating to interaction

Primacy of Written and Spoken Language. Traditionally, written and verbal language has been framed as primary within traditional English-centric science education (Yore & Hand, 2010). Both literacy education and science education have posited a view of scientists as readers and explored how this notion should influence science education (Greenleaf et al., 2011; Holliday, 1984; Holliday & Cain, 2012; Holliday et al., 1994; McClune & Jarman, 2011; Yore et al., 2002). In science classrooms, textbooks and teachers, who frequently employ lecture-heavy pedagogies, have been considered important sources of science content and instructional support (Bruner, 1992; Stern & Roseman, 2004; Vojíř & Rusek, 2019). This could contribute to the prevalence and importance ascribed to written and spoken language.

In secondary science classrooms, essential content can be hidden behind a wall of written and verbal language (Jaipal, 2009). This creates difficulty for students whose greatest reading, writing, speaking, and listening strengths reside in a language other than English, particularly if the all-knowing textbook and teacher lectures are available only in English (González-Howard & McNeill, 2016; Téllez & Mosqueda, 2015).

Language *of* Science. The language *of* science is intricate, containing specific terminology, linguistic features, and discourse which separate it from language in everyday life (Fang, 2005; Seah & Silver, 2020). Though it can be challenging for all learners (Gilbert, 2004), the language *of* science is especially challenging for MLs (Derewianka, 2014; Seah & Silver, 2018). Its specific terminology and linguistic features that represent abstract ideas and approaches can make science-related concepts seem incomprehensible and are often difficult for learners to grasp, all of which contributes to the "mystique of science" (Lemke, 1990, p. 128). These challenges may be especially stressful for MLs who have worked hard to become successful linguistically in social situations and other content areas but feel stumped in science classrooms. Additionally, Aschbacher and colleagues (2010) described how, for some participants, not understanding the language of science caused them to like science less and feel they did not belong in a science classroom (p. 571). This is significant, as a lowered sense of self-efficacy can impede secondary students' science performance (Britner & Pajares, 2006) and could potentially hinder further engagement in science (Betz, 2004).

Challenges relating to participation

Expectations. Beyond language, MLs face challenges relating to participation in science classrooms. First, teachers may have misconceptions about MLs' experiences in previous classrooms or there can be disconnects between students' and teachers' ideas of what constitutes 'appropriate' participation (Harper & de Jong, 2004). For instance, responding to questions (de Jong & Derrick-Mescua, 2003), conducting oral presentations (Schoultz et al., 2001), and contributing to group collaborations (Harper & de Jong, 2004) have all been found to be challenging for MLs in classrooms. These activities may be challenging because of the language knowledge and skills involved, or

because they may not align with MLs' previous experiences in science classrooms, as expectations vary across cultures (de Jong & Harper, 2005). When MLs' participation in secondary content classrooms does not fit teachers' expectations, opportunities for learning can be lost (Berg et al., 2012).

Support. Prior research has shown that with appropriate supports in place, MLs can actively and successfully participate in science classroom activities and learning (Gomez et al., 2019; Manavathu & Zhou, 2012). However, MLs do not always receive support for reasons including, but not limited to, science teachers' beliefs about: MLs' abilities, linguistic diversity, and their own roles as teachers of science (see Kim, 2021 for review). It often falls to classroom teachers to provide the content and language supports MLs need (Viesca et al., 2019) even though many science teachers feel they are underprepared to provide them (Coady et al., 2011; Janzen, 2008).

Support for MLs through Multimodal Composing in Science Classrooms

Given the challenges facing secondary MLs with respect to interaction and participation, this study explores the affordances of multimodal composing within a marine biology classroom. Multimodal composing is the creation of artifacts using multiple modes such as image, sound, and text. Within classrooms, it affords opportunities for MLs to engage in and learn about language, content, and composing (Pacheco et al., 2017; Smith, 2019; Smith et al., 2020; Westlund, 2018) while leveraging their real-world experiences as resources (Matuk et al., 2021). Engagement with and composing about science through various modes is advantageous to all learners, but especially MLs (Ryoo & Bedell, 2019). There is also some evidence to suggest engagement that multimodal composing can work as a tool to increase the diversity of students likely to engage with science (Matuk et al., 2021, p. 699). Multimodal

composing can serve as a space where MLs have opportunities to access their resources for learning while addressing challenges that exist with secondary science classrooms. Importantly, within this study, MLs compose collaboratively in groups of two, therefore when I reference the benefits of multimodal composing relating to language and participation I am viewing multimodal composing as a collaborative process.

Support relating to interaction, beyond written and spoken language

Multimodal composing emphasizes the role of modes beyond language for communication (Jewitt et al., 2016; Kress, 2009). This provides MLs opportunities to engage with and learn through modes in addition to written and spoken language (e.g., image, sound, realia). While composing through multiple modes in classrooms, MLs have access to a wide range of nonlinguistic resources for the learning of content (Goulah, 2017; Suárez, 2020; Zheng et al., 2014), language (Goulah, 2017; Gynne & Bagga-Gupta, 2015; Pacheco & Smith, 2015), and composing (Ajayi, 2015; D'warte, 2014; Dalton et al., 2015). I argue multimodal composing could provide opportunities for MLs to practice taking up language for science and begin demystifying the "mystique of science" (Lemke, 1990, p. 128).

Language for Science. Multimodal composing affords MLs opportunities to engage in science through language in multiple ways rather than emphasizing how MLs "should" use language to engage in science. By viewing language as a tool for meaning making the focus shifts from what it is or should be (i.e., 'correct' vocabulary, grammar, etc.) to what languages does (i.e., how learners use it to engage in science) (Grapin et al., 2019; Lee, 2021). In other words, a language for science perspective in multimodal composing reframes the focus for MLs in science education by centering their

participation and placing language as a resource, or tool for that goal. In this work, valuing language for how it is used by MLs in a biology classroom removes it from the position of gatekeeper to a tool for communication, participation, and learning.

Support relating to participation

Several aspects of multimodal composing make it a prime space for MLs' leveraging of various modes and participation in SEPs in secondary science classrooms. SEPs are recognized as one of the three dimensions of science learning by the Next Generation Science Standards (NGSS Lead States, 2013). The eight overarching SEPs describe what scientists and engineers do as they investigate the natural world. First, multimodal composing is a collaborative process (see Smith, 2014; Smith et al., 2020 for reviews) which is important from a sociocultural perspective, and this dissertation study emphasized this by exploring participants' composing in groups of two. Also, multimodal composing has been found to be engaging for secondary students (see Smith, 2014; Smith et al., 2020 for reviews) which is important for learning as students' active participation in activity is essential for mediation and learning (Karpov, 2005; Vygotsky, 1986). In addition, Jiang and colleagues (2020) found that multimodal composing may drive students' interest and motivation in learning science.

While composing, students use multiple modes to facilitate ongoing interactions (see Hwang & Hu, 2013 for an example from math education) which are spaces for mediation as students leverage tools (Vygotsky, 1978; Karpov, 2005). Multimodal composing allows MLs to explore and display their understandings of concepts through the creation of representations of their ideas. In other words, the making visible (multimodal compositions) of the invisible (MLs' understandings) creates space for expanded peer discussions (Jahnke et al., 2013) and feedback (Jiang et al., 2019). For

instance, students can draw upon their understanding of DNA to create a visual representation which makes their ideas visible, and therefore, available to other learners and the teacher. This not only provides teachers with opportunities to provide feedback, but multimodal composing may also position teachers to shift their expectations for student participation. As students compose, teachers can observe their engagement with content in-the-moment through *multiple modes* rather than depending upon more traditional ideas of participation which often rely upon written or oral language.

Multimodal composing can also grant students autonomy over their participation while teachers can play complementary roles (Jiang & Luk, 2016), as they are positioned as supporters who can scaffold content and composing (Pacheco, et al., 2021). Finally, multimodal composing allows MLs to interact and participate with content while engaging with multiple and diverse audiences (Noguerón-Liu & Hogan, 2017; Pacheco et al., 2017). Multimodal composing can remove traditional classroom barriers relating to space and time (DeBruin-Parecki & Klein, 2003; Price-Dennis & Carrion, 2017) and open opportunities for collaboration and participation beyond classroom walls (see Smith, et al., 2020 for review).

Multimodal Composing in Marine Biology Classrooms

Marine biology, the study of marine organisms, is situated within the larger field of biology, the study of living things. Biology holds a place of importance within science education as it is foundational to other branches of science, is often accompanied by high-stakes assessments (Macpherson, 2009; Bach, 2020), and is sometimes a requirement for college admission (Freeman et al., 2011). Above, I discussed multimodal composing for MLs broadly, focusing upon secondary science education as MLs' learning in biology classrooms is an emerging area of research, particularly

regarding multimodal composing. Unfortunately, I was unable to identify any examples of research exploring multimodal composing in marine biology. Still, I anticipate numerous benefits of multimodal composing for MLs in secondary marine biology. Essential to this study are the notions of various modes and science and engineering practices as I suggest multimodal composing presents opportunities for MLs to leverage various modes and participate in SEPs in a secondary marine biology classroom.

Various Modes

While composing multimodal artifacts in secondary biology classrooms, MLs can use their full linguistic and semiotic repertoires (Pacheco & Smith, 2015; Smith et al., 2017), mixing named languages and nonlinguistic modes to communicate meanings in nuanced ways (García & Sylvan, 2011; Smith et al., 2020). In this dissertation, I explore MLs' use of various modes, including language, as part of participants' composing processes. To define mode, I draw from Kress' (2009) work, defining it as a "socially shaped and culturally given semiotic resource for making meaning" (p. 79).

Science and Engineering Practices (SEPs)

The eight science and engineering practices (SEPs) of the Next Generation Science Standards (NGSS) describe things scientists do to investigate the world, explaining and extending what is meant by "inquiry" and the range of practices that it requires (NGSS, 2013a; 2013b). Previous work by Walsh and McGowan (2017) has demonstrated that students can engage in SEPs while composing a multimodal artifact in a secondary biology classroom. However, their analysis centered on the affordances of support provided to students by science experts rather than students' composing processes. Further, Walsh and McGowan's study did not include MLs (2017). This study

was built upon prior findings by exploring how multilingual learners participated in science and engineering practices as part of their multimodal composing processes.

Statement of the Problem

Science is often a challenging content area for multilingual learners (Buxton & Lee, 2014), even more so than other content areas in K-12 education (Curran & Kitchin, 2019). Though MLs possess multiple resources for learning, they are not always able to leverage them within secondary science classrooms. Multimodal composing has been shown to hold benefits for MLs in other content areas (Baize, 2019; Kane, 2018; Smith, 2019; Smith et al., 2019; Staurseth & Håland, 2018) but few studies have explored its affordances within secondary biology (notable exceptions Castek & Dwyer, 2018; Pierson et al., 2021) and none were identified within secondary marine biology classrooms.

Research Purpose and Questions

This dissertation explored an under-researched area, secondary MLs' multimodal composing in a secondary marine biology classroom and contributed to the larger conversation around MLs' learning strengths and needs in science. Specifically, MLs' needs go beyond language learning, which have sometimes been emphasized without full recognition of the strengths MLs bring to science classrooms (Clark et al., 2012; Nabors & Edwards, 2011; Snow, 2010). In essence, to the science education community this work aims to say; it is not just about language, MLs have resources that can be leveraged for science learning and participation. To the language learning community this work aims to say; it is not just about language, MLs' needs extend beyond learning how to read, write, speak, and listen. They are students of content as

well as language and are expected to learn and participate in multiple contexts. To achieve this work, I will investigate the following two overarching research questions:

- How did multilingual learners use various modes while multimodal composing in a secondary marine biology classroom?
- How did multilingual learners participate in science and engineering practices while multimodal composing in a secondary marine biology classroom?

Significance of the Study

This study contributed to understandings of how multilingual learners can leverage various modes and participate in SEPs as part of their multimodal composing processes. Though there is a growing number of studies of MLs' multimodal composing in secondary science classrooms, English language arts is still the most popular content setting for this work (Smith, et al., 2020). This dissertation is an important step as research on multimodal composing expands to create supportive environments for MLs' in classrooms beyond ELA. Perhaps most importantly, this study will emphasize multimodal composing as a space where MLs can leverage their unique resources and participate as successful members of a science learning community. This is in contrast with some previous work that has framed MLs as students in need of additional support. This dissertation aims to support understandings of MLs' secondary science classroom experiences and perhaps more broadly, framing of members of this group as learners while challenging commonly held beliefs surrounding what counts as valid participation in a secondary science classroom.

This work exists at the intersection of language education, as it centers multilingual learners, science education, as it explores students' participation in science practices in a secondary marine biology classroom, and literacy education, as it

explores a literacy practice, multimodal composing. While there is an emerging body of work that studies how literacy practices can support multilingual learners' participation in K-12 science classrooms (Jiang, 2023; Pierson et al., 2021; Grapin, et al., 2022; Grapin et al., 2023), more work is needed, particularly within secondary education contexts. Additionally, scant research in secondary marine biology education includes multilingual learners at all, in fact, no existing examples were able to be identified.

Chapter Summary

This chapter introduced the dissertation study, provided the research background, stated the problem the work addresses, outlined the research questions, and described the significance of this work.

CHAPTER 2
LITERATURE REVIEW AND THEORETICAL FRAMEWORK

In this chapter, I outline my theoretical perspective for this study and review the relevant literature. I begin by defining learning within sociocultural theory before describing how it has been taken up by scholars in similar studies and how existing findings have influenced this dissertation study. Next, I define various modes, particularly those explored within this study, and participation, from a sociocultural perspective. Finally, I review relevant literature on multilingual learners (MLs) in K-12 schools in the US as well as challenges faced by members of this group, particularly in science education. Then, I review existing literature on multimodal composing for student learning in K-12 content area classrooms, before narrowing the focus to secondary biology, as I was unable to identify any literature on multimodal composing in marine biology classrooms. Finally, I describe the current literature on multimodal composing in secondary biology classrooms both with and with a focus on MLs learners before articulating a need for further qualitative studies to explore this area.

Theoretical Framework

This work is informed by sociocultural theory (Vygotsky, 1978). Sociocultural theory provides an important view of learning, participation, and language.

Sociocultural Theory of Learning

Central to research from a sociocultural perspective is the acknowledgement of the social formation of mind (Wertsch, 1985; Lantolf & Thorne, 2006; Hawkins, 2008). Social activity not only influences cognition, but “is the process through which human cognition is formed” (Lantolf, & Johnson, 2007, p. 878). Higher-order cognitive processes occur first externally, on what Vygotsky (1978) calls the “social” or

“interpsychological” level and later on the “individual” or “intrapsychological” level. Therefore, the role of social activities on learning and development cannot be overstated.

Through sociocultural theory, learning is social, it occurs through interactions between individuals and individuals and tools (Cole, 1996; Engeström, 2001; Vygotsky, 1978) within the zone of proximal development (ZPD) (Mercer & Howe, 2012). Learning is influenced by culture and history partially because the tools that are leveraged through mediation are cultural artifacts. Some suggest thinking of learning as shifts in identity (Gee, 2001) and Moje and Lewis (2007) further described this as “one learns to take on new identities along with new forms of knowledge and participation. Deep, participatory learning involves learning not only the stuff of a discipline-science content, for example-but also how to think and act something like a scientist, even if one does not enter the profession of science.” (p. 19). Central to sociocultural theory, mediation is the facilitation or negotiation of learning through the use of physical or psychological tools (Martin-Beltrán, et al., 2017b). I think of mediation as the work that takes place for the purpose of learning. In K-12 education, teachers mediate students’ learning through interactions and the use of tools, while students also leverage interactions and tools to mediate their own learning and co-construct understandings with other individuals. Over time, mediation moves from external to internal (internalization), as students become able to self-mediate rather than rely on external tools (Vygotsky, 1978).

The goal of external mediation is internalization, the process of a learner turning an external symbolic artifact into an internal psychological artifact to mediate mental activity (Lantolf, 2006). Sometimes characterized as appropriation, internalization refers

to mediation that occurs externally, in the social realm, that is taken up, or appropriated, by learners and changes their participation. For example, a biology teacher may mediate a students' participation in an SEP by reminding the student that engaging in argument from evidence is a science and engineering practice before asking the student to state the evidence for their claim. The teacher may provide further support by returning with the student to the evidence (perhaps from an online source) and reviewing the information. Later, if the mediation was internalized, that same student will be able to independently leverage evidence to form arguments. Importantly, a learner does not simply copy a more knowledgeable other's abilities; instead, they "transform what the experts offer them as they appropriate it" (Lantolf, 2000, p. 17). Transformation refers to the way in which cultural artifacts, tools, or mediation is internalized and appropriated. In essence, it refers to how learners make it their own, rather than copying it (Frawley, 1997; Lantolf, 2006).

The Zone of Proximal Development (ZPD) is the space between what a learner/individual can do independently and what they can do with support from a more knowledgeable other or cultural artifacts (tools) (Vygotsky, 1978). Lantolf (2000) defined it as "not a physical place situated in time and space; rather it is a metaphor for observing and understanding how mediational means are appropriated and internalized" (p. 17). Work in sociocultural theory has presented an expanded notion of the ZPD to from a space for novice-expert interactions to a "collaborative construction of opportunities… for individuals to develop their mental abilities" (Lantolf, 2000, p. 17) where the ZPD can be co-constructed and expanded by groups of peers (Golombek & Johnson, 2004; Martin-Beltrán et al., 2017a).

Tools are “artifacts created by human culture(s) over time” (Lantolf, 2000, p. 1). While some tools are physical (e.g., pencils and paper), others are psychological (e.g., language, symbols, formulas). Tools are used first externally to mediate development before being internalized for internal mediation (e.g., mnemonic to remember algebraic order of operations). Humans use tools to mediate our relationship with the world (Lantolf, 2000). Because tools are created by culture over time, generations can change their tools before passing them on to the next. Not only do individuals use tools to act on the world, the tools act on individuals, shaping their activity – it is a reciprocal relationship (Vygotsky, 1978). In fact, mediational means, such as tools and individuals within the context, “constrain as well as enable action” (Wertsch, 1998, p. 25). When applied to multimodal composing, this idea highlights how different digital and non-digital tools, peers, and the teacher offer unique affordances and limitations for how MLs can engage with composing, language, and SEPs.

Language is the most important psychological tool as it is the foundation for higher cognitive processes (Vygotsky, 1978). In K-12 education, teachers use language to mediate students’ learning and students use language to mediate their own behavior (Lantolf, 2000). For example, when teachers discuss observed misconceptions in class they provide feedback and students ask clarifying feedback. Language, including all languages within MLs linguistic repertoires, is an essential tool to consider in my work with multilingual learners in English-centric biology classrooms.

Scaffolding is a temporary support provided by a more knowledgeable other within the zone of proximal development (Gibbons, 2002). Scaffolds can be used to mediate students’ learning, but they are different from mediation in that they are

temporary (Gibbons, 2002). Mediation is internalized, while scaffolds are removed when no longer needed. Within classrooms, scaffolds are often leveraged by teachers, as they are recognized as the more knowledgeable other. However, expanded ideas of the ZPD also shape conceptions of scaffolding, specifically who can leverage them. Though some hold that the metaphor of scaffolding has no place in Vygotsky's ZPD (Butler, 1998; Xi & Lantolf, 2020), as it does not embrace the full potential for development within it, I acknowledge the recognizability of the term within education and while I agree the metaphor has inherent weaknesses, I cannot deny the power it holds within education, particularly when SCT is being discussed. In science classrooms, common scaffolds include anchor charts on walls to display differences between mitosis and meiosis, visual representations of the parts of a cell, and teachers' feedback.

Sociocultural Theory in Multilingual Classroom Settings

Martin-Beltrán, Guzman, and Chen (2017b) explored how teachers differentiated discourse to mediate MLs' language and literacy learning in a culturally and linguistically diverse high school, outside of classroom time. As students worked in small groups to compose bilingual PowerPoint presentations, teachers modelled language, legitimized students' contributions, asked reflective questions about language use, and offered differentiated feedback during what the authors called "mediational episodes" (p. 48). Teachers' differentiated discourse "created conditions for the emergence of a collective ZPD" (p. 48) which built upon previous work by Martin-Beltrán (2012) in which the ZPD was broadened from a space between a learner and more knowledgeable other to what Martin-Beltrán and colleagues described as "a collective learning space that is constituted through interaction as participants co-construct knowledge together" (p. 102). Findings described how not only did teachers mediate MLs' learning within the

ZPD, but MLs mediated for one another as they co-constructed a ZPD and learned together. This study furthers the conversation on the shift from traditional thinking around novice/expert roles within the ZPD, allowing for recognition of the co-construction of knowledge between learners. This study influences my thinking around how mediation occurs in classrooms, particularly, between which individuals. Teacher-learner and learner-learner interactions were both considered, relating to how MLs use various modes as well as their participation in SEPs. For instance, findings may demonstrate ways in which the classroom affords teacher-student mediation of multimodal composing, but not student-student mediation, while perhaps MLs' use of modes will usually be mediated by students for students.

Martin-Beltrán, Daniel, Peercy, and Silverman (2017a) explored mediation and expansion of the ZPD by MLs in cross-aged peer (CAP) groups in elementary classrooms. In this article, fourth grade students were paired with kindergarten students for a CAP buddy program in which each pair read English texts together. Findings demonstrated that students “made literacy relevant” (p. 157) moment-to-moment, using discursive support to: (1) (re)engage with literacy practices, (2) affirm relationships with peers, and (3) build upon ideas and make meaning of text on their own terms. The focus of this study used the concept of the ZPD to explore how CAP groups co-constructed a “zone of relevance” (p. 157). This zone of relevance was a space where students could draw upon shared experiences “as children of similar cultural and linguistic communities” (p. 163). This is important because it is built upon sociocultural ideas from prior work (Martin- Beltrán 2012; Martin-Beltrán et al., 2017b) by looking specifically into how peers mediated for one another. Findings demonstrate they did so through the

creation of space (within the ZPD) by making literacy and literacy practices relevant in ways they did not when working with teachers or other adults. This study influences my thinking on learner-learner mediation as MLs (and other learners) can make information relevant to one another in ways teachers cannot. While Martin-Beltrán and colleague's (2017a) study centered language and literacy practices in an elementary classroom, I anticipate similar findings are possible in a secondary biology classroom.

Collett (2019) views learning as "shifts in participation in a practice that supports shifts in thinking" (p. 238). Collett posited that a learner's identity can reveal how and why they are able to participate in the practices that are central to learning. The focal student in this study was an ML in a dual language elementary school named Roselyn. Rather than taking up mediation within the ZPD or the expansion of it, Collett used SCT to highlight the importance of participation for learning by exploring Roselyn's opportunities for participation in school-based practices through language. Findings demonstrated Roselyn was positioned differently across school spaces as a Latina language learner and her opportunities to participate were mediated by both her bilingualism and peer relationships in positive and negative ways over time. Collett's work influenced the research questions, as RQ1 interrogates MLs' use of modes, including language, and RQ2, as it explores MLs' participation. Collett's findings overlapped with some of my findings relating to MLs' use of various modes for participation in science. However, Collett's participant was an elementary aged learner, whereas my participants were secondary students with access to different resources and experiences.

Smith (2019) took a different approach to exploring multilingual learners learning through SCT by asking how multiple modes mediated students' collaborative literary interpretation processes in a 10th grade English language arts (ELA) classroom. By centering multiple modalities, Smith was able to uncover the specific affordances for mediation of students' interpretations of literature—an important focus within the ELA curriculum. Findings demonstrated that multiple modes mediated students learning in three ways: (1) conceptualizing themes, (2) constructing multilevel connections to literature, and (3) elucidating literary meaning. Smith then compared how multiple modes mediated students' literary interpretation with how writing mediated this same goal. This is important because writing is the traditional method for mediation of literary interpretation. Smith leveraged SCT to both explore how multiple modes mediated multilingual learner students' learning in an ELA classroom and to establish multimodal composing as valid practice for collaborative literary interpretation. While I did not compare multimodal composing against a more traditional pedagogy, this study did guide my thinking regarding investigating students' multimodal composing from a SCT perspective. For instance, Smith analyzed students' in-the-moment composing moves rather than focusing upon their final products. This comes from an acknowledgement within SCT of the importance of interactions and participation.

Sociocultural Theory in Science Education

This section explores how sociocultural theory has been taken up to explore teaching and learning within K-12 science classrooms. Alozie and colleagues' (2010) work highlighted the importance of data collection within classrooms as participants used tools for multimodal composing. Gibbons (2003) and Lucero (2014) emphasized

the important role teachers play in mediation within science classrooms through their intentional scaffolding moves.

Alozie and colleagues (2010) used sociocultural theory in a secondary science classroom to explore the enactment of scientific discourse communities through project-based curricula. More specifically, they analyzed curriculum and classroom support for the enactment of scientific discussions. The authors viewed teaching and learning as mediated by and grounded in contexts and relationships between individuals. Learning was viewed as the result of the use of physical and digital tools, language practices (including discussion), and cultural models. Importantly for this dissertation study, the authors described sociocultural theory's influence on their research design, stating that it demands studies "be designed to capture and analyze the events and enactments of particular people as they use various tools in particular contexts" (p. 401). Lessons and curricular artifacts were recorded, and findings demonstrated challenges involving scientific discussions within high school classrooms. These challenges related to the amount of content covered, the abstract nature of the content, and difficulties teachers had relating students' everyday discourses, instructional discourses, and scientific discourses. From a sociocultural perspective, difficulties surrounding discussions could be major hindrances to student learning in science classrooms.

Gibbons (2003) took up sociocultural theory to study an elementary teacher's mediation of students' language learning through interactions in a science classroom. In this work, Gibbons took up the term mediation to refer to the "linguistic and discourse choices" of teachers in a science classroom. Findings emphasized teachers' role in students' learning of content and language. Central was the idea of contingency, which

Gibbons defined as “the way an adult judges the need and quality of assistance required by the learner” (p. 267). This work demonstrated the importance of teachers’ role in mediation. In particular, teachers go beyond simply providing feedback through careful consideration of the type of feedback that is appropriate, when, and how much. Joint construction drew from the work of Newman and colleagues (1989) in which they referred to the ZPD as a construction zone and the fact that learning occurs through assisted performance in the context of joint activity (scaffolding) (Newman et al., 1989).

Lucero (2014) used SCT to emphasize the need for teachers to scaffold multilingual learners in content area classrooms, including science, as they develop language. Drawing from the work of Gibbons (2002; 2003; 2006), her study explored teachers’ linguistic scaffolding of Spanish-dominant first-grade multilingual learners' development of academic language in dual-language classrooms. From a sociocultural approach to dual language education, Lucero described language as the medium through which students learn and knowledge is jointly constructed (p. 536). Lucero defined linguistic scaffolding as “instructional moves through which a teacher provides mindful and responsive support for student language output” within the ZPD (p. 538). Specifically, this study examined teachers’ use of oral linguistic scaffolds. Through the leveraging of SCT, Lucero identified and analyzed instances of teachers’ linguistic scaffolding as academic language instruction and found that the instruction was taken up by students “in ways that led to better understanding and use of academic language” (p. 555).

Moving Forward: Various Modes

From a traditional SCT perspective, language is the most important psychological tool (Vygotsky, 1978). It is an important part of external and internal mediation, transfer,

participation, and more. However, research has demonstrated that language is but one resource that MLs bring to secondary biology classrooms (González-Howard et al., 2021; Grapin, 2019). Prior work has demonstrated benefits of multilingual learners' use of language (Collett, 2019; Martin-Beltran et al., 2017a) or multiple modes (Smith, 2019) for learning within classrooms, but new work is needed to explore both together. Therefore, this study explores the modes employed by multilingual learners, including oral and written language, leveraged as part of their composing processes.

To define mode, I draw from Kress' (2009) work, defining it as a "socially shaped and culturally given semiotic resource for making meaning" (p. 79). Though there are numerous modes, this study examines those crucial for participants' classroom compositions. In particular, images, oral language, and written text were used by the participants most frequently as part of their multimodal composing processes. While composing the multimodal artifacts assigned by the teacher in this study (i.e., non-digital poster, digital slideshow, 3D model), case-participants primarily used *space-based* modes which have meaning making potential through the organization of concurrently visible elements (e.g., image, arrangement, shape) (Kress & Mavers, 2005). *Time-based* modes in their compositions (e.g., music, sound) which have temporal potentials for representation through a "temporal succession of elements" (p. 174). The *time-based* mode leveraged by participants for composing in this study was oral language.

In secondary biology classrooms, MLs can use various modes to support peers by translating assignment instructions, student-student collaboration, or to facilitate discussions with the teacher. This study is designed to ascertain some of MLs'

experiences and strengths, including languages, to support understanding of how they use various modes within the classroom (see Appendix A).

Moving Forward: Participation

Participation is essential for learning and development within SCT. Learners must actively participate in cultural activities (e.g., schooling, work, religious systems) to be mediated by other individuals or tools (Karpov, 2005). Without this participation, learning is not possible. Also, through a learner's participation, evidence of internalization may be visible, as they engage in activities (Johnson & Golombek, 2003). This dissertation explored how MLs' participated SEPs as they composed multimodal artifacts. Identification of participation in SEPs was supported by the IONIC observation protocol by Chen and Terada (2021), as described within the following chapter.

Literature Review

In this section, I first review the literature on MLs' multimodal composing in secondary science classrooms before narrowing to multimodal composing in biology classrooms.

Multilingual Learners in Secondary Science Education

Much research has been conducted with MLs in elementary science, but less work has focused upon MLs in secondary science (Pacheco & Brown, 2022). This is concerning, as secondary science includes foundational courses within science education including biology (Freeman et al, 2011). Moreover, secondary biology content can be challenging for many learners (Gomez et al., 2019) and often there are high stakes assessments attached to the course (Macpherson, 2009; Bach, 2020).

Existing research in secondary biology classrooms with MLs has typically foregrounded teachers and instruction. For instance, studies have explored methods,

tools, or professional development leveraged by teachers (Baughman et al., 2013; Greenleaf et al., 2011; Meskill et al., 2019; Qin & Beauchemin, 2022; Seah & Silver, 2020) and teacher motivation (Sandberg, 2019). Fewer studies have centered multilingual students (see Kibler, 2011; Pacheco & Brown, 2022; Pun & Tai, 2021 for exceptions).

Science and Engineering Practices. The Next Generation Science Standards (NGSS Lead States, 2013) describes three dimensions of science learning: (1) core ideas, (2) crosscutting concepts, and (3) science and engineering practices (SEPs). The eight overarching SEPs describe what scientists and engineers do as they investigate the natural world. SEPs extend what is meant by "inquiry" and the range of practices that it requires (NGSS, 2013a; 2013b). Current emphasis on SEPs is part of an effort to shift views of science learning from students' following steps specified by teachers to participation in practices that are important not only within classrooms but also to practicing scientists (Berland et al., 2016). The multimodal nature of SEPs provides multilingual learners opportunities to communicate meaning "regardless of their English language proficiency" (Lee, 2021, p. 1074).

Implications for Current Study

Though studies centering MLs in secondary science classrooms are expanding; the majority of this work has centered teachers and instruction. Therefore, more work is necessary to inform understandings of what MLs are capable of within these classrooms. Specifically, further study is needed to explore how multilingual learners can leverage the unique strengths they bring into science classrooms.

This dissertation study contributes to the asset-oriented conversation surrounding MLs in secondary biology education by emphasizing an asset-based

perspective (de Jong et al., 2016) of multilingual learners and their resources rather than emphasize teachers or instruction. For instance, findings from this study demonstrate how secondary multilingual learners participated in SEPs by tapping into their linguistic, cultural, and academic strengths by leveraging various modes. Within science education literature, this work contributes to perspectives about multilingual learners as more than students who need support in science, but as capable learners who bring numerous resources into science classrooms. Further, this work explored multilingual learners' use of various modes and participation in SEPs within a secondary science classroom.

Multimodal Composing for Multilingual Learners

Multimodal composing has been taken up by numerous groups including English language researchers (Jiang & Luk 2016; Yang & Wu, 2012), special education researchers (Bruce et al., 2013; Feeney, 2003), and general K-12 education researchers (Bowen & Whithaus, 2013; Miller & McVee, 2013). Existing work has demonstrated that multimodal composing is engaging (Miller & McVee, 2013), collaborative (Smith, 2014), and of valuable for multilingual learners in particular (Shin et al., 2021; Pacheco, et al., 2017; Smith, et al., 2020). Benefits for secondary multilingual learners including flexible points of entry for engagement (Jewitt, 2008), flexible exit points which allow composers to engage with their audience "across space and time" (Smith, et al., 2020, p. 9), and opportunities to connect with their communities and family members (Pacheco et al., 2017). Through multimodal composing, multilingual learners can leverage multiple resources to engage, build on, and develop aspects of their identities (Smith, et al., 2020), while learning about language, composing, and content (Pacheco et al., 2017; Westlund, 2018).

While recent work has begun to explore the multimodal composing for student learning in content areas (Castek & Dwyer, 2018; Smith, 2019; Staurseth & Håland, 2019; Vu et al., 2019) more research is needed to gain a fuller understanding of the potentials (Moje, 2009; Smith, 2017; Yi et al., 2019). Importantly, the majority of multimodal composing studies have been conducted in English language arts (ELA) contexts (Chisholm & Olinger, 2017; Shin, 2018; Smith 2017; Smith 2019; Vandommele et al., 2017) though fewer studies have also been conducted in math (Taylor, 2018; Walters et al., 2018), social studies (Staurseth & Håland, 2019; Dalton, 2014) and science classrooms (Castek et al., 2017; Jiang et al., 2020; Jiang et al., 2024; Ran et al., 2023). Often, within science education literature multimodal composing appears with other names (e.g., scientific modeling).

Implications for current study. There are demonstrated benefits of multimodal composing for multilingual learners in secondary classrooms, but less is known about the benefits within secondary science classrooms. This study aims to contribute to the conversation on how multimodal composing can provide opportunities for MLs to use various modes and participate in science practices within secondary biology classrooms.

Multimodal composing in biology classrooms

Multimodal composing has been studied within biology classrooms as student participants produced: digital and physical models (Buckley, 2000; Pierson et al., 2021; Riess & Mischo, 2010; Van Rooy, 2012), dramas (Dorion, 2009), drawings (Robles-Piñeros & Tateo, 2021), infographics (Walsh & McGowan, 2017), posters (Tolbert et al., 2019), and interactive word walls (Weinburgh et al., 2021). Notably, instances of multimodal composing are often labeled as “scientific modeling” (Pierson et al., 2021),

"model-building" (Buckley, 2000), or "practice-based learning" (Walsh & McGowan, 2017).

In these studies, the benefits of multimodal composing in the biology classrooms were described in different ways: promoting of systems thinking (Riess & Mischo, 2010), creating opportunities for engagement in disciplinary argumentation (Walsh & McGowan, 2017), expression and illustration of scientific concepts (Dorion, 2009; Robles-Piñeros & Tateo, 2021), opportunities to make science relevant (Dorion, 2009), opportunities to show relationships between words (Weinburgh et al., 2021), engagement in SEPs (Walsh & McGowan, 2017), and student learning (Buckley, 2000; Walsh & McGowan, 2017). Further, multimodal composing in classrooms created space for mediating both student-student discourse as well student-teacher discourse (Dorion, 2009).

Multimodal Composing in Secondary Biology Classrooms. Though beneficial, multimodal composing in biology classrooms is not without challenges. Dorion (2009) noted that enacting dramas in classrooms requires a large amount of space and time for students' composing and performance. Van Rooy (2012) highlighted the amount of planning time required of teachers and found that multimodal composing did not level the playing field with regard to differences in access to digital technologies, though demonstrated how composing through multiple modes could be accomplished in settings with limited access to digital resources through the composition of analog artifacts such as paper-based physical models.

Participation. In Buckley's (2000) study, learning was assessed using students' scores on a written test, interview data, analysis of students' created models, and

analysis of students' presentations. Findings demonstrated that the focal student had gained "integrated and useful knowledge" (p. 922) of biology content relating to the human circulatory system and she was able to apply that knowledge to answer questions and understand an illustration of "an experimental alternative to heart bypass surgery" (p. 922). Buckley highlighted that while this multimodal composing, referred to by Buckley as "model-building" promoted student learning and access to important pieces of information, effective learning strategies within multimodal composing was also paramount, as not all student participants demonstrated the same level of growth as the focal student.

Walsh and McGowan (2017) explored students' "practice-based learning" (p. 39) in which students produced multimodal compositions to share impacts of climate change and received feedback from scientists. The study highlighted how students' interaction with a scientist about their multimodal compositions promoted not only their engagement in SEPs, but a holistic perspective of SEPs "in which learning one practice [SEP] was embedded in engagement with multiple practices." (p. 38). This work considered MLs' participation in multiple SEPs, but the authors emphasized the role a practicing scientist played in promoting student engagement in SEPs, rather than centering students' own composing processes. Other work has focused MLs' participation but in only one SEP, #2 developing and using models (Pierson et al., 2021).

Various Modes. Prior work has considered both MLs' use of language and other modes. For instance, Walsh and McGowan (2017) found that a practicing scientist supported students' communication of information by highlighting how images

supported clarity through feedback (p. 36) as learners created poster presentations. Tolbert and colleagues (2019) found that teachers created a “linguistic bridge” (p. 1080) between complex science content and students’ everyday language as MLs engaged in multimodal composing to “illustrate and explain the process of the immune system at a cellular level” (p. 1079). However, this study emphasized linguistic over non-linguistic resources, and found that teachers leaned upon their own linguistic resources rather than inviting MLs to leverage their own. Similarly, Weinburgh and colleagues (2021) stressed the importance of multiple modes for communication within science classrooms (p. 379) but studied teachers’ use of multiple modes rather than MLs’. Pierson and colleagues (2021) studied translanguaging (i.e., the use of multiple named languages and modes) and scientific modeling (i.e., multimodal composing) in a secondar science classroom. They found that multimodal composing created a space in which translanguaging and modeling worked hand-in-hand for meaning making. Findings showed possibilities for not only meaning making, but also that translanguaging helped expand what is considered legitimate participation in science classrooms.

Implications for current study

These studies explored the multimodal composing of MLs in secondary biology classrooms but from different perspectives and for different purposes than this dissertation. Walsh and McGowan (2017) explored MLs’ participation in SEPs but emphasized a scientist’s role in the process rather than the learners’. Tolbert and colleagues (2019) and Weinburgh and colleagues (2021) emphasized both language and other modes, but prioritized teachers rather than students in their analysis. Most closely related to this work, Pierson and colleagues (2021) studied MLs’ use of linguistic

and nonlinguistic repertoires through multimodal composing. This work builds upon and contributes to this conversation by exploring the affordances and constraints of multimodal composing for MLs participation in SEPs. However, Pierson and colleagues' (2021) work explored a single practice, 2 developing and using models, whereas this dissertation considered all eight.

Looking Ahead

Within biology classrooms, multimodal composing can take many forms. For instance, students could use Google slides to create visual representations of a strand of DNA with labels and narration. This example fits the description of multimodal composing because it is a student-created artifact that includes image, oral language, and written text. This would also be an example of participation in *Practice 2* "developing and using models" (NGSS, 2013b). Within this study, I explored how MLs used various modes and participated in SEPs while multimodal composing within a secondary marine biology classroom.

Within the existing research on multimodal composing within science classrooms, few studies explore students' use of various modes or participation in SEPs within secondary biology classrooms, and none within marine biology. Of the studies in secondar biology, very few foreground MLs (see review above for exceptions). This presents a need to explore ML's composing practices in this academic as well as the potential for participation in SEPs.

CHAPTER 3
METHODOLOGY

Design of the Study

The following research questions guided this study:

- How did multilingual learners use various modes while multimodal composing in a secondary marine biology classroom?
- How did multilingual learners participate in science and engineering practices while multimodal composing in a secondary marine biology classroom?

To address these research questions, I conducted a qualitative comparative case study in one linguistically diverse secondary marine biology class in a public school in the southeastern US (Stake, 2006). Over the course of six months (Table 3-1), I engaged in participant observation (DeWalt & DeWalt, 2011) within the classroom as students participated in three multimodal composing projects: (1) poster, (2) slideshow, and (3) 3D model. Data collection was completed in three rounds, and each was influenced by analysis of the preceding round(s) and preceding classroom observations. In the following sections, I detail the study, including the participants, site, multimodal workshop, composing projects, data collection and analysis, researcher positionality, limitations, and matters of trustworthiness.

The purpose of this qualitative study was to investigate how multilingual learners used various modes and participated in science and engineering practices (NGSS Lead States, 2013) while multimodal composing. I selected qualitative research methods, as they provide strong approaches to answer questions of *how* (Corbin & Strauss, 2015) and I selected comparative case study to gather more data than a single case could provide (Stake, 2006). Cases are nouns or entities that and each were developed independently before comparing across cases (Stake, 2006). In this study, each case

was made up of one multilingual learner case-participant. This provided opportunities to look closely at participants' use of their various modes (e.g., oral language and images for student-student collaboration) and participation in SEPs (e.g., student participants asking questions about phenomena). I explored my research questions while "using cases as specific illustrations" (Creswell, 2013, p. 97) of how MLs leverage various modes and participate in SEPs. Comparative case study was selected to "closely examine several cases linked together" (Stake, 2006). This design allowed me to develop an understanding of each individual case before making comparisons across the two, to develop deep rather than broad understandings. This study received Institutional Review Board (IRB) approval. Consent and assent were completed by student participants and their guardians, when appropriate. The teacher was also a consented participant. See Table 3-1 for the data collection timeline.

MLs' Use of Various Modes While Multimodal Composing

This work takes up Kress' definition of modes as "socially shaped and culturally given semiotic resource[s] for making meaning" (2009, p. 79). Such a broad definition covers a great number of possible modes for inclusion. Though not an exhaustive list, some of the modes studied as part of multimodal composing include music (Selfe, 2009), gesture (Amgott, 2020; Butler, 2017), facial expression (Mills et al., 2020; Reid & Moses, 2022), animated text (Yang, 2012), oral language (Selfe, 2009; Yang, 2012), still images (Smith, 2017; Rish, 2013; Yang, 2012), and video (Mills, 2010; Smith & Dalton, 2016). The goal of this comparative case study was to take a deep rather than broad view of the modes MLs used while multimodal composing in a secondary marine biology classroom. Therefore, the modes most frequently leveraged by participants, oral

language, image, and written language were included within analysis, as described in sections below (Figure 3-4).

MLs' Participation in SEPs While Multimodal Composing

Definitions of SEPs and examples of students' participation in SEPs vary amongst science educators and science education researchers (Pasley et al., 2016). Chen and Terada (2021a) stated, "there remains broad interpretation and flexibility for researchers and teachers as they incorporate them in their research programs and classrooms" (p. 1505). Therefore, it is necessary to be clear about how ML participation in SEPs was identified.

In this study, participants' participation in SEPs was identified by leaning upon the IONIC observation protocol (Chen & Terada, 2021a). Beyond identification of student participation in SEPs, concepts from the IONIC observation protocol were used to measure student engagement in each of the eight practices, according to four levels of engagement: (1) passive, (2) active, (3) constructive, and (4) interactive. Adjusting use of the protocol was necessitated by this dissertation study's focus upon students' in-the-moment composing practices, as the IONIC observation protocol was designed to assess entire lessons, rather than brief periods of time within lessons. However, Chen and Terada's (2021) work was selected for use as it was the only identified observation protocol that was designed to measure student engagement in the eight science practices. Other similar observation protocols focused upon engineering practices rather than science (Wheeler et al., 2019) or STEM learning outcomes' link to classroom practices (Dringenberg et al., 2012).

However, my use of the protocol was adapted because the IONIC observation protocol was designed to measure student participation in science practices over the

course of entire lessons. In this study, I used the protocol to identify student participation in SEPs during specific instances within lessons. Therefore, I used tools from the observation protocol to first identify instances when participants were participating in SEPs and to evaluate that participation according to the four levels of engagement: passive, active, constructive, and interactive. Importantly, as this study was designed to investigate how multimodal composing could provide MLs opportunities to participate in SEPs in meaningful ways, only instances of student participation in SEPs at the highest two levels, constructive and interactive, were included in analysis.

Research Site

Cypress High School. This study was conducted in a marine biology course at a public high school in the southeastern US. The school, Cypress High (pseudonym) is situated within a mid-sized economically and linguistically diverse county. Approximately 14.5% of residents use a language other than English at home. Just over 3% of students in the school district received English language support services. Approximately 11% of students in the district identify as Hispanic, 60% White, 20% Black, and 9% Other.

Cypress High was a large high school with over 2,400 students located in a suburban neighborhood with numerous single-family homes. 14% of Cypress High students identify as Hispanic, less than 45% as White, 23% as Black, and 16% Other. Approximately 29% of students at Cypress qualified for free or reduced lunch. Cypress High was within a school district that had designated ESOL (English for Speakers of Other Languages) center schools. Within the local school district, the ESOL center schools offered additional supports for students who qualified as “English language

learners." Though Cypress High was not a designated as an ESOL Center, its teachers used "ESOL strategies to ensure that students learn English as well as the class content" (Local district website). Cypress High was selected as the context for this study because the goal of this work was to explore the possibilities of multilingual learners' multimodal composing within a typical U.S. high school and science classroom. Though I acknowledge, it is difficult to define any school or classroom as typical as each is made up of a group of unique individuals.

Ms. Pearson, the participating teacher (all names are pseudonyms) was selected for this study due to her history of supportive instruction for multilingual learners. This assessment was based on my and other researchers' experience with her within a larger research project, SUPER Science. It was the goal of this research to explore what is possible through multimodal composing within a typical secondary science classroom with a skilled teacher. In her first period class, there were two multilingual learners who were identified as ELLs. There were also two multilingual learners who had previously received additional language supports within a school ESOL program but had since exited the program after receiving sufficient scores on English language proficiency assessments. There was also one ML who had never been identified for English language services. All MLs in Ms. Pearson's class used Spanish and English at home. Other student participants in the class used English at home almost exclusively.

Participants

Focal Classroom and Teacher Participant

Purposeful sampling (Patton, 1990) was used to select Ms. Pearson as a teacher participant. As this work required MLs to compose in their secondary science classroom, I sought a teacher who taught MLs, could implement multimodal composing,

and had experience leveraging multiple modalities for instruction. The participating teacher, Ms. Pearson, was a marine biology teacher who had and has twenty-four years of experience as an educator. Two years prior to this study, Ms. Pearson participated in a larger research project, SUPER Science where she and I met. In the larger study, Ms. Pearson served as a teacher participant and I as a graduate assistant. During this time, I came to know Ms. Pearson as a skilled educator with a willingness to try new strategies and a desire to support the MLs in her classroom. In SUPER Science, I noticed Ms. Pearson's instructional skill during the implementation of new instructional strategies and her flexibility as an educator to shift plans based upon her students' needs. These qualities lead me to ask her to participate in this dissertation study. Ms. Pearson used English almost exclusively for instruction but frequently asked her students questions about the other languages they used and encouraged their use of any language in the classroom. When asked to participate in this study, Ms. Pearson responded yes right away and expressed a desire to engage with multimodal composing for student learning.

Ms. Pearson's classroom was a large, white-walled room with desks arranged in small groups that filled the majority of the physical space. The desks were surrounded by cabinets along the walls which held ever-rotating scientific specimen including seaweed, an aquarium full of fish, and a terrarium that housed several crabs. Her classroom walls were filled with science-themes posters and student-created materials from previous classes and marine animal plush toys hung from the ceiling tiles from almost invisible fishing line. At the front of the classroom, sat Ms. Pearson's desk and behind it a separate office and storage room, teeming with even more instructional

materials. The impression I had when first entering Ms. Pearson's classroom was one of interest and enthusiasm.

Students of Cypress High were required to complete three science credits for graduation: one in environmental science, one in biology I and a third credit in a science elective course of their choice. Typically, students took environmental science in ninth grade and Biology I in tenth grade. Ms. Pearson's year-long marine biology course was available to students in 11th grade as an option for the third credit as well as to 12 grade students as an additional course for college preparation. Successful completion of Biology I was the only pre-requisite and chemistry, anatomy, and physiology were suggested co-requisites.

Ms. Pearson's marine biology students selected to take the course rather than one of the other available options: anatomy and physiology, chemistry, physics, or earth and space science. Ms. Pearson stated that some students took her course because of their personal interest in local marine animals, plants, and/or habitats. Some students expressed to me that they selected the course because the previous teacher of the course, Mr. Smith, had been their environmental science teacher and they enjoyed his course. Though, at the beginning of the year, they were surprised to have Ms. Pearson as a teacher, they remained in the course because they liked her teaching style as well. As students within an elective science course, the participants in this study could have made a different selection to earn a science credit. Ms. Pearson stated that her students were aware that marine biology was a more challenging course than some of the other available options, and they chose the class because of either personal interests or teacher preference.

It is important to understand how multimodal composing can support multilingual learners in an elective science course. Previous work has shown that students who take secondary elective science courses generally consider science to be part of their post-secondary plans (Summers, 2021). Though Gisele and Eduardo did not clearly express a desire to pursue science-focused degrees or careers, their selection of course could indicate some degree of interest or buy-in relating to the subject. Further, research has demonstrated that many MLs are members of underrepresented groups within STEM (Science, Technology, Engineering, and Mathematics) higher education and careers (Estrada et al., 2017; Varma, 2018). Therefore, it is crucial to explore pedagogies that support MLs within science classrooms that have the potential to increase the quality and equity of education (Feldman & Malagon, 2017).

Cases

Each case consisted of a single multilingual learner, hereafter referred to as case-participants. This study had two case-participants, Gisele and Eduardo. Case-participants were selected through purposeful sampling (Patton, 1990) to ensure "information-rich cases" (p. 169) for in-depth study. Prior to data collection, I worked with Ms. Pearson on the selection of case-participants. Purposeful sampling was also used to select instrumental-use multiple cases, because the goal was to generate "generalizable findings" (Patton, 2015, p. 408) to suggest changes in research and practice. I sought to include multilingual learners within an English-centric secondary biology classroom. I was open to including participants whose linguistic repertoires included any language other than English. I relied upon Ms. Pearson's knowledge of students to support the sampling process. In the end, Gisele and Eduardo were selected because their backgrounds made them each representative of a large groups

of MLs within K-12 education in the U.S. Specifically, Gisele was born in the U.S. to parents from the Dominican Republic and used mostly Spanish at home. Eduardo was born in the Dominican Republic and moved to the U.S. with his family a few years prior to this study and spoke Spanish at home.

Composing Partners

The student participants in this study also included two composing partners, Lauren and Owen, who engaged in composing with Gisele and Eduardo, the case-participants. Composing partners were selected based on expert recommendation from Ms. Pearson. Ms. Pearson stated that both Lauren and Owen were students who worked hard in class, and she thought they would be strong composing partners for Gisele and Eduardo. The original plan for this study was for Gisele and Lauren to form Focal Pair A and Eduardo to form Focal Pair B and for each focal pair to compose all three projects together. However, Gisele and Eduardo expressed a desire to compose together during the third project so they could include Spanish in their process, which changed the grouping for the third project (Figure 3-1).

Non-Focal Participants

This study took place within a classroom environment, as all students composed in small groups simultaneously. I invited all students in Ms. Pearson's classroom to become participants, so there were some interactions between case-/focal participants and non-focal participants that were included within the analysis.

Researcher as Participant Observer

In this study, I served as a participant observer (Spradley, 1980). According to Spradley, a participant observer must demonstrate explicit awareness by focusing on small details that one would typically ignore. For instance, during the initial observations

prior to data collection, I paid attention to the time case-participants entered the classroom and with whom. During composing observations, I paid attention to the composing choices case-participants made and the resources they chose to use. Participant observers must also alternate between an insider and outsider experience which means to simultaneously be an *outsider* who observers and an *insider* who participates, though Spradley notes that at times a researcher transitions between the two roles rather than always being simultaneous (1980, pp. 55-56). As a participant observer, I was an outsider who took recordings and field notes while also an *insider* who conversed with students and sometimes answered questions about composing or science. Finally, participant observers should do this all while keeping detailed records (Spradley, p. 58). Spradley emphasized the taking and maintaining of both observations and feelings. Throughout this project, I took notes during and after data collection and included things I noticed that went beyond “objective observations” (p. 58) such as when a case-participant seemed upset when they arrived in Ms. Pearson’s classroom or frustrated during composing. In addition, all field notes, observation recordings, and all other data were organized at the end of each day of data collection.

My status within the classroom as a participant allowed me to be involved in the social world of the classroom, while taking note of the details. As a former teacher, I understood how to interact within the setting as an educator, but my role of researcher encompassed a very different set of goals, that of data collection. In recognition that my presence would certainly impact the context, I aimed to be perceived by participants as a student myself rather than as a teacher. For instance, I introduced myself to Ms. Pearson’s students as a university student. During data collection, I dressed less

professionally than a teacher, in an effort to separate myself from that role and build rapport with student participants. A few times outside of class time, students asked questions about college, usually relating to what it might be like for them.

To help normalize my presence within the classroom, I spent three class periods in Ms. Pearson's biology class prior to the start of data collection. Though I had an established relationship with Ms. Pearson and a general understanding of her instruction through our work within the larger research project in previous years, I did not know her students and they did not know me. The three class periods I spent in her classroom prior to collection helped me initiate the process of becoming a member of the learning community, or at least helped to make my presence and observations less obtrusive for participant comfort (Tracy, 2020).

Multimodal Projects

Over the course of six months, Ms. Pearson's students composed three multimodal artifacts, each described below. Each of the three projects was created within different curricular units and therefore had distinct topical learning goals and SEPs of focus. Each project was composed by students in class over the course of four to six class periods. Ms. Pearson had encountered SEPs previously during the larger project, SUPER Science and had since incorporated them into her instruction. I asked that she select one or two SEPs to focus on during each composing project. Ms. Pearson selected *Practice 8, obtaining, evaluating, and communicating information* as the focus practice for all three projects and for the third project, she also included *Practice 2, developing and using models*. Ms. Pearson shared which SEPs she chose for each project outside of class time. I suggested she might present them to students during class, and during the final day of the first composing project, she talked about

Practice 8 with students. However, she later stated that it “felt inauthentic” (personal communication) to present SEPs explicitly and did not discuss SEPs with students again. She continued to discuss SEPs with me outside of instructional time.

Multimodal project #1: Non-digital poster

For multimodal project #1, participants created non-digital posters. Tools for composing included: poster paper, laptops, markers, crayons, and other classroom supplies. Students designed and created their posters within the Medicines of the Sea module. During this module, Ms. Pearson presented information through lectures and videos about some of the known medicinal properties of marine animals and plants while also emphasizing the importance of ocean conservation. The posters included two-dimensional drawings of a marine animal as well as details about its medicinal properties. Students were also required to include information about the medicines it is used to produce and the conditions it is used to treat.

In secondary education contexts, research findings have shown non-digital posters can be used by multilingual learners to express their cultural identities (Honeyford, 2014), use their linguistic resources (Wilson & Boatwright, 2011), and develop understandings of ELA content (Davis & Reed, 2003). In secondary science education, posters have been used by teachers to support differentiated instruction, by offering content engagement through multiple modalities (Maeng & Bell, 2015), add variety to both content presentation and assessment (Billington, 1997), and leverage multiple modalities including color, figures, and photos to communicate scientific concepts (Hay & Thomas, 1999). Much of the most recent literature on multimodal composing in secondary science classrooms emphasizes the affordances of digital composing. However, even now, access to technologies remains inequitable for many

students (Roberts et al., 2018; Shaheen, 2022). In conversation with Ms. Pearson, she stated that posters were part of her instruction so, this was an opportunity to explore if non-digital composing might offer MLs something that may be overlooked by current education research, as the latest and greatest technological advances are celebrated.

Multimodal project #2: Digital slideshow

The second multimodal project included within this study was slideshows composed using Google Slides and included bar graphs. This project was completed during a unit on sharks. Ms. Pearson distributed a handout that included directions for the project and a list of possible shark topics. In secondary education, multimodal composing of slideshows has been used within English language arts (ELA) classroom to support multilingual learners' visualization of content (Smith et al., 2021) and inviting students' out-of-school technological skills for in-school learning (Axel & Kahn, 2023). A search of relevant literature yielded no studies that explored multimodal composing through the creation of slideshows in science classrooms. However, Jiang and colleagues (2020) found that, in a science classroom, multilingual learners' composing of infographics, digital compositions that resemble a single slide, supported participation in new science practices, though they did not emphasize the eight SEPs. I argue that though less researched than other types of multimodal composing in science, the creation of slideshows by multilingual learners could afford opportunities for the use of various modes resources and to participate in SEPs.

Multimodal project #3: 3D model

The third multimodal project consisted of participants creating three-dimensional models of fish using physical materials. Ms. Pearson provided a variety of classroom and art supplies including paper of different thickness, sizes, and colors as well as

scissors, cardboard, tape, and more. This project was created during the unit on bony fish and consisted of designing a new species of fish using concepts covered within the unit. Ms. Pearson includes this activity as part of her instruction each year, but usually students create a two-dimensional drawing rather than a three-dimensional model of their design.

Previous work in secondary science classrooms has demonstrated students' composing of 2D and 3D models holds potential but has also emphasized the need for students' active engagement in "constructing and interpreting representations by actively discussing the properties of representations, including their strengths and limitations" (Waltrip et al., 2010, p. 70). Pierson and colleagues (2021) found the scientific modeling within a multilingual classroom created space for the use of multiple languages within a secondary science classroom. The authors cited the work of Latour (1999) and the National Research Council (2012) to define scientific modeling as "the practice of creating, using, or revising models (conceptual or material representations) to reason or express ideas about a referent phenomenon" (Pierson et al., pp. 777-778). Further, one student's multilingual description of their model "expressed more nuanced understandings of science content than the English translations." (Pierson et al., 2021, p. 795).

Data Collection

Data was collected through multiple sources to support the development of each case. Collection included multiple sources and perspectives within the classroom, as the strength of case study lies in the attention given to the "local situation" (Stake, 2006, p. 8). The local situation, or context, is described through thick description which creates and invites an "active role for the reader" (Erlandson et al., 1993, p. 40). This active role

of reader involves being placed vicariously into the context of a case study so that the reader can interact with the data, in context (vicariously) so that the reader can assess the transferability of the findings (Erlandson et al., 1993). It is worth noting that the authors acknowledged the difficulty in placing a reader vicariously into a context, yet insisted that it is a worthy goal, even if long term. Data collection was guided by the notions of the local situation (Stake, 2006), thick description and transferability (Erlandson et al., 1993).

This section of Chapter 3 describes the connections between collected data and the research questions (Table 3-2) and the stages of data collection organized by important elements of the case and context, including the teacher, the classroom, and the participants. Collected data included: case-participant interviews, composing partner interviews, teacher interviews, classroom observations, field notes, screen, audio and video recordings of case-participants and composing partners.

Teacher

As the teacher, Ms. Pearson was and is an essential part of her classroom. While not the primary focus of this study, her influence was great within the research context. As I spent time in Ms. Pearson' classroom and Cypress High, we had many ongoing conversations. The influence of these interactions on my data collection, understanding of the classroom and the cases were recorded in my field notes.

Teacher Interview. The first data collection activity was a semi-structured interview with Ms. Pearson to support understanding of her approach to teaching MLs, marine biology, and instruction in general. My goal for this initial interview was to engage in conversation with a purpose (Dexter, 1970). Though Ms. Pearson' instruction was not the primary concern of this work, initial interview data could shape my

understanding of the classroom culture as well as interactions that will occur during composing. This interview data was also another source for triangulation (Erlandson et al., 1993). For instance, Ms. Pearson was asked: *Can you share a bit about your instruction of MLs? Can you describe your use of language in the classroom?* And, *Can you describe your use of SEPs in the classroom?*

Classroom (All consented members of the classroom community)

The classroom is a focus within this study because it is the context in which the cases exist (Stake, 2006). Case-participants' use of modes and participation in SEPs during composing will be mediated by elements of the classroom and other students in it. To develop understandings of the research context, I collected data through observations, video recordings, and the collection of artifacts.

Artifacts

During my time in Ms. Pearson' classroom, I collected or photographed instructional materials used during composing lessons. These included presentations, handouts, assignments, grading rubrics, and more. For instance, Ms. Pearson shared the written directions for the Medicines of the Sea Poster Project, which students used during the first composing project (Figure 3-2).

Video recordings

As students engaged in the three composing projects, I created video recordings of the classroom using a Swivl robot and mini iPad. The Swivl robot held the mini-iPad and directed its camera to follow a marker, which was placed near the case-participants and composing partners. I include this within the section on the classroom, as the goal of these video recordings was to provide information on the classroom as participants composed. Cross-composing group interactions and collaborations were captured on

these video recordings of the whole classroom as well as instances when participants moved away from their laptop for composing purposes and non-composing purposes. These videos supported the creation of video logs and transcripts as they provided a more wide-angle perspective than each group's webcam recordings and the SWIVL's audio recorders served as a backup for laptop audio recordings.

Observations

Initial Observations. In an effort to normalize my presence, observe the physical space, and observe the classroom functioning as a whole, I spent time observing in Ms. Pearson' classroom for three class periods prior to data collection. During these initial observations, I did not create video or audio recordings, nor did I take notes in class. However, afterward I created handwritten and digital field notes drawing from memories and reflections from the observations. I also took photographs of the classroom itself to support thick description, which is described by Erlandson and colleagues (1993) as "collect[ing] sufficiently detailed descriptions of data in context and report[ing] them with sufficient detail and precision to allow judgments about transferability." (p. 33).

Composing Observations. I used observations of the physical classroom setting with field notes to support thick description of the space as students engage in composing. Student seating arrangement, wall coverings, and other classroom artifacts will be noted through photographs, as they change throughout the study. Observations of students as they compose provided close observations (Patton, 1990) and were conducted over the course of six months within one school year in four 3-6 day sessions. While the case-participants were my primary focus, they composed in the classroom with other students. Therefore, I included consented non-focal participants in

my field notes as they relate to the context of the research site and case and case-participants' composing. As part of the learning environment, all students played a role in the research site and I sought to develop an understanding of the classroom in general, its culture, and how students interacted with one another.

Field Notes. I took field notes during all observations, though there were times when scribbling on a notebook or typing on my phone was not appropriate within the classroom setting. In these instances, to honor my role as participant observer (Spradley, 1980), I refrained from recording notes, but created field notes from memory at a later time. When it was appropriate for the situation, I created handwritten field notes. As I had video, screen, and audio recordings of participants during composing, I focused my field notes upon the classroom in general, specific details not captured by recordings, and possible moments for further analysis. For instance, when a case-participant was late to class I recorded the reason and when I overheard something of potential interest from case-participants' conversations I notated what I heard and included the time.

Case-Participants and Composing Partners

The two MLs, Gisele and Eduardo were case-participants, while Lauren and Owen were their composing partners. Case-participants and composing partners were both interviewed, completed written reflections, and were recorded during composing sessions, as described below. However, Gisele and Eduardo as the cases, were the focus of data collection while Lauren and Owen were included because their composing involved the case-participants.

Participant interviews

I conducted semi-structured individual interviews (Appendix A) with each case-participant and composing partner before the first multimodal composing project began. These initial interviews sought to learn details about three main topics: language use, participation in SEPs, and their composing experiences. Upon completion of the third and final multimodal composing project, I conducted semi-structured individual final interviews with case- participants and composing partners to gain their reflections and perspectives on their composing (Appendix B).

The initial student interview protocol (Appendix A) was designed to develop understandings of case-participants' experiences using various modes. For instance, how they used languages and non-linguistic resources for particular purposes, and with whom (e.g., the use of Spanish with grandparents, emojis with friends, English with teachers, and multiple languages with friends). Questions within the "Composing" section were designed to develop an understanding of participants' experiences with multimodal composing, questions in the "SEPs" section are designed to understand participants' experiences with SEPs, while questions in the "Communicative Resources" section were designed to understand case-participants experiences with various modes, including languages.

The final student interview protocol (Appendix B) was designed to gain an understanding of case-participants' composing processes, how they described using various modes while multimodal composing, and how they described their experiences with participating in SEPs during the three composing projects. In the final student interview protocol, both the "Composing" and "Communicative Resources" sections are different from the corresponding sections on the initial student interview protocol.

Regarding composing, my intentions shifted from gaining an understanding of case-participants' experiences with multimodal composing to collecting information about elements of the classroom that they describe as helping their composing or making it more difficult. Regarding communicative resources, from the initial to final interview, my focus shifted from understanding what their experiences with various modes were to gathering data on how they described using various modes while composing. However, the questions within the "SEPs" section remained unchanged, to learn how case-participants described their participation in SEPs during the multimodal composing projects.

Written reflections

Each case-participant and composing partner completed a written reflection after completing each of the three projects. The forms (Appendices E, F, and G) asked four questions that directly related to the research questions.

- What languages did you use while making your infographic?
- How did you [insert SEP(s) of focus] while making your infographic?
- Did anything help you compose in class?
- Did anything make composing in class more difficult?

The first question relates to RQ #1, the second to RQ #2, and the third and fourth to context. Case-participants' and composing partners' responses to these questions provided an additional layer of data. These forms were designed to require little time to complete and relate directly to the research questions. These reflections supported triangulation during the analysis phase (Erlandson et al., 1993).

Laptop recordings

Case-participants' and their composing partners' laptop computers were used to record students' digital composing moves. Screen recordings captured the websites students visited, their page navigation, and composing moves using Camtasia. The laptop camera recorded case-participants and their composing partners as they composed directly in front of the computer and the computer microphone captured their composing conversations.

These recordings allowed me to view who was composing during different times of their process while the computers' microphones recorded students' self-talk and discussions between composers as they collaborated. Discussions between students, between students and Ms. Pearson, as well as between students and myself were captured via the laptop recordings. Playback of these recordings provided a visual of students' in-the-moment composing moves, along with their faces and conversations with one another. Laptop recordings will first be saved on the password protected computers of each composing group and later backed up on the researcher's hard drive.

Artifacts

I also collected student-created artifacts from case-participants' and their composing partners' composing. These artifacts included screen grabs of moments during their composing processes, photographs of their projects, photographs of their handwritten notes, and other artifacts created by students during their composing process.

Data Analysis

In this study, data was analyzed according to principles of grounded theory from the work of Corbin and Strauss (2015). Procedures from grounded theory allow a researcher to explore a topic or phenomenon from multiple perspectives in context which supports the development of "comprehensive explanations" (p. 11). These comprehensive explanations go beyond description or telling of the story of what occurred. This is accomplished through the systematic development of interrelated categories to "form a theoretical framework that explains something about a phenomenon." (Hage, 1972, p. 34).

The work of Corbin and Strauss (2015) supported this dissertation as it offered clear steps to take during the iterative analysis process. From my research questions, I built descriptions of what occurred before engaging in further analysis to develop comprehensive explanations of what occurred within the research setting. Analysis was divided into three main phases. Phase I occurred during data collection and included the creation and open-coding of case-participants' composing and interview transcripts (Table 3-3). Phase II began after data collection and included iterative rounds of deductive and axial coding of video logs, transcripts, and written reflections for each individual case (Table 3-4). Phase III consisted of comparative case analysis (Table 3-5).

Data were analyzed through constant comparisons, wherein data were broken down and compared to identify similarities and differences (Corbin & Strauss, 2015). The pieces of data were assigned codes and data with similarities were grouped under the same conceptual headings, called concepts. Concepts were grouped together to form categories, with attention to the properties that defined them and differentiated

concepts from one another as well as the dimensions that limited how much a property can vary. Categories were integrated around themes (Figure 3-3). Analysis was an iterative process, as new data was collected and analyzed, new concepts were formed then applied to previous data to ensure they fit.

Four themes were developed around Research Question 1: (1) interact with classmates, (2) position themselves, (3) enact their vision of science, and (4) participate in science and engineering practices (SEPs). Due to the salience of SEPs within the context of NGSS and science education, the fourth theme was explored as Research Question 2. This aligned with grounded theory and participant observation in that they both promote a constant process of evaluating hypotheses and research questions (Corbin & Strauss, 2015; Dewalt & Dewalt, 2002).

As stated above, this study took up Kress' definition of modes as "socially shaped and culturally given semiotic resource[s] for making meaning" (2009, p. 79). Therefore, the initial stages of analysis took note of the modes used by case-participants for composing. Also, I worked to situate case-participant's classroom composing within their previous experiences with composing. For instance, Eduardo described having a strong interest and experience with art, therefore, I gave special attention to whether or how this was leveraged during his composing. During analysis, it became clear that some modes were more salient than others within the case-participants' composing, oral language, image, and written text (Figure 3-4). Additionally, there differences in the modes leveraged by case-participants across the non-digital poster (Figure 3-5), digital slideshow (Figure 3-6), and 3D model projects (Figure 3-7). 3D models were included within the mode of image as they have similar,

though not the same, space-based affordances, as photographs and drawings in that they have meaning making potential through the organization of concurrently visible elements (Kress & Mavers, 2005). Further, the inclusion of 3D representations within image aligns with prior work (MODE, 2012).

Phase I

As noted in Table 3-1, Phase I analysis occurred at the conclusion of each round of data collection: after the initial interviews, upon completion of each composing project, and after the final interviews. Phase I was designed to support initial understandings and to guide the following stages of data collection. For instance, during Phase I analysis, I noticed that case-participants Gisele and Eduardo used Spanish infrequently as they composed with their composing partners, Lauren and Owen, during the first and second projects. This preliminary finding, along with Gisele's expressed interest in composing with Eduardo led me to regroup case students for the third and final composing project. In the third project, Gisele composed with Eduardo and Lauren with Owen (Figure 3-1). Further, Phase I of data analysis was used for open coding, with the modes participants used for composing and SEPs in mind, which was guided by the research questions (Table 3-6).

Initial interviews

The first step of Phase I was the creation of transcripts from case-participants', composing partners', and Ms. Pearson's initial interviews. Before coding, I read transcripts in their entirety to "enter vicariously into the life of participants" (Corbin & Strauss, 2015) in an attempt to see from their perspectives. Next, I began the process of open coding as a systematic and iterative process that allowed me to immerse myself in the data. Open codes were created by breaking down the interview transcripts into

manageable pieces for analysis (Charmaz, 2006). Code assignment was guided by the two research questions of this study; therefore, I paid careful attention to pieces of that that might eventually help me develop an understanding of case-participants' use of various modes or their participation in SEPs. I assigned open codes to begin the process of identifying concepts. This process provided opportunities to think about the data, consider its implications, and compare it to other data. I developed initial concepts by writing open codes on notecards and organizing them into groups as a visual strategy before recording concepts using handwritten notes in the margins of transcripts. This was an iterative process, as initial concepts were then reapplied to the transcripts and adjustments were made. During this process, I was mining the early data for "analytic ideas to pursue in further data collection and analysis" (Charmaz, 2006, p. 46).

During this process, I reflected upon the goals of the interview, which were to develop understandings of participants' experiences with various modes, SEPs, and with multimodal composing. Essentially, the goal of the initial student interviews were to get to know them. Therefore, when breaking apart data and while assigning concepts to each piece, I reflected upon what participants' responses revealed. Importantly, the open coding of each case-participant's interview was separate. Concepts identified related to individual participants and cross-group comparisons were not made during Phase I.

Video logs

After case-participants and composing partners completed the first composing project, time-stamped video logs of their composing processes were created (Figure 3-8). One log was created per day for each pair's composing sessions. This study

included two case-participants who composed Project #1 with their partners over five days. Therefore, Project #1 included ten video logs. The creation of video logs involved viewing the case-participants' and their composing partners' laptop recordings (audio, screen, and webcam) while using Microsoft Excel to create logs as written records of their composing processes. Simultaneously, I sought important instances for further analysis, by identifying moments of interest guided by my research questions. This was an effort to identify moments in time that could help me understand how case-participants used various modes or participated in SEPs during multimodal composing. The goal of this step was two-fold: 1) create a video log to which comments and memos can be added throughout multiple rounds of coding, and 2) identify instances for further analysis within Phase II.

Written reflections

Written reflections (Appendices E, F, and G) were open coded, to identify concepts. For instance, Gisele wrote that she used Spanish as she created the 3D model with Eduardo, "because our fish was from the Dominican Republic". However, Eduardo wrote that he used only English while creating the 3D model. This supported evidence that they used various modes to position themselves differently within the classroom. The written reflection questions were also used as a space where case-participants and composing partners could share their thoughts freely as they became more comfortable over time. They provided insight into things that occurred during composing sessions and supported triangulation.

Field notes

Importantly, as video, audio, and webcam recordings focused upon each composing pair individually, I relied on field notes to support my understanding of the

classroom context. Though, I also recorded notes for case-participants in the field notes as well. These details were added as comments into the respective video logs. There were no cross-case comparisons at this stage.

Final interview transcripts

After the composing projects and final interviews were completed, I created transcripts for case-participants' final interviews as well as Ms. Pearson's. I read through each before engaging in analysis to develop an understanding of each case-participant's perspective (Corbin & Strauss, 2015).

Next, I began the process of open coding by breaking down the interview transcripts into manageable pieces for analysis by open coding. Open codes were assigned to pieces of data based on the content rather than the size or amount of data. For instance, some open codes were assigned to phrases, others were assigned to multiple lines of transcript. This attention to small pieces of data was in effort to not miss any data that could later support the development of themes. I created a memo for each piece of raw data (Corbin & Strauss, 2015) to record the low-level concept assigned to it, along with my thinking when it was assigned. Concepts were recorded in the margins of the transcript. When participants' interview responses refer to a moment in time during their composing process, or one of the projects, a note was added to the corresponding video log.

During this process, I reflected upon the goals of the interview, which were to collect data about participants' use of various modes and participation in SEPs while composing. The goal of Ms. Pearson's final interview was to continue to develop context. Once again, the open coding of Ms. Pearson's interview and that of each case-

participant were separate. So, concepts identified related to individual participants. Cross-case comparisons were not made during Phase I.

Phase II

Phase II of analysis involved iterative rounds of deductive and axial coding of data driven by the two research questions. Data relating to each case was analyzed separately, as no cross-case comparisons were made at this stage.

Development of Cases. Phase II began with deductive coding of the video logs and interview transcripts that were created during Phase I. The video logs and interview transcripts also contained open codes from Phase I, relating to each research question. During Phase II, these artifacts supported further analysis to ensure each individual case was well-developed and understood by the researcher prior to cross-case analysis (Stake, 2006). Therefore, I began by analyzing each case separately.

Single case analysis. First, I engaged in an iterative coding process, using the constant comparative method (Corbin & Strauss, 2015), applying concepts identified through round one to all pieces of data deductively, linking as appropriate (Corbin & Strauss, 2015) and updating memos. During this time, I worked to develop “theoretical sensitivity” (Corbin & Strauss, 2015, p. 266), being in tune with the meanings behind the data. Each case was analyzed separately. Prior to Phase II, I spent hours interviewing case-participants, their composing partners and in the classroom, as well as with Ms. Pearson interviewing and preparing for multimodal composing sessions. It was important to hold the memory of the context as I developed each case. I then used axial coding to reassemble data broken apart during open-coding (Charmaz, 2014). This process included multiple rounds of coding, exploring each case separately, moving sequentially between interview transcripts, composing videos, and video logs to

establish larger categories, leaning upon memos to follow the “data trail” (Corbin & Strauss, 2015, p. 265). For example, at the start of Phase II, I began with case-participant Gisele in composing project 1, using axial coding to define categories across all five video logs. Categories identified at this point of Phase II for Gisele included: prioritized product, images for communication, and guided by teacher-provided directions. Then, I used those categories to deductively code all five video logs alongside video and screen recordings before moving to composing projects 2 and 3. Some categories, such as prioritized product remained, while images for communication was further developed according to the goals of the communication to include images for collaboration.

Next, I used axial coding to define categories across Gisele’s interviews and written reflections, moving chronologically before deductively coding all transcripts using the categories. This was an iterative process, I identified concepts that are not captured by the categories, then adapted, adding or removing categories as appropriate. When I had core categories for Gisele, I moved to case-participant, Eduardo, and conducted the same process. No cross-case analysis was conducted at this stage.

Phase III

Phase III consisted of cross-case analysis to compare the cases developed during Phase II with one another.

Comparative Case Analysis. Comparative case analysis was conducted by applying axial coding (Charmaz, 2006) to all themes from each individual case to generate overall themes across the two cases. This process employed analysis techniques from multiple case analysis (Stake, 2006). According to Stake, it is important to maintain findings from individual cases during cross-case analysis. Therefore, while

analyzing across the two cases, I read through the data and findings of each case as I applied them to the research questions. For instance, I read through the findings of Gisele as I considered RQ1: How did multilingual learners use various modes while multimodal composing in a secondary marine biology classroom? I noted that Gisele prioritized high scores on assignments and used written text, oral language, and images to achieve her desired scores. I also read through the findings of Eduardo and noted that he prioritized demonstrating his skills of creating images and oral language to display his knowledge while composing. It was during the comparative case analysis that I recognized that each case-participant was using various modes to position themselves within the classroom, but in very different ways. This theme will be further discussed in the following chapter.

Trustworthiness

To develop the quality of this design and establish trustworthiness, I followed a broadly accepted set of standards including credibility, transferability, dependability, and confirmability (Erlandson et al., 1993). These criteria and methods to establish trustworthiness are described in the following sections.

Credibility

Credibility is essentially the believability in the findings of a research process. To support credibility, I worked to achieve triangulation, the application of multiple perspectives for analysis of the same data (Erlandson, 1993). The collection of video, audio, and screen recordings along with interviews, debrief conversations, and written reflections allowed me to compare students' comments about their language use,

participation in SEPs, and composing to their actions, their conversations, and composing moves.

I further supported credibility through member checking (Lincoln & Guba, 1985). This checking was done informally during spontaneous conversations, interviews, and debrief conversations with case-participants, composing partners, as well as the teacher, to provide opportunities for them to challenge my interpretations and correct errors (Erlandson et al., 1993, p. 142). Peer debriefing was also used to bolster credibility of this dissertation study throughout the data collection, analysis and writing processes (Lincoln & Guba, 1985). I relied upon peers who were graduate students, engaged in similar research within either language or science education, and had K-12 teaching experience to serve in this capacity. These peers participated in conversations about the study and reviewed perceptions and findings as I moved throughout the process.

Transferability

Transferability, the applicability of findings within other contexts or with other participants (Lincoln & Guba, 1985) was built through thick description (Erlandson et al., 1993). Erlandson and colleagues emphasized that it is the job of the researcher who writes a research report to “produce a document that will allow for active participation on the part of the reader and provide the basis for developing working hypotheses that can be applied in other contexts.” (p. 41). Through thick description, a researcher should put the reader of their study vicariously into the context so that transferability can be judged (Erlandson et al., 1993). Though the primary responsibility for transferability to a new context is on “those who would apply it to the receiving context” (p. 40), the reader is influenced by the choices of the author (Erlandson et al., 1993).

In this study, I worked to achieve thick description was developed through the inclusion of sights, sounds, and relationships from Ms. Pearson' classroom. Details from interviews with the teacher, case-participants, prolonged engagement, as well as detailed descriptions of case-participants, the classroom, and Cypress High support readers' judgements about transferability.

Dependability

Dependability, or evidence that a repeat study conducted with similar participants in a similar context would have similar findings (Lincoln & Guba, 1985, p. 290), is an important part of establishing trustworthiness. To establish dependability of my findings, I established an "audit trail" by maintaining a detailed account of the methodology through notes of observations, methodological shifts, and interpretations. In addition, I maintained copies of all collected data (e.g., transcripts, screen recordings, classroom artifacts, etc.) until completion of the study.

Confirmability

Confirmability is the degree to which findings are produced by inquiry rather than researcher biases (Erlandson et al., 1993). To establish confirmability, I maintained field notes, including analytical notes and maintain data, as described above.

Positionality

As a qualitative researcher, I am a research instrument (Guba & Lincoln, 1981). I brought my experiences, ideas, goals, and more to this study. As a former public school teacher, I brought knowledge of and experiences into the research context. However, my personal background as a student in secondary science classrooms is very different from the backgrounds of my case-participants, as I learned science in classrooms through my home language, English.

During data collection, both my background as a former teacher and my appearance as a white female might have influenced student participants to view me as a teacher or authority figure within the classroom. If students perceived me as a teacher, within the classroom that might have helped normalize my presence. However, I wanted participants, particularly case-participants to interact with me honestly without viewing me as someone who might assess them in some way, as a teacher. Therefore, I introduced myself to them as a university student, shared some of my experiences as a student and attempted to appear slightly less professional than a teacher. During data analysis, I gave special attention to data relating to my two research questions, and therefore might have missed unrelated findings.

As an ESOL/Bilingual Education doctoral student, I believe it is essential to conduct research in such a way that highlights the benefits of bi/multilingualism and empowers all students to use their full semiotic repertoires to their advantage within classroom spaces (Menken & Sánchez, 2019). Further, I acknowledge bias towards the benefits of multimodal composing, especially for multilingual learners. I will focus this work on case-participants' use of modes and participation in SEPs and may therefore neglect to notice benefits and shortcomings of multimodal composing in this context outside of this scope.

Chapter Summary

Within this chapter I outlined the design of this qualitative study. I described the research site, Cypress High, as well as the teacher whose classroom it will be conducted in. I also illustrated fictional student participants, based on informal conversations with Ms. Pearson and my experiences within other secondary biology classrooms. I described how the research questions are connected to the research

methods and analysis, as well as my role as participant observer and the three planned multimodal projects as well as projected timelines and artifacts that were such as interview protocols.

Table 3-1. Data Collection Timeline

Date	Data Collected	Reasoning
November, 2022	Time in classroom	Understand context; become a less obtrusive presence
December, 2022	Initial Participant Interviews	R.Q.s; Guide Projects 1, 2, & 3
January, 2023	Project #1	R.Q.s
February, 2023	#1 Preliminary Analysis	Guide Project 2
March, 2023	Project #2	R.Q.s
March, 2023	#2 Preliminary Analysis	Guide Project 3
March-April, 2023	Project #3	R.Q.s
April, 2023	#3 Preliminary Analysis	Guide Final Interviews
April, 2023	Final Participant Interviews	R.Q.s

Table 3-2. Data Collection in Relation to Research Questions and Context

Data Collection	**RQ 1:** How did multilingual learners use various modes while multimodal composing in a secondary biology classroom?	**RQ 2:** How multilingual learners participate in SEPs while multimodal composing in a secondary biology classroom?	**Understanding of the Research Context**
Classroom:			
Video observation	+	+	+
Field notes	+	+	+
Artifacts	+	+	+
Teacher:			
Interview			+
Ongoing Conversations			+
Case-participants and composing partners:			
Initial interview	+	+	+
Laptop recordings	+	+	+
Observations; field notes	+	+	+
Composing artifacts	+	+	+
Written reflections	+	+	+

Table 3-3. Phase I of Data Analysis

Analysis	Initial interviews	Non-digital poster project	Slideshow project	3D model project	Final interviews
Transcribe & open code	X				X
Create & open code video logs		X	X	X	
Open code written reflections		X	X	X	

Table 3-4. Phase II of Data Analysis

Case 1, Gisele	- Iterative coding process, deductive & axial of: o Initial interview transcript o Non-digital poster project data ▪ Video log ▪ Video, audio, and screen recordings ▪ Written reflections o Slideshow project data ▪ Video log ▪ Video, audio, and screen recordings ▪ Written reflections o 3D model project data ▪ Video log ▪ Video, audio, and screen recordings ▪ Written reflections o Final interview transcript
Case 2, Eduardo	- Iterative coding process, deductive & axial of: o Initial interview transcript o Non-digital poster project data ▪ Video log ▪ Video, audio, and screen recordings ▪ Written reflections o Slideshow project data ▪ Video log ▪ Video, audio, and screen recordings ▪ Written reflections o 3D model project data ▪ Video log ▪ Video, audio, and screen recordings ▪ Written reflections o Final interview transcript

Table 3-5. Phase III of Data Analysis

Deductive & axial coding across cases, iterative process	
Case 1 Gisele - Themes o Categories	Case 2, Eduardo - Themes o Categories

Table 3-6. Data Analysis

Data Analysis	**RQ 1:** How did multilingual learners use various modes while multimodal composing in a secondary biology classroom?	**RQ 2:** How did multilingual learners participate in science and engineering practices while multimodal composing in a secondary marine biology classroom?	**Context**
Classroom:			
Video observation	+	+	+
Field notes	+	+	+
Artifacts	+	+	+
Teacher:			
Interview transcript			+
Field notes	+	+	+
Case-participants and composing partners:			
Initial interview transcripts	+	+	+
Laptop recordings	+	+	+
Observations; field notes	+	+	+
Composing artifacts	+	+	+
Written reflections	+	+	+

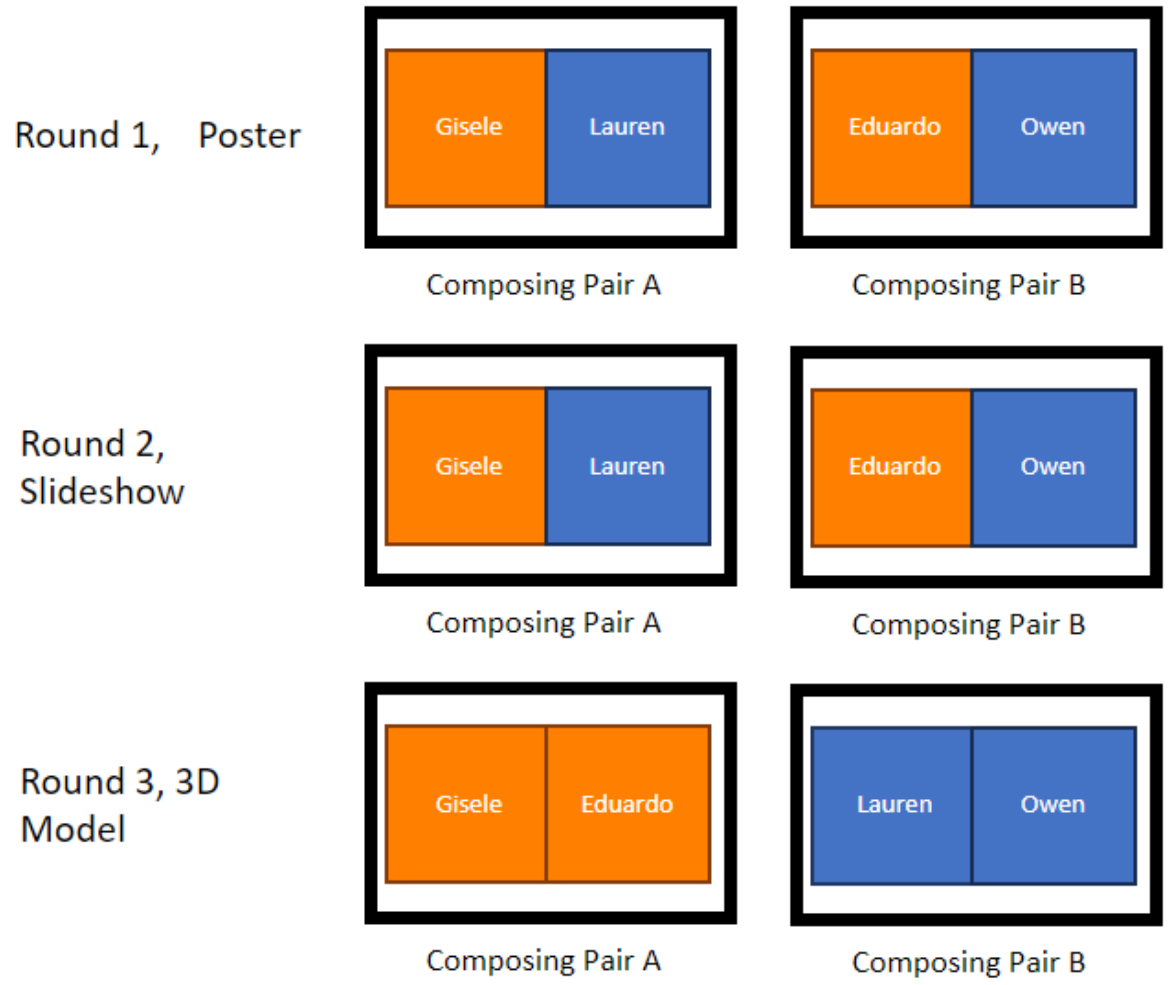


Figure 3-1. Visual representation of participant grouping in composing pairs. Note: Orange background = case-participant; blue background = composing partner

Medicines of the Sea Poster Project **Names:** _____

Scientists have been collecting and studying marine organisms, especially sessile ones that contain chemicals that might be used to treat human diseases. They have discovered chemicals that marine animals use to protect themselves against viruses, bacteria, etc. and have extracted these chemicals to create drugs used to treat humans.
You and a partner (no groups of three, but you may work by yourself) will research a drug used on humans derived from a marine organism.

Poster:

- Title
- Name of the drug
- Common name of the organism it came from
- Organism classification (Phylum, Class, Genus, Species)
- Where does the organism live? Habitat and what ocean. *For example - in coral reefs in the Caribbean.*
- Draw the organism in its habitat.
- When was it discovered?
- Explain how the animal uses this chemical and why it makes a good drug for humans. This must be a paragraph.
- What is it used to treat? (what disease or issue)

Figure 3-2. Written directions for the Medicines of the Sea Poster Project from Ms. Pearson.

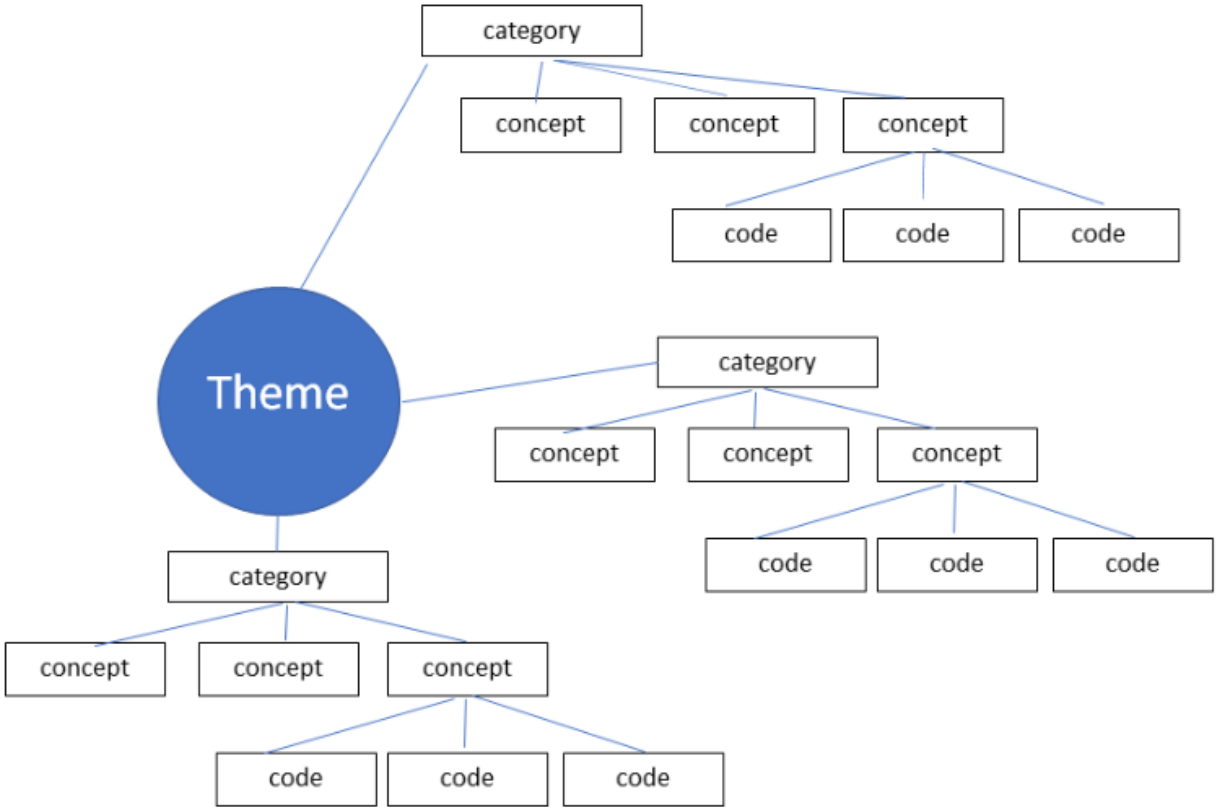


Figure 3-3. Visual representation of codes, concepts, categories, and themes.

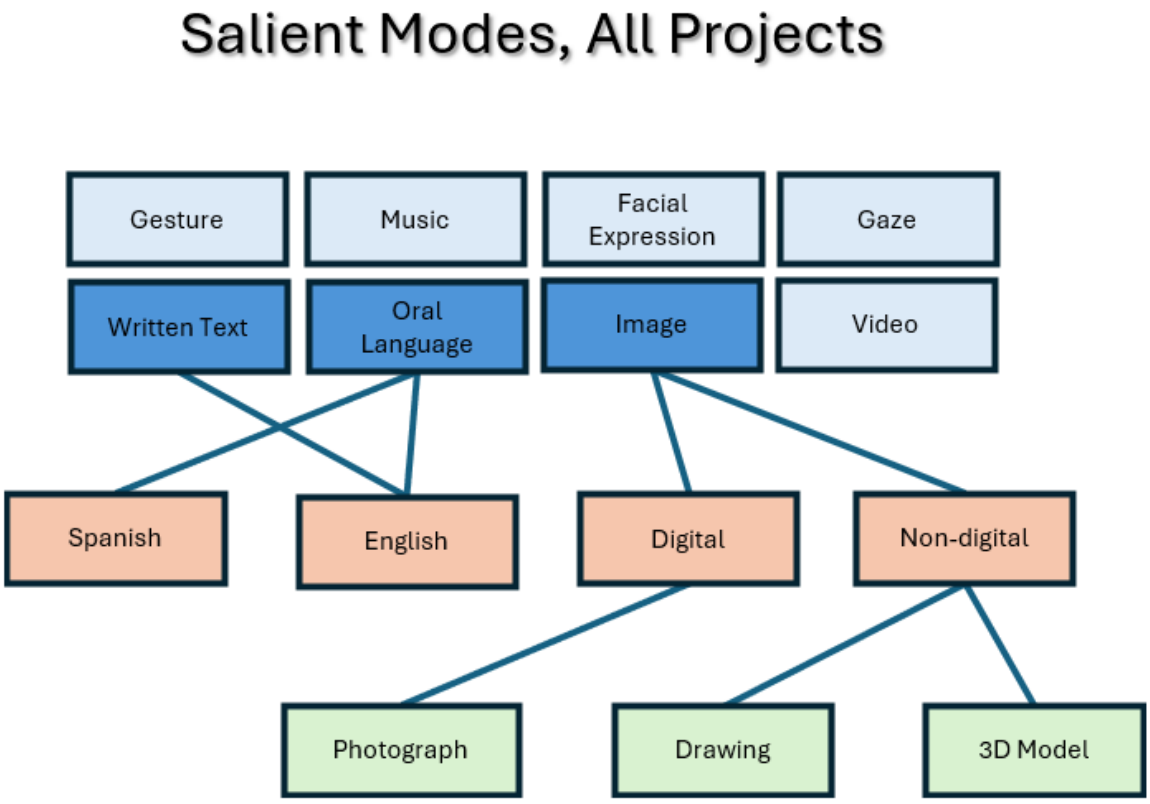


Figure 3-4. Visual representation of salient modes.

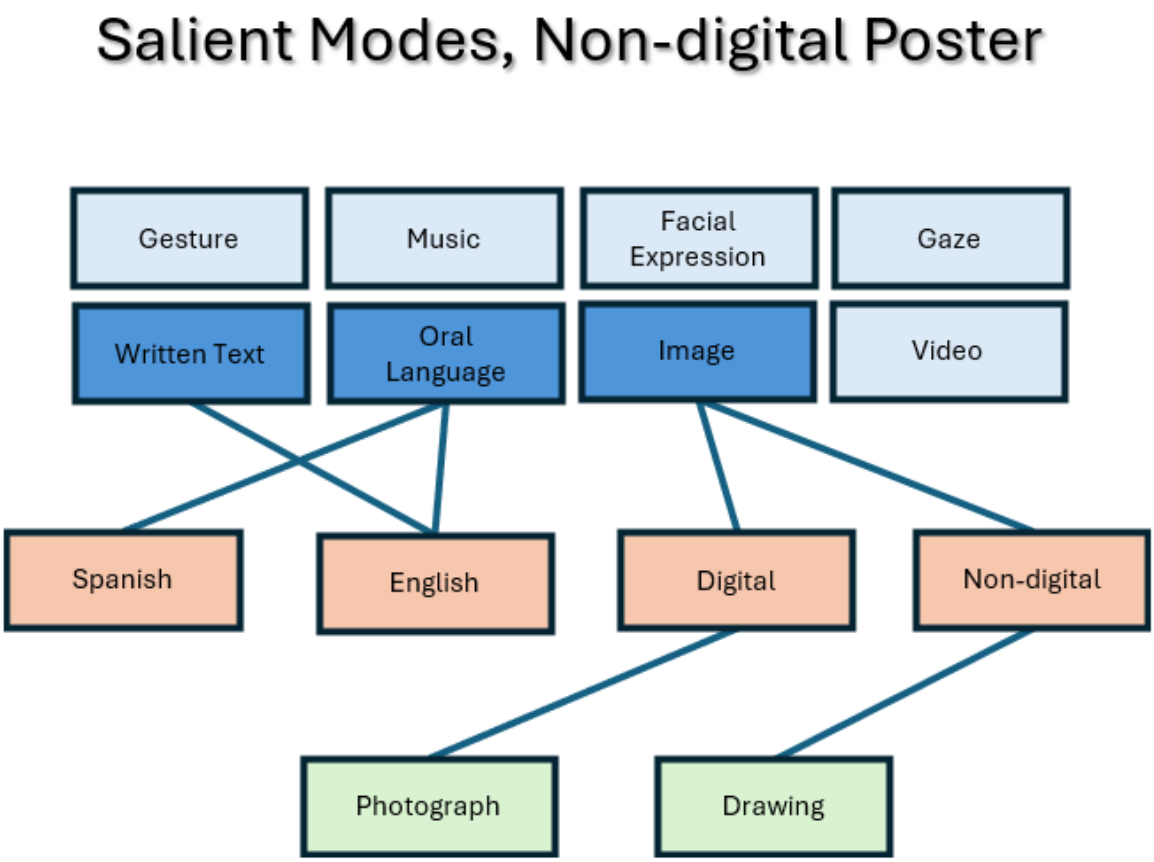


Figure 3-5. Visual representation of salient modes used in non-digital poster project.

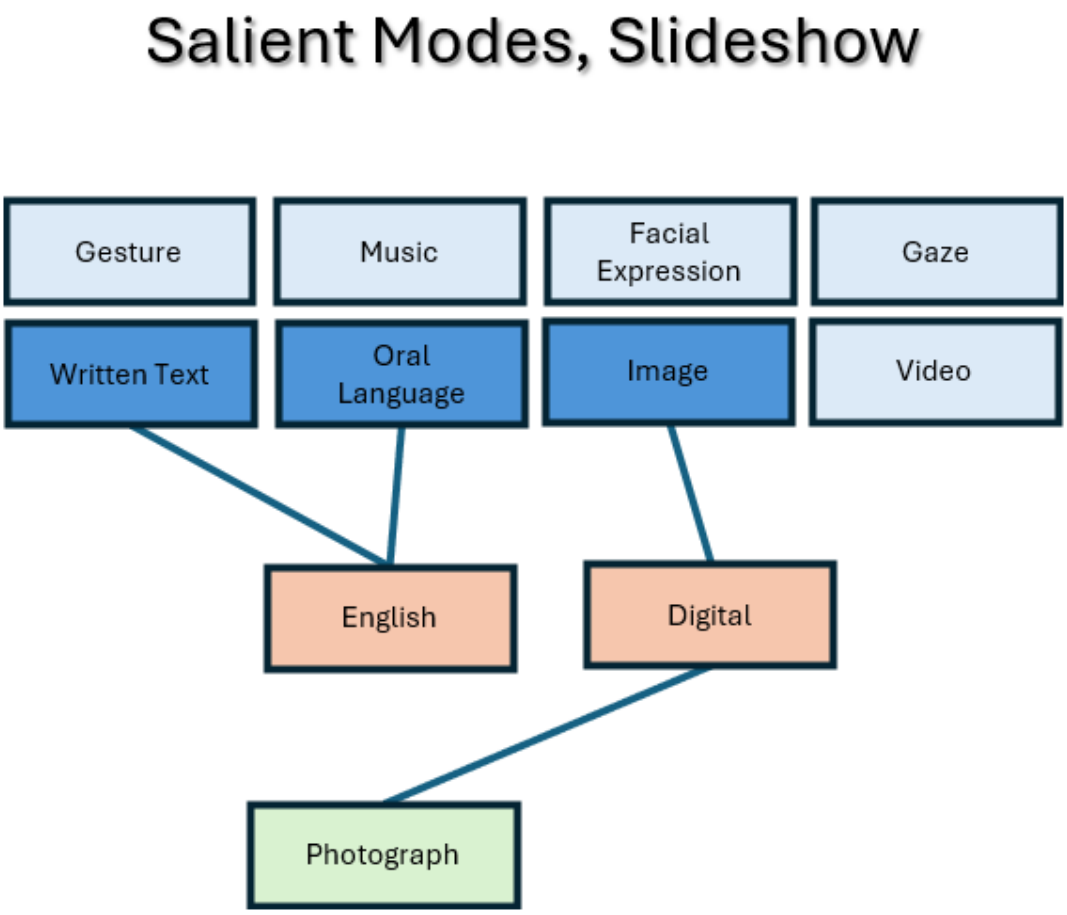


Figure 3-6. Visual representation of salient modes used in digital slideshow project.

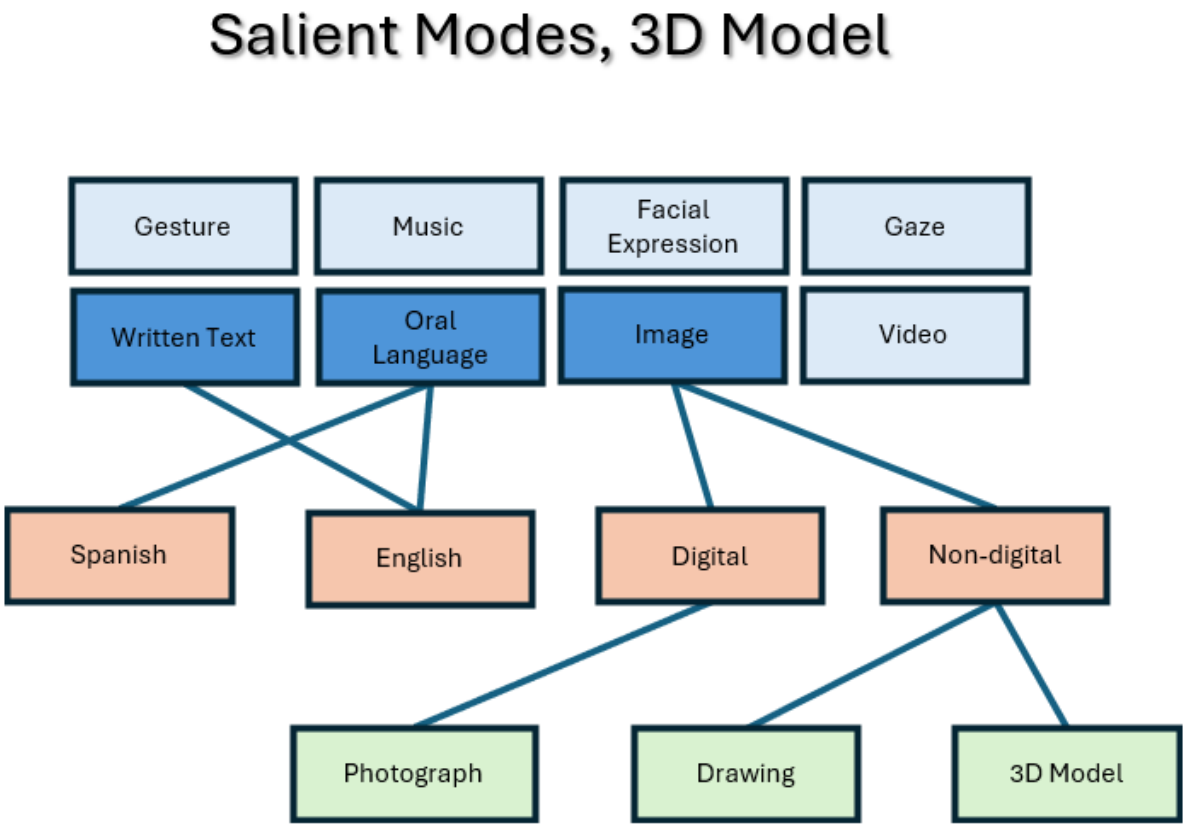


Figure 3-7. Visual representation of salient modes used in 3D model project.

	1.19.2023; Group 2 Composing			
Time	**What's Happening**	**Concept**	**Memo**	**Phase II**
10:23-15:23	Students 2.a & 2.b are searching a database provided by Ms. Pearson, seeking information on the process of cell division.	Content search		Possible participation with *Practice 2*

Figure 3-8. Example of Video Log

CHAPTER 4
FINDINGS

This chapter presents a detailed case for each case-participant to illustrate their use of various modes and participation in science and engineering practices within and across their three projects. These cases lay the groundwork for the comparisons made in the latter sections of the chapter. Overarching themes are organized into sections that align with each research question. While analyzing the first research question, which asked how MLs' used various modes, four themes arose from the data: (1) to interact with classmates, (2) to position themselves, (3) to do science, and (4) to participate in SEPs. Due to the salience of SEPs within science education, the fourth theme was explored as Research Question 2.

Case Studies

In this section, I present the two cases and present findings of each relating to the two research questions. These sections first provide general information about each participant gathered during the initial student interviews and data collection, as well as specific background relating to their experiences using various modes, including language, and experiences with participation in science and engineering practices. Next, the two English monolingual composing partner composing partners are introduced. Finally, findings are presented relating to the two research questions:

- How did multilingual learners use various modes while multimodal composing in a secondary marine biology classroom?
- How did multilingual learners participate in science and engineering practices while multimodal composing in a secondary marine biology classroom?

Gisele: The Social Butterfly Who Likes To Get Things Done

Gisele, a junior at Cypress High, was a member of the weightlifting team and a presenter for the school morning news channel, which explained why seemingly everyone knew her. Each morning, she entered Ms. Pearson's first-period marine biology classroom and greeted nearly every classmate by name. Gisele was charismatic and had strong leadership skills. She was often observed making decisions for groups in class, but only after considering and validating others' opinions.

Prior to data collection, I spent time in Ms. Pearson's classroom to normalize my presence, become a participant within the context, and develop an understanding of the daily routines of the full participants of the classroom context (Dewalt & Dewalt, 2011). During that time, Gisele sometimes entered the classroom early and moved around the room, talking with multiple groups of students. Once class began, Gisele focused on the lessons. She listened intently, discussed concepts with her peers, and asked Ms. Pearson questions when needed. She was overheard encouraging her peers by acknowledging their strengths and giving them the space to contribute to discussions. It was clear, Gisele used her social skills to support those around her at school.

At home, Gisele lived with her parents and two younger siblings. Her parents grew up in the Dominican Republic and moved to the United States before Gisele and her siblings were born. Her mother worked as a mail carrier, which allowed her to complete her work without frequent interactions in English. Gisele explained that her mother was more confident communicating in Spanish than in English. Gisele's father worked in business and was confident communicating in Spanish and English. Her younger siblings—a sister and a brother—were both more confident communicating in English than in Spanish. Gisele stated that she was confident communicating in both

languages. As the oldest sibling, she was sometimes responsible for her younger siblings at home. She spoke of helping her family in multiple ways, including language brokering for her mom during appointments and meetings and reading notices sent home from her younger siblings' school.

Gisele expressed that her heritage was an important part of her identity. Her family had strong ties to the Dominican Republic as many of her extended family members lived there. Gisele and her immediate family visited when they were able, though she wished they could more often. During data collection, several of her extended family members visited from the Dominican Republic and stayed with Gisele's family. She stated that she really enjoyed spending time with them.

Gisele's strengths

Gisele was skillful in communicating with those around her including her classmates and her teacher, Ms. Pearson. On numerous occasions I observed as she engaged in interactions with others, assessed them, their needs, and shifted her communication strategies accordingly. This reflected Gisele's desire to support others' understanding, which she described during the initial interview:

> I use Spanish just like [for] any type of talk I'm having with my mom. Even when we're having serious conversations, you'd think I'd talk in English to try to express myself better, but I always try to use Spanish so she can understand me better rather than me trying to express myself. Cause we, I eventually, like, no matter how long it takes, I, I'll get my point across.

Within this section, I describe Gisele's linguistic, cultural, and social strengths that were recognized during data collection. These strengths were identified through interviews, classroom observations, and composing recordings and she used various modes to tap into these strengths during composing. For instance, Gisele leveraged oral language in English and Spanish to tap into her social strengths, which aligns with

prior work that found the strategic use of multiple languages, (i.e., code-switching) was leveraged by MLs to tap into their social skills for communication within classrooms (Martínez, 2010; Martínez, 2018). Analysis illustrated how during data collection, Gisele accessed her strengths via various modes within the science classroom.

Establishing some of Gisele's strengths helped me explore how she tapped into them by using various modes as she composed. This study explored how two case-participants used various modes to tap into their identified strengths for particular purposes within a secondary science classroom. However, while certain strengths were evident during data collection, it is important to note that Gisele, and all learners, have extensive strengths and resources all of which are not possible to be identified and understood within any single study.

Language of Home. Like the majority of MLs in U.S. K-12 schools (Office of English Language Acquisition, 2023), Gisele primarily spoke Spanish at home. She described Spanish as being important to her for expressing herself at with family and online. However, English was also used for specific purposes in Gisele's home. For instance, Gisele mentioned that her dad sometimes received work calls during dinner and always spoke English during these calls. She said it seemed kind of funny to hear him switch languages so quickly at the dinner table, from a casual discussion about the day in Spanish, then into English for a professional conversation when his phone rang.

Gisele said she usually communicated with her younger siblings through English when their parents were not at home, except when she needed to persuade them to do their homework or chores. She explained her siblings were more likely to oblige because, as she put it, "'Go clean your room' sounds way more threatening when I say

that in Spanish.” She supposed this was because the statement in Spanish reminded them of their mother. At work, Gisele spoke Spanish with a colleague who spoke Portuguese. She explained that even though they spoke different languages, they were usually able to understand one another due to linguistic similarities and shared slang.

Language of School. Gisele stated when it came to academic language, she was more confident in English. She mentioned that she did not use Spanish at school except during Spanish class, where she felt she did well, and with new students who only spoke Spanish. She described an instance when she helped a new student from Guatemala navigate the school and interactions with teachers. Gisele seemed to buy into the idea that Spanish was not a valuable skill within her school setting, which aligns with previous work (Daniel & Pacheco, 2016; Martínez et al., 2010). During our initial interview, Gisele mentioned that she has experienced instances when she begins a conversation with a classmate in Spanish and was surprised when they responded in English, so she switched to English as well.

Various Modes. Regarding multiple modalities, Gisele described herself as an active user of social media and stated she liked to create and share images and videos, especially those with political themes. Gisele posted on social media using both Spanish and English but usually consumed more content in Spanish. Further, she was more likely to share content that was in Spanish with her family, particularly her mother. Gisele said that one of her videos once went “a little bit viral” on Snapchat and she quickly changed her accounts to private because she did not enjoy the "feeling of being watched.” She acknowledged that even though she was considered an extrovert, she said, “I don’t really like people. I like to keep to myself. I would always choose my

company over someone else's." This was interesting, because in person, she often had a lot of attention from other students, and she appeared to feel comfortable in the spotlight. Gisele did not describe using multiple modalities at school in any capacity.

Gisele's experiences with science and engineering practices

During the initial interview, I asked Gisele about her experience with each of the eight science and engineering practices (Table 4-1) from the NGSS (2013). This was used to develop an understanding of her previous experiences and to guide later data collection and analysis. This section reports on Gisele's previous participation in SEPs, hereafter referred to as *Practices*.

Personal Life Connections. During the interview, Gisele often responded by describing how she used the practices in her personal life, connecting science practices with personal experiences. For instance, when discussing her experience with *Practice 5, use mathematics and computational thinking*, she described preparing budgets for grocery shopping and ensuring she stuck to it as she made selections in the store and also while calculating what she needs to lift when weightlifting. Also, when discussing *Practice 6, constructing explanations and designing solutions*, she spoke of helping her mom understand things like English internet slang by describing them in Spanish and how these actions help her mother understand her 13-year-old brother in conversations. Gisele's connections between science practices and her personal life provided a perspective of SEPs that has been seldom explored within education research (see Penuel, 2016 for an exception), as SEPs have often been studied within scientific settings in schools (Alsultan et al., 2021; Pierson et al., 2020) and out-of-schools (DeLisi et al., 2021; Maiorca et al., 2021; Simpson et al., 2020).

Personal Life Differences. In addition to connections to science practices, Gisele also drew differences between her personal experiences and school experiences. For instance, when asked if she ever used *Practice 5, using mathematics and computational thinking*, she responded “Not the way that high school wants me to. Like, I’d never ever use geometry in my day-to-day life.” (Gisele, initial interview). However, she went on to describe how she used mathematical thinking to both help her family with budgeting and grocery shopping and as part of weight lifting, as described above. Also, when asked about *Practice 8, obtaining, evaluating, and communicating information* Gisele stated that this was something that she did in science during labs in science class but “in the real world” (Gisele initial interview) she obtained information, but did not evaluate or communicate information.

Personal Positioning. In addition to connections and differences between her personal life, Gisele also mentioned aspects of how she viewed herself as a person in relation to the *practices*. For instance, when asked about her experience with *Practice 1, asking questions and defining problems*, Gisele said that she was a logical person and spoke about solving problems “with [her] head rather than [her] heart” (Gisele, initial interview) using strategies such as a pro and con list. At another point, she stated that she considered herself a problem solver and spoke of using language and multiple modalities flexibly to support communication and interpersonal relationships with family and friends and described using different approaches with different individuals.

Lauren, Gisele’s Composing Partner

Lauren was a senior at Cypress High and a student athlete. At home, Lauren spoke only English with her family and friends, with whom she described having close relationships. In her free time, outside of school and sports practice, Lauren enjoyed

camping with her family. At school, Ms. Pearson described her as a kind and hard-working student. Before and during data collection, I noticed that Lauren seemed to have numerous friends in the class, including Gisele. Throughout data collection, Lauren spoke of looking forward to attending college the following year. When it came to college, Lauren had a lot of opportunities, as an exceptional student athlete. It was known that she had multiple scholarship offers and she was in the process of deciding where she wanted to attend. During data collection, Lauren participated in National Signing Day to announce her acceptance of a full scholarship to a university in the southeast U.S. Afterward, she expressed her enthusiasm about her future. Lauren did state that she knew and liked Gisele, though they didn't appear to be close friends prior to composing.

RQ1: How did multilingual learners use while multimodal composing in a secondary marine biology classroom?

During the three composing sessions, Gisele leveraged modes, mainly oral language and digital images, to: (1) collaborate with her peers, (2) participate in science, and (2) position herself within classroom. These are explored further within the following sections.

Gisele leveraged various modes to interact with classmates

Analysis of data revealed Gisele leveraged various modes to express her ideas and collaborate with her composing partners.

Express Ideas. Gisele used oral language to share her ideas within the composing process. She often participated in verbal discussions with her partners to share her ideas and hear theirs, but when it came to specific details of design, she often leaned upon images to communicate with precision. For instance, as she and Eduardo

designed their 3D model of a fish, Gisele used images from Google to support her communication with her partner (Figure 4-1).

Excerpt B

> Gisele: [begins new search 'koi fish'] You know how they have all those wispy fins, and like... [she used her index fingers to trace around her mouth, indicating the fins near koi fish mouths] they kind of look like a dragons, a little bit, koi fish [images of koi fish appeared] but, they're fat and ugly. Look at them, they look like cows. Like, the front, you see how it has that, and then it has all the wispy stuff? Our fish could look like that in the front. Can you draw something like that?
>
> Eduardo: I wouldn't say they looks ugly
>
> Gisele: Huh?
>
> Eduardo: I wouldn't say that it looks ugly.
>
> Gisele: Yeah, I just, our fish is better, is what I'm saying. You know, like this fish is ok, but look at that [pointed to image of koi on screen], like it has little things, all the things, you know what I mean? And then it'll have two more fins on the side so it'll be extra fast. Or, is that biologically impossible? (R3D1) 36:56

In this example, Gisele used images of koi fish and oral language to communicate how she pictured their model's fins by referring to similarities she desired their model to have, "Like, the front, you see how it has that, and then it has all the wispy stuff? Our fish could look like that in the front." She also described ways she did not want their model to resemble koi, "Look at them, they look like cows" and clarified, "this fish is ok, but look at that [pointed to image of koi on screen] like it has little things, all the things. You know what I mean?" She also included a question "Or, is that biologically impossible?" which gave Eduardo an opening to share his thoughts. This excerpt demonstrates how Gisele used images to communicate details in ways that her words alone could not.

Keeping on Track. Gisele also used various modes to keep her and her partners' progress on track to be submitted by due dates, for better or worse. One example of this was during the final day of the second composing project, Gisele and Lauren were searching for whale shark-related raw data to create a graph to add to their digital slideshow, as required by Ms. Pearson. They were scrolling through pages on sharkbook.ai when they encountered a line graph, a small spreadsheet, and a set of bar graphs (Figure 4-2). Lauren quietly but excitedly said, "Oh shoot, look at this!" then they both leaned in close to the screen as Lauren read part of the description of the graphs. They continued scrolling up and down the page before selecting a link to a larger version of a line graph that represented the number of newly identified whale sharks from the Western Central Atlantic Ocean from 1999-2015 (McKenney et al., 2017). As Gisele and her partner looked at the line graph, Gisele expressed an idea:

> Gisele [whispered]: Hmm, what if we, do *that*?
>
> Lauren [whispered]: Yeah, we could just, I was just about to say.
>
> Gisele [whispered]: Go back and just copy that website, it's not like she is going to scroll all the way down.
>
> Lauren: [navigated back to their Google Sheets page] Alright, so we need year on the left-hand column, right?
>
> Gisele: On the bottom.
>
> Lauren: So yeah, left column.
>
> Gisele: Oh, left column, yeah.
>
> Lauren: So, what year did they start? [navigated to the line graph] 1998.

This excerpt shows the conversation between Gisele and Lauren as they decided to copy data from an existing bar graph rather than locate raw data online to create a new graph, as was required by Ms. Pearson for the assignment. Over the next seven

minutes, Gisele and Lauren navigated between the line graph and their Google Sheet copy and pasting information directly into cells to create their new graph. Gisele and Lauren were not observed to discuss the information represented, so it was unclear whether or not they understood what the graph meant. Notably, they were incorrect on the year first represented, it was actually 1999, not 1998. This was an example of Gisele participating in multimodal composing to represent information through multiple modes, but I would argue, without much benefit. In this instance, Gisele's desire to keep on track for the deadline, which was at the end of the class period, led her to miss a potential opportunity to *obtain, evaluate, and communicate information*.

Though, there was evidence of positive aspects of Gisele's desire to stay on track. For instance, Gisele evaluated her composing partner's needs for support in-the-moment by judging his use of oral language. This topic came up during the final interview when Gisele mentioned that she noticed, while working with Eduardo, when he was silent, it was a sign that he had stopped making progress. She explained,

> It was a real drastic change when I started working with Eduardo because I, you know, for me and Lauren, silence is good. It means we're like, we're working really hard. Me and Eduardo, it means he's stuck, and something's wrong.

Here, Gisele described one way she was able to recognize when Eduardo needed support to maintain progress during project 3. As Gisele and Eduardo collaborated, they would agree on what needed to be done and establish their roles for the day before beginning composing during which time they often discussed topics unrelated to the fish model. Gisele described these conversations as, at least partially a strategy for composing at a faster pace, "I think honestly, maybe I was complaining a lot, but um, talking we might have worked a little bit faster." (Final Interview).

Gisele also acknowledged that she enjoyed hearing stories from Eduardo, many of their conversations were about people, places, and activities in the Dominican Republic, where they both had strong ties. Gisele said:

> I was asking [Eduardo], cause I like, love hearing about it cause Eduardo like grew up in the D.R. I was asking him about his experiences over there and he was telling me and like just all this stuff where he grew up and stuff like that.
>
> So, I loved hearing like, I mean, even though they were time consuming, I loved all of Eduardo's little stories like, they remind me of home.

Though Gisele and Eduardo almost always used English while composing, their conversations tapped into important aspects of their linguistic and cultural identities. For Gisele, composing with Eduardo in their science classroom created opportunities for her to form meaningful connections, learn more about her own heritage, and be reminded of her home. Interestingly, in the end, Gisele's appreciation of Eduardo overcame her desire to complete projects quickly. When asked if she were to do another composing project, which of her partners would she like to collaborate again she responded:

> Honestly, Eduardo. Which is just so funny just because I feel like I could not try to get him to be fast or anything. Like he works at his own pace, but it was just, Eduardo is so like, his mind is really interesting to me and I like how he interpreted things and I like talking about the D.R. And it was so funny now that I'm really thinking about it, I feel like, um, Owen and Lauren finished way faster on theirs than me and Lauren ever have on our projects, which almost makes me feel like how Edward's making me feel. I feel like maybe I might have held Lauren back in some aspects, which is so funny. So, I feel like I might have been Lauren's Eduardo at some point and now that I'm kind of seeing it like that, I would honestly choose Eduardo, just cause we do make good a good team at the end of the day. And well, when it comes to partners, I feel like he definitely worked better with me anyways because him and Owen were like really late on that one project, or like, it was mostly Owen saying things and Eduardo was just like, yeah, sure. But with me, he was like, "Hey, I think we should do this. Maybe this." So yeah, just for the benefit of us both, I would choose Eduardo. (Final Interview)

This excerpt demonstrates Gisele's reflections on her composing practices and Eduardo's as well. She noted that she found Eduardo interesting, liked "how he interpreted things" and that she enjoyed talking about the Dominican Republic. Gisele also highlighted how composing with her might have benefitted Eduardo. In particular, she pointed out that when Eduardo composed with Owen he agreed with his Owen's suggestions and while composing with her, he expressed his ideas. She stated that she and Eduardo "make a good team" even though if they were to work together again, Gisele acknowledged, she "could not try to get him to be fast or anything."

Gisele used various modes to enact her vision of engaging in science

Gisele seemed to view multimodal composing as a class assignment, rather than an opportunity to explore a wondering or pursue creativity. Though these projects offered her chances to be creative, Gisele preferred to stick to instructions from Ms. Pearson. Still, during all three of the projects, the poster, the digital slideshow, and the physical model she leveraged various modes to be an active participant in the science classroom, as she saw it.

Followed Directions. Gisele participated in the three composing projects by following closely to the directions from Ms. Pearson, completing no more and no less than was required. In fact, the teacher-provided directions guided her composing moves for better and for worse. For example, after creating their slideshow about whale sharks Gisele and Lauren were informed that their work needed to be presented in front of the class. Gisele was frustrated because she thought this presentation requirement was not clearly communicated in the written directions given by Ms. Pearson. She later said it was difficult to present the slideshow, explaining:

> I feel like I found out towards the end that we had to present with each other and I would not have made our information so technical and hard to like read, kind of, or digest. If I knew we were gonna present, like it would've been kind of a way different format. (Final Interview)

This led me to wonder whether clearer directions might have caused Gisele to read and discuss content about whale sharks project during composing with intention, as they would have prepared to speak and answer questions about their work. This presents a more nuanced perspective on the issue of classroom presentations of student-created multimodal compositions within classrooms, as prior work has shown only positive (Hafner, 2014; Jewitt, 2008) or negative effects (Hellmich et al., 2021). Analysis of composing sessions found that Gisele did a lot of copy and pasting of text and images from Google searches into her Google Slides presentation without much interaction. Gisele seemed to view her completion of class assignments as the doing of science, regardless of the level of her interaction with the material, peers, and her teacher but perhaps a clearly expressed requirement of presentation would have promoted more interaction.

Gisele leveraged modes to position herself

Throughout data collection, Gisele used modes including oral language and images to position herself as a good student within the science classroom. This positioning reflected her desire to be successful by earning a good grade but also to support those around her. She was an active participant in the composing process. Several time during interviews and during composing sessions she commented on her desire to submit her projects on time, follow directions closely, and earn a high score. Doing these things seemed to be how Gisele viewed being a good student and her commitment to them didn’t end at the conversation level, she was committed to being

successful in the marine biology course, which she equated to earning a high grade. For instance, as she and Lauren composed their Medicines of the Sea poster, I asked if they used only in English, Gisele replied:

> Yes. I can't do it in Spanish, Lauren [tapped Lauren on the arm] doesn't know Spanish. And Ms. Pearson would *not* grade my poster if it was in Spanish, at all. She's not gonna understand it either. Because she's not gonna understand it either. She'd be like "Well it just makes it harder for me to grade."

Interestingly, Ms. Pearson said that she would in fact grade work submitted in Spanish and English but this did not change Gisele's plans. Because Ms. Pearson did not read Spanish, Gisele did not want to submit work in Spanish. For Gisele, submitting quality work and earning high scores were extremely important and this positioned Ms. Pearson, the giver of grades, as the most powerful person in science. Though Gisele was capable of using Spanish for composing, within the context of Ms. Pearson's classroom, she felt she could or should not. In this way, the science classroom restricted Gisele's access to Spanish. Though the use of multiple languages has long been recognized as beneficial for MLs in K-12 classrooms (de Jong, 2011; Jiménez et al., 1996; Pavlenko & Blackledge, 2004), creating multilingual spaces within English-centric classrooms can be a challenge (Li & Lin, 2019; Vaish, 2019). English monolingual teachers can provide scaffolds to support MLs' use of languages beyond English, but it requires intentional and ongoing effort (Daniel et al., 2019). Though Ms. Pearson told Gisele she could composing in Spanish as well as English and assured her that work submitted in Spanish would be graded, it was not enough to promote Gisele's use of Spanish in her classroom.

Supporting Others. As Gisele explained, "I can't do it in Spanish, Lauren [tapped Lauren on the arm] doesn't know Spanish." In fact, during Gisele's initial

interview, she first stated that she didn't really have any "Spanish friends" at school, though after further thought, she listed a few friends who used Spanish and English but noted that "we just always talk in English." This aligns with prior work that suggested secondary MLs' use of language other than English may be guided by their peers' use of language (Daniel & Pacheco, 2016).

When composing with Eduardo, a Spanish-English multilingual learner, Gisele described using Spanish to support communication while they composed their 3D model together:

> If I felt like Eduardo was not understanding what I was saying, I would simply just repeat it back to him in Spanish so that he could get what I was saying and then talk a little bit in Spanish back and forth."

Here, Gisele described a scenario within the science classroom in which she was able to use Spanish while positioning herself as a good student. Though during data collection Gisele expressed to me a desire to use Spanish, she was selective about doing so. Working with Eduardo seemed to create a context in which Gisele considered the use of Spanish to be appropriate. When using English with Lauren and while using Spanish with Eduardo, Gisele's use of oral language while composing was reflective of her commitment to supporting her classmates. During the final interview, she described her beliefs on the importance of teamwork by stating:

> I think, yeah, especially in class, I think everybody should at least know how to work in a team. Like, I prefer working by myself a lot, but I'm often, especially in class, sought out to either help someone with their questions or be, if, if I'm going to, if there's gonna be a group, people usually come to me. Not only cause I do the work a lot, but because I explain things as I'm doing them. So, I think teamwork is really important, yeah. Especially in a classroom.

Gisele realized that she could support her classmates. She recognized that she was "sought out" to answer questions and be part of group work both because she was

willing to do the work and because she was willing to explain things as she did them. Though Gisele preferred to work alone, this preference seemed to be overcome by her belief in the importance of teamwork, “Especially in a classroom.” ML peer collaboration has great potential for MLs’ development of content and language learning (Martin-Beltrán et al., 2018; Storch 1999, 2001, 2008; Sato and Ballinger, 2016). However, this study found that Gisele not only realized that value of supporting others for their benefit, but for her own as well. This was further supported by her statements about how she and Eduardo’s collaboration was mutually beneficial, and given the opportunity, she would choose to collaborate with him again (above). Gisele positioned herself as a good student who cared about not only her own success, but that of others as well.

RQ2: How did multilingual learners participate in science and engineering practices while multimodal composing in a secondary marine biology classroom?

This section addresses research question 2 by describing how Gisele participated in SEPs while multimodal composing. Identification of Gisele’s participation in science and engineering practices (SEPs) was supported by the IONIC observation protocol (Chen & Terada, 2021a). As discussed in the previous chapter, these findings report only participation in SEPs that occurred within the highest two levels of engagement, the collaborative and interactive levels. Gisele participated in SEPs during multimodal composing by leaning into her strengths, according to how she positioned herself, and according to her understandings, or misunderstandings, of science.

Gisele participated in SEPs by leaning into her strengths

Spanish and English. Gisele used Spanish and English flexibly to participate in SEPs throughout the composing projects. For instance, Gisele participated in *Practice 8, obtaining, evaluating, and communicating information* with her composing partner,

Lauren, as they created a poster. In particular, Gisele and Lauren *evaluated* how the information they obtained online answered a question in their assignment directions and how they could *communicate* it to others in the poster using oral language:

> Gisele: [reading aloud from teacher-provided directions] So, “Based on what you have learned about medicine of the sea, how is it important for humans, marine animals, marine habitats and oceans in general?”
>
> So, based on everything we learned and evaluated, and obtained, how is all this stuff important, for the greater good, of all this stuff?
>
> Lauren: Umm, I would say everything needs the, I don't know how to like word it, but everything needs the other thing, like, humans needs to medicines that come from coral, and all this stuff. But, I don't know, I feel like it's just, I don't know how to say it.
>
> Gisele: It's all connected.
>
> Lauren: Yeah
>
> Gisele: They need each other.
>
> Lauren: Everything needs each other.
>
> Gisele: That's one point.
>
> Lauren: because humans need, the medicines and stuff that we find, from coral, but coral needs humans, to like, preserve it, in a way?
>
> Gisele: Yeah!
>
> Lauren: Like, help it? I don't know.
>
> Gisele: They need each other. That's one point. Another point we can list is by being able to, mmm…
>
> Lauren: [reading from the teacher-provided directions] “What is important for humans, marine animals, marine habitats, and oceans in general?”
>
> Lauren: Ummm, if you harm one organism... well that's kind of like the same idea as we did.
>
> Gisele: Using medicines of the sea, greatly benefits, like the quality of life for humans.
>
> Lauren: Yeah

Here, Gisele read the directions and posed the question to her composing partner. Lauren responded aloud, “I would say everything needs the, I don't know how to like word it, but everything needs the other thing, like, humans needs to medicines that come from coral, and all this stuff.” Before inviting Gisele to respond by stating, “But, I don't know, I feel like it's just, I don't know how to say it.” Then, Gisele consolidated Lauren’s point into four words, “They need each other.” According to the NGSS, (NGSS Lead States, 2013b) Gisele and Lauren were participating in *Practice 8, obtaining, evaluating, and communicating information* in this instance by reading scientific information online, then reflecting upon the technical information to summarize complex information (i.e., the relationships between humans, marine animals, marine habitats and oceans in general) (p. 6). This was an example of Gisele using her social and linguistic strengths to promote her and her composing partner’s participation in *Practice 8*. During this interaction, they used oral language to participate in *Practice 8* as part of their composing process while discussing the interconnectedness of humans, animals, and the environment, important concepts within marine biology (Cava et al., 2005).

Similarly, when composing with Eduardo, a Spanish English multilingual learner, Gisele used Spanish speaking and listening to support her participation in SEPs. When asked how she used Spanish while designing the 3D model, she explained that there were times she “felt like Eduardo was not understanding” so she would repeat herself in Spanish and then “talk a little bit in Spanish back and forth.” In instances like these, Gisele used Spanish to communicate with Eduardo to *develop* their 3D model, part of *Practice 2, developing and using models*. According to the NGSS (NGSS Lead States, 2013b), modeling includes “developing models to predict and show relationships among

variables between systems and their components in the natural and designed worlds" (p. 6). While developing a 3D model of a new species of bony fish with Eduardo, Gisele leaned upon her linguistic strengths to support communication and collaboration as they developed and revised their model to illustrate the relationships between the designed fish and the ecosystem it lived within. Additionally, I would argue that during instances such as this, Gisele was simultaneously participatin in *Practice 8*, as she communicated scientific ideas about phenomena and the development of their design. This overlap of *Practices* aligns with previous findings (Becker & Jacobsen, 2019; Granger et al., 2019; Pasley et al., 2016).

Images for Ideas. To share ideas with her composing partners, Gisele leaned into her aesthetic strength of using images for communication, similarly to how she described doing so via social media. In the excerpt below, Gisele selected and used digital images to visually represent and communicate her ideas. She and Eduardo were in the initial stages of designing their 3D model of a fish species. Gisele had Googled "fish model project" and was showing Eduardo the image results (Figure 4-3).

> Gisele: I asked Ms. Pearson if we could do something like this, let me show you, and she said 'no'. You know, I wanted to make something like *this* [pointed to screen] or like *that* [pointed to screen]. Isn't that nice stuff?
>
> Eduardo: It's ok.
>
> Gisele: Thank you! I know you're lying.
>
> Eduardo: I mean I feel like I've done this before. I don't know where though, or when.
>
> Gisele: Look at this. *This* one looks just like our fish. [both smile]
>
> Eduardo: I mean, according to your description, yes.
>
> [They scrolled down]

> Eduardo: Yeah, because I'm thinking something more like this [pointed to screen], orange and the blue. [(Figure 4-4)]
>
> Gisele: What do you mean, like this one?
>
> Eduardo: No, like this one [pointed to the screen], but more [placed hands palms flat together].
>
> Gisele: Oooh.
>
> Eduardo: Because, you said it was going to be a bit, narrower.

Here, Gisele was participating in *Practice 2, developing and using models*, using images to communicate her ideas, as she often did (above). Gisele used the images as focal points, discussing the aspects that she liked, "You know, I wanted to make something like *this* [pointed to screen] or like *that* [pointed to screen]. Isn't that nice stuff?" When minor disagreements arose, they negotiated their design process by making suggestions and asking clarifying questions. For instance, when Gisele asked, "What do you mean, like this one? [pointed to screen]" Eduardo responded, "No, like this one [pointed to the screen]." In this instance, Gisele used images to communicate her ideas, but it was Eduardo who reminded her of the relationship between their model and their selected habitat, a coral reef, in which their fish needed to make sharp turns, "Because, you said it was going to be a bit, narrower." This reminder from Eduardo supported their model development to illustrate the relationships between components of a system, which was appropriate participation in *Practice 2* for students in 9-12 grade (NGSS Lead States, 2023b, p. 6).

Gisele's use of digital images for communication as part of her participation in *Practice 2* reflected her depiction of how she used images to communicate with her family and friends via social media. This demonstrates how Gisele leaned into her aesthetic strengths for participation in an SEP while multimodal composing. Again, I

argue there was also overlap with Gisele's participation in *Practice 8* within this example.

Importance of Written Text. While Gisele frequently used images as she composed, she also valued written text, as all projects included written elements within the teacher-provided directions. Gisele's prioritization of written text was solidified by a previous experience in Ms. Pearson's class when she lost points on a poster assignment because her text included misspellings. Gisele brought this up while creating her poster as she and I discussed her plan for composing.

> Gisele: I want to get the title down so I can get my boxes of information and *then* the drawing, because I'm just going to do little pieces of coral floating around. Because, I was going to just draw the fish snail, but we have to do the habitat too.
>
> Amber: Ok, so, you're feeling like the design is really important?
>
> Gisele: Oh yeah. I always take a long time for that. Like, my last poster is over there [pointed to the poster on the wall].
>
> Amber: Oh, yeah, it's good.
>
> Gisele: And, as you can see, the information was kinda last minute, but then, the drawing and stuff took forever.
>
> Amber: Right. So, how are you wanting to make this one different?
>
> Gisele: Um, I'm just trying to focus on my information more. Because, I got points off on that one because I misspelled words. So, I'm going to try to make sure that doesn't happen again.

As Gisele composed her poster, balancing the text with the drawings, she was participating in *Practice 8*, specifically in *communicating information* by "connecting multiple forms of media into a cohesive presentation" (Chen & Terada, 2021b, p. 30). This piece of the conversation demonstrated some of Gisele's considerations for connecting and balancing the modes of written text and image, or forms of media, into

her presentation. Once again, at the heart of this balancing act was Gisele's desire to earn a high score on the project and ensure that she didn't lose points on the writing requirements. This might have been why she volunteered to be responsible for the written components on both the poster (Figure 4-5) and 3D model projects (Figure 4-6). Notably, in the excerpt above, Gisele referred to the written text portion as "information" seemingly hinting that she didn't recognize that the images also communicated information. This was interesting, as she often used images to portray information in contexts outside of the science classroom, as described during the initial interview. This is an example of how Gisele leaned into her aesthetic strengths by using images within the science classroom, but didn't recognize the communicative power of the images she selected. Perhaps, the teacher's previous focus upon written text for grades lead Gisele to consider the written text the communicator of "information" and the images as secondary. This represented a missed opportunity for her full comprehension of *Practice 8* (Chen & Terada, 2021b; NGSS Lead States, 2013b).

Gisele participated in SEPs according to how she positioned herself

Throughout data collection, Giselle participated in SEPs as a good student, how she positioned herself within the science classroom. This was evidenced by her efforts to stay on track, but lead to some missed opportunities and her prioritization of assignments over science.

Staying on Track. During the third project, Gisele collaborated with Eduardo to create a 3D model of a new species of fish. Due to the nature of this project, they frequently participated in *Practice 2, developing and using models*. The excerpt below is from the first day of the project as Gisele and Eduardo were in the initial stages of designing the model. Just prior to this, Eduardo and Gisele discussed the details of the

plan for their 3D model and at this point, Gisele directed her attention to the handout with the directions to ensure they were on track.

> Gisele: So, let me sum it up.
>
> Our habitat: coral reef.
>
> The fish tail: rounded, so it can be like fast, making sharp turns.
>
> The body shape: compressiform, which is the one that is skinny like this [put hands flat together] but, it's also going to be like short skinny, so that it can fit inside cracks, but not like an eel skinny, just like a little bit smaller than most compressiform fish.
>
> And the mouth is terminal so it can like pick at the coral, picking at things, picking at barnacles too, and then like, just eating whatever really.
>
> And then the colors are like, not a lot but it has a big range. It's like, it's spotted, so warm colors, or like orange, brown, red, and then like light colors on top, darker colors on bottom, and it can camouflage, in the warm color range. So, it can't be blue or purple, but it can be like, *those* different colors.
>
> And, it eats barnacles and coral.
>
> Now, we need a name.

This excerpt shows how Gisele included the activity directions as part of their participation in *Practice 8* and *Practice 2*. Specifically, she read notes that she had written on the printed directions that were provided by Ms. Pearson (Figure 4-7), listing each requirement of the assignment along with their response, "Our habitat: coral reef. The fish tail: rounded…" along with additional details that illustrated their reasoning, "so it can be like fast, making sharp turns." This illustrates how Gisele used the printed directions to guide her "communication of scientific information about phenomena" as part of her participation in *Practice 8* (NGSS Lead States, 2013b). Further, she also used the teacher-provided directions to shape her development of a model to illustrate

the relationships between fish anatomy and its habitat, as part of her participation in *Practice 2* (NGSS Lead States, 2013b).

The directions guided Gisele creation of her own notes (i.e., use of written text) and conversations (i.e., use of oral language) with her partner, Eduardo, to ensure that they did not miss any requirements. Gisele considered apects of the model that she may or may not have otherwise considered and included without the prompting from the printed directions. This excerpt illustrates how, at times, Gisele's performance as a good student who followed directions and kept on track supported her participation in SEPs. However, this was not always the case.

Possible Opportunity Loss. Though Ms. Pearson's handouts often directed Gisele to participate in *Practices 2* and *8*, Gisele's reluctance to relax her commitment to following the directions meant that she did no more and no less than they required. In some instances, Gisele's dedication to following the directions cost her potential opportunities for participation in SEPs. For instance, as Gisele and Lauren *obtained information* (*Practice 8*) for their poster, they searched Google for "medicines that originated from the ocean" and came across a medical research article (Malve, 2016). The article included a list of various types of marine drugs, organized by their actions (p. 84). As they looked over the list Gisele was interested in the neuroprotective category "Oh, this one's from seaweed... neuroprotective, and it's approved for Alzheimer's disease?! That one's cool Lauren, I like that one." Gisele and Lauren spent the remainder of the class period *obtaining information* on neuroprotective drugs developed using the extracts of South Indian green seaweed. During that time, they critically read scientific literature to determine the central ideas, attempted to "summarize complex

information by paraphrasing them in simpler but still accurate terms" (NGSS Lead States, 2013b, p. 6), all appropriate participation in Practice 8 for 9th-12th grade learners. At one point, they recruited Ms. Pearson to help them understand the article, as it included a great deal of technical information and terms (Malve, 2016). Unfortunately, Gisele and Lauren later abandoned their plans to explore neuroprotective medicines in favor of a medicine that had more readily available and easily comprehensible information sources. A few days later, I asked Gisele why she chose ziconotide as their Medicine of the Sea. She explained:

> Gisele: Well, I actually wanted to do a different one with Lauren, but we couldn't find like, they were just testing it. There was like one, that was supposed to be helping with Alzheimer's and onset dementia, but it was too early to be writing a research paper on that. Like, they had just kind of started the trials for it. So, we did this one instead.
>
> Amber: So, it was kind of early in the process of the development of that drug, you felt.
>
> Gisele: Mhm, way too early.
>
> Amber: Why not do this on an emerging drug? Why pick one that is more established?
>
> Gisele: Because part of this [picked up the handout page with directions] is finding out where the drug comes from and stuff like that. Where, we couldn't even find the specific, kind of, because it was, I think seaweed. We couldn't even find the specific kind of seaweed. We knew what they wanted to treat it for, but we couldn't find out any of the specifics. So, we were going to be missing a lot of information if we did that, and it was going to be a lot of time trying to research about it, and trying to digest these very hard to read articles.

Here, Gisele described not following her initial interest in a potential neuroprotective drug, "There was like one, that was supposed to be helping with Alzheimer's and onset dementia…" and her reasoning for not pursuing it within the project, "…but it was too early to be writing a research paper on that. Like, they had just kind of started the trials

for it. So, we did this one instead." Importantly, when questioned further, Gisele referred directly to the printed directions from Ms. Patterson, "Because part of this [picked up the handout page with directions] is finding out where the drug comes from and stuff like that." She continued by explaining that though she and Lauren understood the goal of the potential medicine, she and Lauren felt they did not have enough details at the time to complete the requirements set forth by Ms. Pearson, "We knew what they wanted to treat it for, but we couldn't find out any of the specifics. So, we were going to be missing a lot of information if we did that…" Additionally, Gisele noted time as a consideration, as the thought that finding the type of information requested in the directions would require too much time, "it was going to be a lot of time trying to research about it, and trying to digest these very hard to read articles." This depicts how Gisele's commitment to being a good student, who didn't stray from the teacher-provided directions, caused her to stop exploring a topic she was curious about.

Gisele participated in SEPs according to her understandings of science

Throughout data collection, Giselle's participation in *Practice 2, developing and using models* and *Practice 8, obtaining, evaluating, and communicating information* while multimodal composing was shaped by her understandings, and misunderstandings, of science.

Science as Straightforward. Giselle had a perception of science as known and agreed upon facts that simply needed to be memorized. She expressed this perspective on several occasions. For example, while *obtaining information* for her poster, Gisele mentioned to me that she didn't trust a lot of information she found online, because "It's very easy to cherry pick your information. But, you know, science information, you can't really mix that up too much." Additionally, during the final interview, Gisele indicated that

there was no value in hearing new perspectives in science, “Unless, I like remember something incorrectly, then somebody can correct me on it.”

This view of science as a system of straightforward, agreed upon information shaped her participation in *Practice 8, obtaining, evaluating, and communicating information* because she did not see a reason to evaluate the scientific information she obtained online for accuracy. According to the NGSS’s (2013b) descriptions of *Practice 8* in grades 9-12, participation can include “evaluating scientific information from multiple authoritative sources, assessing the evidence and usefulness of each source” and “evaluate the validity and reliability of… multiple claims” (p. 6). This demonstrates that Gisele’s view of science shaped, or limited, her participation in *Practice 8*.

Gisele’s view of science differed from current perspectives in science education. The National Research Council’s Framework (National Research Council, 2012), holds a view of science as “both a body of knowledge and evidence-based, model and theory building enterprise that continually extends, refines, and revises knowledge.” (NGSS, 2024). Gisele’s view aligned with science as a body of knowledge, but her perspective differed otherwise. During the final interview, she contrasted science with poetry.

> Gisele: There’s like a limited amount of room for you to vary the answer [in science] rather than like poetry, there’s like a million different ways you can interpret one thing or another.
>
> Amber: But in science there’s…
>
> Gisele: Limited, yeah. You’re either right or you’re wrong.

This view of science aligned with previous findings of secondary students from around the world’s views of science (Lyons, 2007) and Gisele’s comment, “You’re either right or your wrong” closely mirrors a quote from a secondary student in Australia within a previous study who spoke about physical science: “[physical science is] really

structured, you're either wrong or right, it's not creative" (Lyons, 2003, p. 100). Interestingly, the quote from the Lyons work was published over 20 years ago. One might hope that students today would have a diffent understanding of science.

Though it was not explicit within the data, it is possible that Gisele's view of science also influenced her use of oral language during composing. Specifically, her decision to use English almost entirely during composing within her science classroom. Gisele seemed to understand the classroom as an English space where Spanish was not valued, which would align with prior work (Daniel & Pacheco, 2016; Martínez et al., 2008).

Eduardo, A Curious Thinker Who Took His Time

Eduardo, a senior at Cypress High, was described by Ms. Pearson as quiet but very bright; she mentioned that he worked hard on his assignments and seemed to have a sincere interest in science. I noticed that he entered class each morning and walked immediately to a seat in the back. Prior to formal data collection, I didn't frequently notice Eduardo interact with his classmates; however, when he did, I overheard thoughtful conversations and laughter. During the initial interview, he told me that his best friend had recently moved away and at that time he was finding it difficult to find new friends and build meaningful connections. By the end of data collection, he had several new friends and stated he was excited about the new relationships.

At home, Eduardo lived with his parents and three younger siblings. Eduardo and his family had moved from the Dominican Republic to the U.S. several years prior for his father's graduate programs, first to a state in the western U.S. then later to the southeast. His mother was a stay-at-home parent and his father was in the final stages of his Ph.D. program in engineering education at a major university near Cypress High

and defended his dissertation during data collection for this project. During the initial interview, Eduardo spoke at length about his experiences in U.S. schools. At his previous school, in the Western U.S., he felt he had access to more resources, such as his own laptop, whereas at Cypress High, Eduardo's family had to purchase a computer for his schoolwork. Eduardo mentioned that his parents were happy about the move for professional and personal reasons, and he understood, but wished he had the same friends and learning resources as he did at his old school.

Eduardo spoke at length about how he liked to spend time at home gaming and creating art. He stated that Minecraft™ was one of his favorite games as he liked being able to add code to implement changes within the game. He also mentioned that he would like to use his sketches and drawings as designs for stickers in the future. Though Eduardo enjoyed being an agent of change within video games, he described the creative process differently. He described his creative process as being almost accidental, saying that designs just came to him when he didn't need them. He felt they could not be forced but rather just happened.

Eduardo's strengths

Eduardo had many resources including Spanish, English, drawing, as well as experiences with video creating and editing. Though Eduardo wase quiet in class, when he spoke with classmates or Ms. Pearson, he listened closely and took time to think about his words before speaking. Though Eduardo acknowledged that, at times, he had felt embarrassed in classes when unable to express himself effectively through English. Still, Eduardo was willing to speak up during class when he had something to say.

Establishing some of Eduardo's strengths helped me explore how he tapped into them by using various modes within his composing. This study explored how two case-

participants used various modes to tap into their identified strengths for particular purposes within a secondary science classroom. However, while certain strengths were evident during data collection, it is important to note that Eduardo, and all learners, have extensive strengths and resources all of which are not possible to be identified and understood within any single study.

Language of Home. Spanish was the primary language in Eduardo's home. In fact, he estimated that he used Spanish at home 99% of the time. Eduardo had strong connections to the Dominican Republic, as he lived there until adolescence and had many relatives who remained there. During data collection, Eduardo and his family traveled to the Dominican Republic for the holiday season. They spent several weeks with family while during the break from their respective academic programs. Eduardo didn't speak much about his trip with me afterward; he said he had a good time when I asked, but he didn't elaborate.

Eduardo used Spanish and English to communicate when he played online video games with other players across the globe. Eduardo gave multiple examples of how gaming online allowed him to hear many languages. He said he could often understand large portions of conversations in Japanese thanks to English cognates. He also said he has noted many similarities between Spanish and languages such as Polish and Portuguese. Eduardo seemed to enjoy discussing language during our interviews.

Language of School. Eduardo said he used only English at school, but he did express some complexities. For instance, he said there were times he felt it was difficult to express himself in English while at school, particularly when he felt nervous. In particular, he said it was difficult to answer teachers' questions in a whole group setting

because, “When I want to speak English, I think Spanish. When I want to speak Spanish, I think English.” However, Eduardo stated that even though it was a challenge, he often raised his hand to answer teacher’s questions because he had good responses and ideas. However, when it was time to speak aloud, in English, sometimes his nerves got the better of him and he found it difficult to communicate his thoughts. During the initial interview, Eduardo said:

> The thing is when I’m not in front of the class talking, I know, like I know exactly what’s wrong or what’s like right. But, when I’m in front of the class, I’m always wrong. I’m always wrong, no matter what, I’m always wrong. It, it just don’t work.

Various Modes. Eduardo described himself as a creative person and said he enjoyed art and graphic design. He liked to draw and sketch on paper as well as compose using digital tools. At his previous school, he took a class where he developed his design skills using Adobe premiere. When it came to social media, Eduardo was more of a consumer rather than a producer. He enjoyed videos that allowed him to watch others’ code in new aspects of video games which helped him gather new strategies. In his free time, Eduardo dedicated many hours to drawing. He always had paper and a pencil so he could quickly sketch ideas as they arose to have them for later use.

Eduardo’s experiences with science and engineering practices

During the initial interview, I asked Eduardo about the kinds of things that scientists do to study the world before asking about each of the eight NGSS (2013) SEPs. He spoke of research, data analysis, and asking questions, which covered parts of *Practices 1* asking questions and defining problems and *4 analyzing and interpreting data* without prompting. Though he said he a lot about his dad’s work beyond the fact

that it was in the field of engineering education, Eduardo's responses lead me to wonder if he participates in conversations about science at home.

Considerable Experience. Perhaps the most noteworthy part of Eduardo's responses is that he not only stated that he had experiences with each of the eight practices, but he was able to provide examples of how he had participated in each practice. For instance, when asked about *Practice 2, developing and using models*, Eduardo spoke of making models at school, including a DNA strand, using computer-aided design (CAD) software, and creating ceramics. Not all of Eduardo's examples involved school activities. For example, when asked about *Practice 4, analyzing and interpreting data*, he spoke about his study of machine learning over the summer at home. He said he didn't fully understand how machine learning worked, but he took notes on post its and kept them in a line on his desk to support his study of the topic.

Strong Opinions. In addition to sharing examples of his experiences participating in science practices, Eduardo described opinions relating to several. For instance, when asked about *Practice 1 ask questions and define problems*, Eduardo said that this is something he does often, and believes it is an important part of doing science, "I feel like for science, I feel like you genuinely need to have a question." He went on to talk about questioning as part of genuine curiosity: "It [genuine curiosity] is not only a motivation, but it's just make it easier to research because you actually want to, you actually have a goal for yourself. You want to know why something happens." Within this conversation he indicated that he did not consider individuals without genuine curiosity and questions to be scientists. In particular, he mentioned that he didn't consider his dad to be a scientist because, as he put it, "I just never been able to

see his work. And he is always so, he always sounds like he is just doing homework." He continued:

> I feel like he puts in the effort, but I feel like for science, I feel like you genuinely need to have a question. Uh, and there's a lot of people like that, but I, I look at them and I know they're put in the effort, but I feel like they don't have genuine curiosity about what they're researching.

It seemed that Eduardo had understandings and experiences of science practices but perhaps didn't quite appreciate the less interesting and more tedious aspects of science.

Desire to Understand, Willingness to Ask. When I asked Eduardo to tell me about his experiences with *Practice 5 using mathematics and computational thinking*, he immediately responded by asking what I meant by computational thinking. This question caught me by surprise, not because I thought he should know the answer in fact, it was a more than reasonable question, but rather because it was at that moment that I realized no other student participant had asked. I wondered why that might be, and while those wonderings go beyond the scope of this study, this was a significant moment in the study, as it was the first time I noted Eduardo's willingness to ask questions, even when others are unwilling to ask. This spoke to Eduardo's willingness to explore that in which he was interested, even if that meant asking a simple question that others may not, for whatever reason.

Owen, Eduardo's Composing Partner

Owen, a junior at Cypress High, was a friendly student who smiled often. At home, Owen spoke only English with family and friends. A member of JROTC, Owen was often in uniform during class. Ms. Pearson described him as an interested student but mentioned that he did not always submit assignments on time or ask questions

when she thought he might have them. Owen had friends in the class and usually sat with and spoke with members of his friend group. Other than his use of English only, Owen didn't speak much about his life outside of school beyond his JROTC activities and his plans to enlist in the air force after graduation. He spoke with enthusiasm when he described his future plans in the military. Prior to data collection, Eduardo was not a member of Owen's friend group, but Owen stated that he knew Eduardo and thought he was very knowledgeable and was excited to work with him on class projects. Through my interactions with Owen, I got the impression that he cared about his grades but felt that there were out-of-school obstacles that prevented him from always doing his best in Ms. Pearson's class.

RQ1: How did multilingual learners use various modes while multimodal composing in a secondary marine biology classroom?

Throughout composing, Eduardo used oral language and images, particularly those he created via drawing, to enact his vision of engaging in science, position himself within the classroom, and to interact with classmates.

Eduardo used various modes to enact his vision of engaging in science

Throughout the composing projects, Eduardo participated in the science classroom activities in ways that reflected his view of science and how he thought it should be done.

Interest > Time. During the initial interview with Eduardo, he stated that he thought science should be driven by genuine curiosity. This view was evident in his approach to composing. For instance, Eduardo used images to communicate information in ways that satisfied his curiosity or that he found interesting or enjoyable by leaning into drawing to create both the poster (Figure 4-8) and 3D model (Figure 4-

9). Eduardo wanted his drawings to be as accurate as possible, he agonized over them during composing sessions. In fact, Eduardo remained dedicated to creating detailed visual representations through drawing even when Ms. Pearson encouraged him to consider other aspects of projects for the sake of time. During the poster and 3D model projects, Ms. Pearson encouraged Eduardo to spend less time drawing by making statements to the class, obviously for Eduardo's sake. She stood directly behind his chair and said to the class "If you know your animal lives in a coral reef, draw a coral reef. It doesn't have to be fancy, just make it look like a coral reef." She then leaned forward and whispered directly to Eduardo, "That goes for you too" and later "I am worried about... getting done by the end of class." In some of these instances, Eduardo responded by explaining the details of his plan, "I mean, I'm drawing three different seaweeds, then I'm going to fill the back." Other times his composing partner would respond in his defense, such as when Owen responded to her concern:

> Ms. Pearson: [to Eduardo] Will you have time to get that done? You're focusing on those details intensely.
>
> Owen: They're important.
>
> Ms. Pearson: Ok, I'm just saying, you better give yourself enough time...
>
> Owen: [smiles] You hatin'?
>
> Ms. Pearson: [smiles back] I would never!
>
> Owen: [still smiling] Alright then.

At other times, Eduardo would respond to Ms. Pearson's concerns about time by drawing faster, once, she responded, "There you go, faster, faster." But, at no point, did Eduardo ever cease drawing in response to her statements. It seemed Eduardo was

more concerned with the quality in his visual representations than the time it took to compose them.

Though Eduardo's lack of concern for time during composing was concerning for Ms. Pearson, it reflected his dedication to clear communication through drawing, a nonverbal mode in which he excelled. When considered alongside his previous attempts at expressing his ideas through oral language in class via English it is unsurprising that he would want to spend time using a mode through which he could expertly express his ideas:

> The thing is when I'm not in front of the class talking, I know, like I know exactly what's wrong or what's like right. But, when I'm in front of the class, I'm always wrong. I'm always wrong, no matter what, I'm always wrong. It, it just don't work.

When drawing, there was no pressure to speak aloud, no immediate need to express himself through a mode that was, at times, challenging. Multimodal composing offered Eduardo an opportunity to participate in the doing of science and pursue a personal interest simultaneously. This aligns with prior work that recognized multimodal composing as a space where students can leverage personal interests for academic purposes in English education (Hull & Katz, 2006). For Eduardo, it seemed that creating precise drawings was of more importance than keeping up with Ms. Pearson's time-related expectations.

All about the Details. Eduardo's drawings were not great in number, but they were full of intentional details. For instance, while composing the 3D model, Eduardo and his partner Gisele were negotiating how their dragon fish could eat coral. Eduardo maintained that there was no way a bony fish could digest coral, so Gisele decided their dragon fish would bite off small pieces and filter out the nutrients before spitting the

colorful coral back out of its mouth. She said this was similar to how the classroom fish picked up then spit out rocks. They supposed this process would look something akin to a dragon breathing fire. Eduardo agreed to the plan but did not like their initial design of a fish with a terminal shaped mouth, which he said resembled the mouth of a common goldfish. While working separately on day three of the 3D model project, Eduardo drew a new design for their fish's mouth before bringing it up with Gisele (Figure 4-10).

> Eduardo: [handed the model to Gisele] So, you like the fish Gisele?
>
> Gisele: I will tell you my truthful, honest opinion. [She lifted it up, and looked it over] Uhhhh... Yeah [smiled].
>
> Eduardo: I made the mouth, more, like open, like a beak kind of thing, like more sharp. For the coral.
>
> Gisele: Mhm, yeah. dang, we'll mention that.
>
> Eduardo: Because, originally made uh, too soft looking.

When asked about the shape of the fish's mouth during the final interview (Figure 4-10), Eduardo explained:

> So, for the shape of the mouth, originally, it was just going to have a normal mouth. Uh, but since [Gisele] thought it would be a great idea for the fish to eat coral, I thought that only like turtles eat corals and sponges, uh, because according to me, and then I, I did look it up afterwards. Turtles, they eat corals and sponges because, uh, they have toxins the fish cannot eat, I think. And also because the turtles have, well, beaks. So, instead I had this, I made this kind of beak, mouth thing. Like it, it looks like a beak, but it's not like the turtle beak. Like the fish probably has like, I don't know how the mouth would work really. Because, so the way the feed the fish, it's, it's, it kind of takes in coral, filters everything out of the coral and then spits the coral. So, I'm not sure how the mouth would work, but I know it's definitely not just as big as in the turtle, because the turtle just eats the coral. The fish doesn't eat the entire coral.

This excerpt highlights some of the considerations Eduardo made when developing the model. His design was not just about drawing, but about the concepts the model needed to convey, "I thought that only like turtles eat corals and sponges… turtles have,

well, beaks. So, instead I had this, I made this kind of beak, mouth thing." He also considered that since their dragon fish would bite off pieces of coral would need a beak-like mouth, similar to that of sea turtle. However, since their dragon fish would not eat coral, but rather "filter everything out of the coral then spits the coral" he acknowledged that there were differences between their mouth design and that of a sea turtle and seemed comfortable with the uncertainties involved, "I'm not sure how the mouth would work, but I know it's definitely not just as big as in the turtle." Eduardo's commitment to the details and willingness to bring a new design to life reflected his vision of engaging in science and he did so via drawing.

Eduardo used various modes to position himself

Eduardo leveraged language and multiple modes to impress others. He used oral language and his artistic skills to position himself as a knowledgeable expert and skilled artist.

Knowledgeable Expert. Eduardo enjoyed sharing things he knew. This was true in science class and in other areas as well. He spoke about this during the final interview, explaining that he enjoyed "saying random facts about things" because:

> Eduardo: I just find it like, I just like when I say something that is interesting that other people don't know. Uh, for example, my English class, uh, we were talking about, uh, so for some reason, I don't know why most people don't know basic geography.
>
> Uh, and I'm really good at it. So every time, uh, we have to talk about places in the English class, which we do a lot, uh, I'm the one that knows geography and I'm also like the nerdy person that I, I always goes "actually" and starts a really long paragraph explaining why things are in a certain way.

During the multimodal composing projects, Eduardo used oral language, drawing, and color to share his knowledge about science, the Dominican Republic, and Spanish

language. If he felt confident about his knowledge, he was quick to share it with others. Once, he did so by correcting Gisele as she briefly explained Spanish-English differences in syntax to Lauren. This occurred during the second project, as Eduardo composed a slideshow with Owen and Gisele worked with Lauren. During Gisele and Lauren's conversation, Gisele made the statement: "Yeah, like the sentences [in Spanish] are all in reverse." Two minutes, four seconds later, as all four were composing and discussing other topics, Eduardo looked up and said to Gisele:

> Eduardo: Um, by the way, you don't say things backward in Spanish
>
> Gisele: You don't? What do you mean? Like, for example, whale shark.
>
> Eduardo: I think that is objectives.
>
> Gisele: Oh, like a misconception?
>
> Eduardo: I think it's *objectives*. I think.
>
> Gisele: Oh, yeah yeah, I see what you're saying. Sometimes. That's true.
>
> Eduardo: You could just translate entire sentences exactly as it is, to and from Spanish.
>
> Gisele: [to Lauren] Not everything like, como te llama, is not, nombre, it's not backward like that. Como te llama is like what is your name.

In this example, Eduardo interjected into Gisele and Lauren's conversation to correct Gisele's statement about sentences in Spanish by stating during a quite moment, "Um, by the way, you don't say things backward in Spanish." During the two minutes between the remark and the correction, Gisele and Lauren had spoken about *obtaining information* on whale shark migration while Eduardo was looking down at his paper drawing something unrelated to the project (Figure 4-11). Initially, Eduardo appeared to be unconcerned about Gisele's statement, but in the end he took the opportunity to correct her and position himself as the expert on Spanish language. Interestingly, after

he said, “I think that is objectives.” Gisele offered him a different term in English, “Oh, like a misconception?” He did not take it up and she agreed with him, not taking an opportunity to position herself as an expert on English.

Skilled Artist. In addition to demonstrating his knowledge, Eduardo also enjoyed displaying his artistic skills, particularly drawing. When asked during the final interview what he liked about making the poster, slideshow, and 3D model, Eduardo responded,

> Uh, the fact that we had to work in groups. Which most people, most, uh, like most classes don't really have group projects. And even if they do, I feel like I don't get to like, socialize with people and this one, I feel like it did kind of a bit. Um, and the fact that I tried, uh, quote unquote tried, uh, to use my, artistic skills on, uh, like show and in a certain way to brag about it.

Eduardo’s position as an artist was acknowledged and valued by other students. For instance, when Eduardo and Gisele were in the first stages of designing their 3D model, Gisele allowed him to make major design decisions based on what would be the best fit for his artistic skills. Further, she made it clear that she wanted their project to benefit from his skills.

> Gisele: For our, actual thing, do you want to create a life size model or do you want to do a drawing or painting?
>
> Eduardo: I don’t know.
>
> Gisele: What’s easier for you? Cause I want to, want to kind of abuse your creative drawing skills and let you draw it.
>
> Eduardo: [laughed and smiled] Huh?
>
> Gisele: Yeah, that’s what I’m trying to say.
>
> Eduardo: Yeah, but I...
>
> Gisele: Show me some of your artismo, artisticness.

The tone of this exchange was one of friendliness, Eduardo smiled and appeared to appreciate the compliments and Gisele’s acknowledgement of his skills.

Eduardo used various modes to interact with classmates

Eduardo used various modes to interact with his classmates. He used his artistic skills through drawing and oral language to collaborate, brag about his skills and knowledge, and develop personal connections with peers.

Bragging for Confidence. Eduardo spoke of the importance of friendships from the very beginning of data collection. During the first interview, he stated that a close friend had recently moved away and he was having difficulty forming a new close friendship. During the final interview, he said he was excited because he had made new friends and developed closer relationships acquaintances both in his classes and online. Though Eduardo did not share the names of his new friends, he did talk about how using his resources, particularly his drawing skills, while collaborating helped him feel confident and socialize with others.

> Amber: What did you like about making the poster and the PowerPoint and the fish?
>
> Eduardo: Uh, the fact that we had to work in groups. Which most people, most, uh, like most classes don't really have group projects, and even if they do, I feel like I don't get to like, socialize with people and this one, I feel like it did kind of a bit. Um, and the fact that I tried, uh, quote unquote tried, uh, to use my, artistic skills on, uh, like show and in a certain way to brag about it.
>
> Amber: Yeah?
>
> Eduardo: Uh, yeah.
>
> Amber: Okay, so you feel like, creating these things helped you really show your artistic skills. Did that help you in science or help you socially or?
>
> Eduardo: I would say socially,
>
> Amber: yeah.
>
> Eduardo: Yes.

Amber: How so?

Eduardo: Um, like I said I just, it just make me feel more confident, just being able to brag on things. I don't know why.

For Eduardo, who expressed a desire to develop new friendships, multimodal composing was a space where interacting with peers was also a chance to "socialize." He explained that most of his classes didn't include group projects and "even if they do, I feel like I don't get to like socialize with people." Still, multimodal composing in science didn't present a typical opportunity for socializing, for a student of Eduardo's artistic prowess, it was an opportunity to show off his drawing skills for a meaningful purpose which made him "feel more confident." Confidence is key in science education. Prior work has shown that students' self-confidence and interest in science is linked to higher science achievement (Chang & Cheng, 2008; Honicke & Broadbent, 2016; Tuan et al., 2005), persistence in completing challenging tasks (e.g., Baldwin et al., 1999; Britner & Pajares, 2006), and the pursuit of a career in science, technology, engineering, and mathematics (STEM) career (Byars-Winston et al., 2010).

Personal and Cultural Connections. Eduardo also interacted with Gisele to develop personal and cultural connections, usually involving the Dominican Republic and Spanish language. Because Eduardo lived in the Dominican Republic until age 12, he was able to share information and stories with Gisele about growing up and attending school there. On one Monday morning, Eduardo told Gisele that he visited an arts festival over the weekend where he learned about larimar, a gemstone that can only be found near the city of Barahona, DR. He said he hadn't heard of it previously, and together, they looked up more information on Google (Figure 4-12) and he shared where she could find the larimar vendor from the art festival. Gisele said she had also

never heard of larimar before, though they were both familiar with amber being commonly found in the Dominican Republic.

Drawing to Collaborate. Eduardo used his design skills as part of the collaborative composing process. Though Eduardo drew images himself, he asked his partners for their feedback and thoughts. For instance, when planning their medicine of the sea poster, Eduardo asked Owen how they should draw antillogorgia elisabethae, what they referred to as “sea lavender.” In the excerpt below, Eduardo and Owen were looking at google image results of antillogorgia elisabethae (Figure 4-13) and Eduardo had asked Owen for his opinion on how they should draw their sea lavender on their poster.

> Eduardo: The thing is, I don't know if I should go like *this*, or like *this* [pointed to images on the screen]
>
> Owen: Like, you don't know if you want it like sticking out of the rock or like sticking upwards?
>
> Eduardo: [looked down at paper and sketched two design ideas (Figure 4-14)] Yeah, but I don’t know the way I would do it. I could draw it more like this, kind of going more randomly.
>
> Owen: Yeah.
>
> Eduardo: And for the other one, I could just draw a line, like, from the line.
>
> Owen: I think that looks more accurate to how it really is, because, you know how it’s got like the center kinda stalk.

Above, Eduardo said “I could just draw a line, like, from the line” but, because he was also sketching what he meant (Figure 4-14), alongside the images of actual “sea lavender” on the screen (Figure 4-13), Owen understood he meant a design with branches coming off a center stalk. Here, Eduardo used images, a drawing, and his words to communicate his meaning and invite Owen’s collaboration. Afterward, Owen

gave his opinion and Eduardo agreed with Owen, that the center stalk design would be "easier for people to understand" and they continued with their composing process. This was an example of Eduardo using his knowledge and artistic skills to both communicate and collaborate.

RQ2: How did multilingual learners participate in science and engineering practices while multimodal composing in a secondary marine biology classroom?

This section addresses RQ2 by describing how Eduardo participated in SEPs while multimodal composing. As previously discussed, Eduardo's participation in science and engineering practices (SEPs) was identified using an observation protocol (Chen & Terada, 2021a). Eduardo participated in SEPs during multimodal composing by leaning into his strengths, according to how he positioned himself, and according to his understandings, or misunderstandings, of science.

Eduardo participated in SEPs by leaning into his strengths

Image. During both the poster and 3D model projects, Eduardo participated in *Practice 2 developing and using models* through drawing images. He sometimes began his process by sketching with pencil on paper (Figures 4-14 & Figure 4-15) before finalizing the design with color (Figure 4-8) and, in the case of the 3D model, shape (Figure 4-9). Chen and Terada (2021b) describe the highest level of participation in *Practice 2* as when students "develop a model to explain phenomena through the process of co-construction" (p. 9). The NGSS (2013b) states that modeling can include the development of a model to "describe unobservable mechanisms" which Eduardo and Owen did, as the referrant of their model (i.e., coral) existed beneath ocean waters. While creating the poster, Eduardo worked with his partner, Owen, to create an accurate representation of antillogorgia elisabethae, that included the polyps on the

surface of the coral which they stated contained the chemical compounds which were used for their medicinal properties. To that end, Eduardo used his artistic skills to include what he called a “zoomed in perspective” of the surface of the coral (Figure 4-16). This is an example of Eduardo using drawing to participate in *Practice 2* by developing a model to explain phenomena that was otherwise unobservable within their classroom, a common use for models in science classrooms (Miller & Kastens, 2017, p. 642).

Eduardo participated in SEPs according to how he positioned himself

Eduardo positioned himself as knowledgeable and artistic, and this was evident within his participation in science and engineering practices while multimodal composing.

Knowledgeable. Eduardo participated in science practices as a knowledgeable student in the science classroom. As he composed, he shared information he knew with his composing partners, and others nearby, and held tightly to his ideas when challenged. For instance, when creating the 3D model, Eduardo wanted their fish to eat barnacles, but Gisele wanted their fish to eat coral. However, Eduardo was confident that coral was toxic for fish and therefore, could not be eaten by their fictional new species. Gisele pointed to one of the classroom aquariums and said “You know what those fish do? They eat the rocks, and they eat whatever is on the rocks, then they vomit the rocks back out so, our fish should do that too.” She went on to say that fish that eat broken pieces of coral could be helpful by picking up the broken pieces of coral, seemingly for the environment. Eduardo responded by saying “Usually, coral are toxic for fish... I’m pretty sure.” He added that he thought turtles had something in their

stomachs to make coral safe for them. Gisele looked up the information on the laptop using a Google search (Figure 4-17) and read aloud.

> Gisele: Yeah, “a lot of fish eat the soft inner tissue of coral polyps” I’m not sure what that means...
>
> Eduardo: That's polyps, polyps are the uh, polyps.
>
> Gisele: What is that? The soft one?
>
> Eduardo: Like the thing that...
>
> Gisele: Like the thing that the clown fish eats, I mean lives in?
>
> Eduardo: No, like, the thing that, uh, medusa, uh, jellyfish.
>
> Gisele: So, an animal?
>
> Eduardo: I mean, corals are animals too, but, coral polyp is not a coral.
>
> Gisele: This is so confusing. I’m not gonna lie,
>
> Eduardo: The thing that looks like a cylinder with tentacles.
>
> Gisele: Nope, nothing. But, I think...
>
> Eduardo: We learned that in class!
>
> Gisele: What was the thing you were saying something about turtles that have, like... Once we move on from a lesson I forget everything.

This conversation continued for several minutes more before Gisele ended it by stating, in a friendly manner, “Our fish is eating coral. That’s it. It’s like a turtle ok?” In this example, Eduardo was not able to explain what coral polyps were to Gisele, but he was firm that they were not coral and their fish could not eat coral. In this example, Eduardo and Gisele were participating in *Practice 8* by reading (i.e., obtaining) scientific information online, but without “synthesizing information from multiple appropriate sources” or assessing the creditbility of those sources (NGSS Lead States, 2013b). Eduardo evaluated information only against his own beliefs, which in this case were

incorrect. According to Ms. Pearson, “Coral polyps are coral. They’re the soft living part—the hard part is their “exoskeleton” that they build and live inside.” In this case, Eduardo’s participation in *Practice 8* as a knowledgeable student, was less than helpful.

Artistic. Though Eduardo used his artistic skills to participate in SEPs by drawing precise and detailed images, in the final interview, Eduardo described his desire for perfection as somewhat of a hindrance. When asked if anything made it difficult to compose his poster, he replied:

> Eduardo: I would say no. I would say the only constraint was myself and then being able to stick with art, with an art, uh, with an art uh, design? I don't think design is the word I'm looking for, but I'll stick with it. Uh, basically like stick with an idea because I was constantly trying to see how to fit things in the poster and I ended up over thinking it a lot and then didn't, couldn't do a poster as well as other people that, most of which are probably worse at drawing than me.
>
> But usually, because like usually when it comes to simple things like this, posters, even if people draw bad, they'll, their posters will still look better because they don't try to perfect it. Then mine, I'm just trying to get like a cool idea or something that it looks like extremely different by doing so, I just end up wasting all my time.

In the above excerpt, Eduardo described spending a lot of time working to implement a “cool idea” for communicating information (*Practice 8*) but over thinking made it difficult for him to complete it. This demonstrated that while Eduardo maintained his confidence in his abilities, he felt he wasted time trying to make things perfect. According to the NGSS (2013b), his communication of scientific information and ideas through multiple formats (i.e., image, written text) was part of grade-level appropriate participation in *Practice 8*. However, this excerpt highlighted a challenge of participating as scientists within the constraints of a secondary science classroom, specifically relating to the reality of time.

Eduardo participated in SEPs according to his understandings of science

During multimodal composing, Eduardo participated in *Practice 2 developing and using models* and *Practice 8 obtaining, evaluating, and communicating information*. Analysis identified evidence that his participation in the Practices was shaped by his understandings, and misunderstandings, of science.

Natural, Effortless. As previously discussed, Eduardo expressed during his initial interview, he believed that genuine curiosity was important for scientists. When asked about his experiences participating in *Practice 1, asking questions and defining problems*, Eduardo replied:

> Yes. Yes, a lot. My dad has actually said that I would be a better scientist than him. If I did, if I wanted to, just because I ask a lot of questions about really everything, even if I have no reason to. Unlike him because he, uh, he has to come up with the questions, he has to think about it. I don't. I just ask questions. and I, I know what I wanted to say earlier. Uh, I feel like he puts in the effort, but I feel like for science, I feel like you genuinely need to have a question. Uh, and there's a lot of people like that, but I, I look at them and I know they're put in the effort, but I feel like they don't have genuine curiosity about what they're researching.

This excerpt demonstrates Eduardo's confidence in his abilities as well as his beliefs about how scientists should approach asking questions. He stated, "I feel like [my dad] puts in the effort, but I feel like for science, I feel like you genuinely need to have a question." Eduardo thought that his personal practice of asking questions "about really everything, even if I have no reason to" was an important part of doing science, and he expressed that this view was supported by his father. Eduardo contrasted his own approach to asking questions with his father's, "[my dad] has to come up with the questions, he has to think about it. I don't. I just ask questions." This highlights Eduardo's view of science as a seemingly effortless process, which differed from the approach he has witnessed from his father and others, as he added, "There's a lot of

people like that, but I, I look at them and I know they're put in the effort, but I feel like they don't have genuine curiosity about what they're researching." As Eduardo put it, "[my dad] always sounds like he is just doing homework."

These statements show his preference for genuine curiosity over effort. Analysis of his composing practices revealed that Eduardo valued curiosity, and his interests. For instance, while Eduardo used drawing for participation in SEPs in beneficial ways, when he was unable to use this skill, his participation in SEPs looked very different. For instance, during the second composing project, Eduardo and Owen created a slideshow on Sharks in the Media. This activity required them to 1) gather information from the internet 2) create a graph to represent their choice of data on the topic, and 3) compose slides to be shared with their class. The slides were later presented in the class, but they were not part of data collection. This project was the only one in this study to include digital composing rather than physical artifacts. This difference was significant, as Eduardo was unable to use drawing for participation in SEPs or composing. Though Eduardo did, at times, support the creation of the slideshow, he was frequently off task, drawing. During slideshow composing sessions, Eduardo drew detailed sketches of aliens, which were unrelated to the project.

The data revealed beneficial aspects of Eduardo's view of science such as creativity and participation in SEPs when he was able to follow his interests and compose via drawing. However, during the slideshow project when he was not able to use drawing, Eduardo's pursuit of curiosity and all that he finds interesting seemed to lead him away from the aspects of participating in SEPs that he found less fun. There is currently a great deal of focus within science education on making science fun and

enjoyable for K-12 learners (Bobrowsky, 2018; Byers, 2012; Pursitasari et al., 2019) and increasing their beliefs in their science potential (Avraamidou, 2020; Tytler, 2014; Vincent-Ruz & Schunn, 2018), but Eduardo's case presents a different challenge. He found science enjoyable and held strong beliefs in his science potential, but disengaged when he was not able to leverage his preferred mode, on-digital images.

Comparative Case Analysis

In the following sections, I provide a comparative case analysis (Stake, 2006) of Gisele and Eduardo's use of various modes. These findings are organized by the three main themes that demonstrate how MLs use multiple modes while multimodal composing: 1) to interact with classmates, 2) to position themselves, and 3) to participate in science. This section explores these three themes from the study of the research question:

How did multilingual learners use various modes while multimodal composing in a secondary marine biology classroom?

Gisele and Eduardo used various modes while multimodal composing to position themselves within the science classroom, interact with classmates, and enact their visions of engaging in science

Positioning themselves within the classroom

This study found that MLs used multiple modes to position themselves in the science classroom. However, Gisele and Eduardo did so in very different ways. Gisele positioned herself in the classroom as someone who submited her work on time or early, earned high grades, and followed directions. I describe this as Gisele's positioning of herself as a 'good student.' Eduardo, on the other hand, positioned himself as knowledgeable about science and Spanish and as artistic.

Within the science classroom, Gisele positioned herself in a way that would help her achieve her goal of earning a high score. This was evident by her numerous and frequent references to the directions during composing, her decisions to prioritize compliance over quality when copying data from an existing graph into a new template to meet the requirements of the assignment but without understanding the data she was representing. When questions about content or composing arose, Gisele referred to Ms. Pearson, the giver of grades. For instance, during the first project, Gisele and Lauren needed to explain why medicines of the sea were important for “humans, marine animals, marine habitats, and oceans in general.” They thought there were overlapping benefits and found it difficult to differentiate distinct benefits for each. Gisele first suggested, “let’s just pretend they’re different” but Lauren reminded her that the question was worth a significant portion of their grade. Gisele responded with a sigh, “I know.” Gisele came up with another idea, “Let’s kind of, steal the answer from Ms. Pearson.” Then, Gisele and Lauren walked to Ms. Patterson’s desk and Gisele asked her the question.

Eduardo positioned himself as knowledgeable about Spanish and science as well as a skilled artist. This was evident from his dedication to composing precise visual representations, his correction of Gisele’s statements about Spanish, and his reluctance to accept suggestions that clashed with his beliefs about scientific information. For instance, Eduardo pushed back against Gisele’s desire to design a fish that ate coral because he believed coral was toxic to fish and would therefore be an unrealistic trait for their new species. However, Eduardo’s beliefs about scientific information were not always correct, as some species of fish are known to eat coral (Cole et al., 2008).

Gisele wanted to earn a high score and Eduardo wanted to impress. Gisele did not seem to mind whether or not she participated in new practices or understood new information in science class, preferring instead to receive a good grade. Similarly, Eduardo did not seem to care about obtaining new details about scientific information, but nor did he seem to care whether or not he received a good grade. His desire was to use his knowledge and drawing skills to “brag” in front of his classmates, which he stated made him feel more confident.

Student positioning in science is not a new topic within education research (Ritchie, 2002). Student positioning can be done by teachers (Smith, 2022; Wang, 2020) or by students (Ofek-Geva & Fortus, 2023). Studies have found that multilingual learners’ positioning affects their participation in school settings (Martin-Beltran, 2013). Prior work has found that students can position themselves as experts, as learners, or in any number of ways in classrooms (Martin-Beltran, 2013). Ofek-Geva and Fortus (2023) found that adolescent science students’ self-positioning in relation to science was influenced by their experiences in- and out-of-school, which aligns with findings from this study. For instance, Eduardo’s out-of-school experiences with his father, and likely other scientists, likely influenced how he positioned himself as knowledgeable. As he put it, “My dad has actually said that I would be a better scientist than him.”

Multimodal composing gave Gisele and Eduardo opportunities to position themselves through various modes within the classroom. However, there were distinct differences between the practices of these two case-participants. Specifically, these findings illustrate how Eduardo created drawings to show off his artistic skills in ways that: (1) were valued within the science classroom and (2) he had not done previously,

according to him and Ms. Pearson. Additionally, composing in close proximity to Gisele allowed him to position himself as knowledgeable about Spanish language as well, but this may be more appropriately attributed to the collaborative and student-directed aspects of their composing rather than the use of various modes. Still, it is worth consideration because prior to this project, Gisele had never heard Eduardo discuss Spanish.

For Gisele, multimodal composing created a space where she leveraged her social, academic, and linguistic skills to position herself as a good student. Gisele used images and oral language to support herself by completing assignments on time and earning high scores, but particularly to support her peers. For instance, she leaned upon Spanish oral language to support communication with Eduardo and images to facilitate their collaboration and composing along with oral language as they created detailed aspects of their 3D model, including the mouth shape (Figure 4-10). Though she used various modes to complete assignments on time and earn good grades for herself, Gisele was a student who achieved these things when not multimodal composing. However, it was while supporting others that Gisele's strategic use of various modes while multimodal composing really shone.

Though this was not clearly stated by Gisele, it is worth noting that her out-of-school responsibilities might have influenced how she positioned herself. In particular, Gisele described sharing responsibilities for grocery shopping, language brokering, and babysitting all in addition to attending school, participating in sports and working a part-time job. Gisele's positioning as a good student prioritized getting things done rather

than indulging in extensive explorations. Perhaps, this was a reflection of how she navigated multiple priorities.

Interacting with classmates

Interaction is important for MLs within all learning contexts, as it is through interactions that mediation occurs (Vygotsky, 1978). It is between individuals and the tools they leverage that the work of learning occurs. Within science, interaction is of particular importance for student participation in science and engineering practices as the practices themselves require communication. For instance, *Practice 8, obtain, evaluate, and communicate information*, one of the two practices Gisele and Eduardo participated in during this study, has the facilitation of communication at its core. Composing through various modes within a science classroom allowed MLs to leverage their strengths, or preferences, for communication.

Aligning with prior work (Smith, 2017), Gisele and Eduardo both exhibited "modal preferences" (p. 11) in that they leaned upon particular modes to do more communicative work than others. Both case-participants expressed *visual modal preferences* by leaning heavily upon images for communication during composing, Eduardo his own drawings and Gisele digital images online.

In addition to a preference for images, Gisele and Eduardo used oral language to interact with classmates while multimodal composing, but in different ways. Gisele used language and images to collaborate with her partners and to keep composing on track. While Eduardo used language and drawings to build his confidence, collaborate with his composing partners, and to develop personal and cultural connections.

Gisele leveraged modes to communicate with her peers. She was proficient in finding just the right image to communicate her ideas to her composing partners and

would use oral language to discuss what she meant until she felt she was understood (as noted above from the initial interview). These findings demonstrate that various modes were important for Gisele's communication with classmates and supported her in ways a single mode could not.

Additionally, Gisele frequently referred to directions given by Ms. Pearson to ensure she and her composing partners were on track to submit compositions on time, which was part of how she viewed being a "good student," for better and for worse. For instance, while composing the slideshow, Gisele would sometimes copy information directly from the internet and pasting it into her digital slides. Gisele, and Lauren's, lack of understanding about the information they included became evident when they were unable to answer basic questions about it (see above). Additionally, the topic arose during Gisele's final interview and she said, "I would not have made our information so technical and hard to like read, kind of, or digest." if had she known she and Lauren would have to present the slideshow in class. It appeared that Gisele copy and pasted information they didn't understand along with some pictures into an attractive slideshow template. Gisele did use oral language and images communicate her ideas and collaborate with Lauren while creating the slideshow, but they had more to do with getting an assignment submitted and less to do with science than one might hope. However, during the poster and 3D model projects, Gisele used those same modes to share her ideas and collaborate in positive ways, which demonstrated that in this context, non-digital composing held particular benefits.

Eduardo leveraged oral language and images to communicate with his classmates in ways that made him feel confident. In the final interview, Eduardo said

using his drawing skills in science class helped him socially and “just make me feel more confident, just being able to brag on things.” He also developed personal and cultural connections with Gisele, particularly as they worked together during the 3D model project. Gisele grew up in the states, but her parents, like Eduardo, were from the Dominican Republic and she enjoyed hearing about what it was like to grow up and attend school there. Also, Eduardo supported Gisele’s pronunciation of the names of cities in the Dominican Republic as they searched for a fun name to give to their fish model, thought they eventually landed on “dragon fish” because dragon is a Spanish-English cognate. Previous work has demonstrated that multilingual learners’ use of home language in the science classroom gave them the confidence to share their ideas and participate in “meaningful classroom interactions” (Mavuru and Ramnarain, 2020). Findings of this study extend this beyond language, as Eduardo stated that the use of images allowed him to leverage his artistic skills to make him feel confident in the science classroom. Still, this leads to the obvious question, could the use of Spanish have promoted Eduardo’s confidence further?

Gisele used various modes to flexibly navigate interactions productively with her composing partners, even when things were frustrating. For instance, she spoke of allowing Eduardo to talk constantly about whatever he wished as he composed the 3D model and she participated in those conversations via English and Spanish oral language. Gisele felt Eduardo’s use of oral language provided him something that he needed to remain on task, which served her own goal of getting the assignment submitted on time and for a high score, though she at times found this frustrating, “Eduardo is really hard to work with because he was like telling all these stories.”

However, Gisele was interested in some of Eduardo's stories, as least those that pertained to the Dominican Republic. She stated that she enjoyed hearing about his life there, as she has only been able to visit. As they worked together, she asked him numerous questions about places he has been, things he has done, and the locations of his family members and she also shared with him about her own experiences and family members.

Eduardo had a different approach to frustrating situations during composing, he disengaged. For the second project Eduardo and Owen created a slideshow presentation on the topic of Sharks in the Media and they found it difficult to sort through the multitude of options within that topic. Ms. Pearson recognized that this was a challenging topic in conversation with me, she mentioned it might have been too broad. During the composing of the digital slideshow, Eduardo frequently sat quietly, scrolled on his phone, or drew pictures unrelated to marine biology. Initially, it seemed when Eduardo participated in a project that did not allow use of his artistic skills, he was less interested in participating actively. However, upon further analysis, there were differences in the interactions between Eduardo and Owen during the slideshow and the poster projects. For instance, as described above, Owen supported Eduardo's drawing for the poster, even defending his time on the details when Ms. Pearson protested. However, when Eduardo attempted to collaborate on the slideshow project, Owen was not always receptive. For instance, when searching for longitudinal data points to use for their graph, they found an article from therevelator.org that discussed data from an annual survey about American fears from Chapman University (Figure 4-18). Eduardo

looked at the screen with the top result (Figure 4-18) for about one minute, then Owen said to conduct a new search to look up shark movies and Eduardo responded:

> Eduardo: Yeah, but this is interesting because it says that they do that, annually.
>
> Owen: Right, so?
>
> Eduardo: So, like, uh
>
> Owen: Did you find one for this year, maybe?
>
> Eduardo: They may have the data.
>
> Owen: Or last year?
>
> Eduardo: They may have the data.
>
> [clicked the article's link, error message]
>
> Eduardo: But, they do it annually. It's an annual survey.
>
> Owen: Do, do we really... Can you pull up and find maybe... Uh, type in current 2020, or 2022. It's more likely that they probably did it last year.

After this exchange, Eduardo ran new searches at Owen's behest and the data from the Chapman University survey was not sought again. After a few minutes, Eduardo began drawing a picture of an alien on paper and Owen took over the laptop. There were more instances when Eduardo attempted to raise ideas but Owen did not take them up during the slideshow project. There was a difference between the way Owen treated Eduardo when he drew to compose and they way he treated Eduardo when he had suggestions for finding data online. This highlights how Eduardo used images, specifically the creation of drawings, to interact with Owen while positioned as skilled but their interaction looked differently when Eduardo interacted with Owen in a different context, where his artistic skills were not beneficial.

Though Gisele expressed a desire to compose with Eduardo so that they could use Spanish together, this did not come to fruition. Unfortunately, Gisele's interactions with Eduardo in the classroom seemed to reflect previous interactions with other Spanish-speaking classmates in that they wanted to communicate via English. Eduardo did pronounce the names of cities in the Dominican Republic, he used little Spanish otherwise. However, Gisele did not lament their interactions through English, in fact, during in her final interview, she spoke enthusiastically about the cultural and linguistic connections they made. She enjoyed hearing of his stories from growing up in the Dominican Republic, being able to ask him questions, and gather new information about larimar, the gemstone unique to the D.R. Though the science classroom remained an English space, Gisele and Eduardo found ways to form cultural connections via English oral language and images in particular.

To enact their individual visions of engagement in science

Gisele and Eduardo both used various modes to enact their personal ideas of what it meant to engage in science in their marine biology classroom. This enactment varied between the two, depending upon their views of science. For example, Gisele viewed doing science in class as following directions from the science teacher. As previously discussed, this was not always to her advantage, as her strategy of copy and pasting written text and images from the internet was a missed opportunity and superficial participation in *Practice 8 obtaining, evaluating, and communicating information*. However, there were times when Gisele's commitment to following the directions worked in her favor, as when composing the 3D model with Eduardo. While Eduardo was busy drawing each intricate detail of their fish, she served as the go-between for him and the end goal of submission, by leveraging oral language, written

text, and contributing to their 3D model, an image, by cutting paper dots. She ensured that the written component of the model was complete (Figure 4-9) and that they made adequate progress by executing aspects of the design like cutting out spots brown and creating the brown and white spots for the camouflage. Additionally, she kept Eduardo engaged by listening to his stories and asking questions about science and his life.

Eduardo used various modes to do science while composing differently than Gisele, as he had a different perspective of science. In his initial interview, he stated that science should be led by genuine curiosity and when composing in science this seemed to mean Eduardo pursuing his interests. This typically looked like Eduardo participating in *Practice 2* and *Practice 8*, at least the *communicating information* piece, through the creation of an image via drawing. As previously discussed, Ms. Pearson expressed concern about the amount of time he dedicated to his precise visual representations. Then again, in the third project Gisele was the one providing "pressure" about the amount of time he spent drawing and on other visual aspects of their 3D model. Eduardo did not speak about Ms. Pearson's encouragement for him to get things done quickly, but he spoke about his experience with Gisele during the final interview and described feeling "pressure" from Gisele. When asked what he thought about the pressure, he said:

> Eduardo: I mean, it wasn't bad. It was just, uh, it kind of felt more, uh, like sort of calling me out.
>
> Uh, because there was calling me out with the other project. So this one felt more, uh, I don't know, like in a certain way more direct, but isn't more direct. It's just the same the only difference is that now I feel responsible, but if I don't do anything.
>
> Amber: Do you feel like, or do you have positive or negative feelings about the pressure?

Eduardo: Neither, I would say, yeah, I would say it's neutral. Like, I didn't really mind it.

Later in the interview, Eduardo also stated that he wasn't sure if he would have gotten the 3D model completed by the deadline without pressure from Gisele. When asked if he would rather complete another project with Owen or Gisele, he chose Gisele. During the third composing project, as Gisele and Eduardo composed together, his willingness to pursue interests and curiosity and her desire to follow directions seemed almost complementary as they were each enacting their views of science in their own ways.

RQ2: How did multilingual learners participate in science and engineering practices while multimodal composing in a secondary marine biology classroom?

Gisele and Eduardo participated in SEPs while multimodal composing in marine biology: (1) by leaning into their strengths, (2) according to how they positioned themselves within the classroom, and (3) according to their understandings, or misunderstandings of science.

Leaning into strengths

Gisele and Eduardo participated in science and engineering practices, specifically *Practice 2* and *Practice 8*, by leaning into their strengths through leveraging various modes. However, there were distinct differences in which modes they used and how they did so. Gisele employed oral language, digital images, and written text to participate in SEPs including when she expressed her own ideas and worked alongside Lauren to comprehend and communicate scientific information to their audience (Chen & Terada, 2021a). Eduardo, on the other hand, also used oral language but leaned heavily upon non-digital images, in particular those he drew himself to develop a model

to communicate the relationship between components within a system (NGSS Lead States, 2013b, p. 6).

Gisele used Spanish and English to participate in SEPs. During the final interview, she described "interpreting" scientific terms as she *obtained information* in Spanish because of the linguistic similarities to Latin. She also explained that there was some information she restated information to Eduardo in Spanish to support his understanding. She also used images to *communicate information* to an audience. For example, Gisele stated in the final interview that the slideshow was her favorite project because she enjoyed selecting images to include. She stated:

> I feel like it's a really nice and fun way to present information to people. You can always use images from like another source, an outer source, but probably my favorite because you don't have to like sit there and draw something. And, I'm not artistic, so that's probably why.

Gisele went on to say, "I'm so bad at being creative, but when I'm presented with, so-and-so information, I'm good at organizing it and presenting it to someone else and explaining it to someone else." Gisele felt that the option to compose using existing digital images not only allowed her to avoid drawing but empowered her to use her strengths. However, considering that she composed the slideshow by copy and pasting images and information that she did not understand and did not feel confident about presenting, the reality might be that she liked that creating the slideshow was an easy lift for her.

Eduardo participated in science and engineering practices by leaning heavily on drawing. For him, multimodal composing projects that included drawing brought together two things he enjoyed, science and art. However, he was clear about which he wanted to pursue, as he explained to Gisele during a discussion about fish:

Gisele: How do you know all these things?

Eduardo: Because I like science.

Gisele: Oh, that's a good reason.

Eduardo: I don't want to *do* science, but I *like* science.

Gisele: What do you want to do then?

Eduardo: Art.

Eduardo's desire to do art through drawing was evident during all three composing projects. For instance, during the poster and 3D model projects, he committed the time and energy he deemed appropriate for creating detailed and accurate images to *develop models* and *communicate information*. During the slideshow project, his desire to do art was observed as he sketched images of aliens unrealted to the project. However, during the poster and 3D model projects, his efforts went beyond simply creating sketches, as he did while working off topic during the second project. Specifically, he leveraged his artistic skills to develop a model to describe unobservable mechanisms and illustrate relationships between components of a system (NGSS Lead States, 2013b). Eduardo also *obtained and evaluated information* by using English with his composing partners. However, when Eduardo participated in *evaluating information*, he did so by evaluating new information against his current beliefs, rather than looking outward. For instance, when discussing whether fish could eat coral, Gisele used Google to find an answer and found that many fish eat coral polyps. Eduardo insisted that coral polyps were not coral, and this was something they had learned in class. However, in conversation with Ms. Pearson, I learned that in class she taught that coral polyps were part of coral, the soft inner tissue. So, for Eduardo, not *evaluating information* meant that he sometimes communicated incorrect details. This represented

a missed opportunity deeper participation in *Practice 8*, as the NGSS (2013b) includes the evaluating the validity and reliability of multiple claims, as well as the comparison of multiple sources as part of appropriate participation for students in grades 9-12.

Perhaps the most noticeable difference between Gisele and Eduardo's participation in science and engineering practices was the types of images they used. Eduardo created drawings while Gisele used existing images from the internet. However, another important difference involved their use of language. Gisele used both Spanish and English while Eduardo used only English, with a few exceptions, for instance when he pronounced "dragon" in both English and Spanish to demonstrate the difference. Gisele and Eduardo both mentioned her use of Spanish when they composed together, but they both agreed that Eduardo only responded to her in English. Gisele felt that her use of Spanish helped him understand what she was trying to say, but he did not say so. Unfortunately, this conversation was not captured by data collection. They stated that it occurred during their composing of the 3D model, but it must have occured when they moved away from the laptop to select materials. Still, each participant leaned into their particular strengths via various modes to participate in SEPs during multimodal composing.

Participation aligned with their positioning as students in science

Gisele and Eduardo participated in science and engineering practices according to how they positioned themselves in the science classroom. Gisele positioned herself as a "good student" and her participation in SEPs was guided by her desire to stay on track by following the directions. There was evidence to suggest that this caused her to prioritize assignments over science and miss some opportunities. Eduardo participated

in science and engineering practices as a knowledgeable student with strong artistic skills.

While composing, Gisele kept the printed directions nearby and referred to them frequently. Assignment directions lead Gisele's composing for better and worse. When creating the 3D model with Eduardo, the directions caused Gisele to consider multiple aspects of their new species of fish including its habitat, diet, camouflage, as well as the shape of its tail, mouth, body, and fins. This was clear as she used oral language to discuss the aspects of their plan and in her creation of the model. In this project, the directions were the deciding factor in how much detail she included. In fact, Gisele even missed an opportunity to explore neuroprotective medicines from seaweed, a topic she deemed interesting, because she was concerned about the amount of time it would take to gather information about a medicine without readily-available grade level texts on the topic. This was a missed opportunity, as in the science classroom they had access to Ms. Pearson for guidance as they explored complex texts to support their participation in *Practice 8* through their crucial reading of scientific literature to obtain scientific information, summarize compliex evidence and information through paraphrasing in simpler terms (NGSS Lead States, 2023b). Further, they might have asked Ms. Pearson to adjust the directions to support their exploration, but they were not observed to have considered this. Gisele viewed the directions as inflexible and permanent.

Eduardo approached participating in science and engineering practices as a knowledgeable student who valued genuine curiosity and as such, he pursued his interests in science. This became problematic when he chose to evaluate scientific information based on his own beliefs and memory from class rather than referring to

outside sources. This hindered his participation in *Practice 8, obtaining, evaluating, and communicating information* and *Practice 2, developing and using models*. For Eduardo, *communicating information* aligned nicely with his position as a knowledgeable and artistic student in the science classroom and *obtaining information* was something he could do in collaboration with his composing peers and could therefore facilitate socializing. Though it is important to note that both the poster and 3D model projects allowed Eduardo to participate in *designing models*, *obtaining information* and *communicating information*, aspects of *Practice 2* and *Practice 8*, this participation could have gone further. For instance, scientists work is cyclical and often includes many rounds of revisions (Miller & Kastens, 2017). However, Eduardo's unwillingness to look to external sources to evaluate information or question his own perspectives seemed to reflect a perspective of a non-scientist. In particular, rather than pull back the curtain on the practices of scientists, for Eduardo, multimodal composing was an opportunity for him to participate in science class as a knowledgeable and skilled artist, without expanding his understandings of science and what it means to participate. Existing work has shown that a lack of public understanding about how scientists study the world is a longstanding challenge and can promote public mistrust of scientific findings (Oreskes & Conway, 2010).

Another challenge relating to Eduardo's participation in SEPs was the time it took to produce detailed visual representations through drawing. As always in K-12 classrooms, time is a major consideration and even with Ms. Pearson's reminders about it, Eduardo remained committed to his goal of perfection. Though, in the end, Eduardo acknowledged that he thought some of his efforts to implement a "cool idea or

something that it looks like extremely different" took a great deal of time and might not have been the best use of it.

Gisele and Eduardo both participated in SEPs according to how they positioned themselves in the classroom, therefore it looked different for each of them. Eduardo's participation in SEPs was driven by curiosity. He exhibited less interest in Ms. Pearson's directions or expectations, and he neglected to evaluate his own assumptions, an important part of participation in SEPs (NGSS Lead States, 2013b). Gisele's participation was led by the teacher and the directions and expectations she provided. For Eduardo, multimodal composing was a space for exploration. For Gisele, it was a space to, in some ways, maintain the status quo set forth by her position as a good student, which left her perspective of science and the science classroom unchallenged, which goes against some primary goals of the NGSS (Buxton & Lee, 2023).

Participation aligned with their understandings of science

Gisele and Eduardo both participated in science and engineering practices according to how they understood science. Gisele viewed science as a set of known and comprehensible facts while Eduardo viewed science as a pursuit of knowledge.

Not only did Eduardo view science as a pursuit of knowledge, but he thought that this pursuit was best when undertaken by individuals with questions driven by what he called "genuine curiosity." He also stated that this curiosity helped scientists stay motivated to find answers. Analysis suggested that what Eduardo discussed as curiosity materialized within his composing process as following his interests. Because his interest of drawing was able to be leveraged for participation in science and engineering practices, it supported him as he developed models and communicated information. It did not seem to help him remain engaged when faced with challenge, while composing

the slideshow with Owen. During that time, Owen did not take up Eduardo's ideas for composing and Eduardo had difficulty obtaining the information he sought. Rather than ask Ms. Pearson for help, as Gisele had done many times, Eduardo returned to drawing, but of topics unrelated to the task at hand.

Gisele viewed science as straightforward, it was a body of information that others understood and she just needed to memorize pieces long enough to complete projects and earn a high score in the course. She was not observed to have difficulty remaining on task even when faced with challenges during composing. Gisele was committed to completing assignments in their entirety and submitting them on time which led her to participate in *Practice 8* and *Practice 2*, simply by following the directions of the assignments. Similarly to Eduardo, Gisele encountered a challenge during the slideshow project, when she and Lauren were unable to locate raw data on whale sharks that could be used to create a graph. In contrast to Eduardo's going off task approach, she remained dedicated to getting the assignment done, leading her to choose to copy data from an existing graph, even though she and Lauren did not seem to understand what it represented. In that instance, her dedication was at the expense of meaningful participation in science and engineering practices, as they missed opportunities to "compare, integrate, and evaluate sources of information presented in different media for formats" (NGSS Lead States, 2013b, p. 15) by choosing instead to solely copy and paste.

Summary

Overall, case-participants Gisele and Eduardo, participated in science and engineering practices, specifically *Practice 2, developing and using models* and *Practice 8, obtaining, evaluating, and communicating information*: 1) by using various modes, 2)

according to how they positioned themselves, and 3) according to their understandings of science. These findings show how each case-participant tapped into their unique and multiple strengths via multiple modes while multimodal composing. Furthermore, these findings illustrate how they used various modes during multimodal composing within a marine biology classroom to participate in essential science practices, particularly to *Practice 2, designing and using models* and *Practice 8, obtain, evaluate, and communicate information.*

Table 4-1. Next Generation Science Standards' Science and Engineering Practices

Practice number	Practice Description	Example
1	Asking questions and defining problems	Students ask why there are microorganisms in their tap water and whether or not they are safe.
2	Developing and using models	Students create models of different types of microorganisms found in water.
3	Planning and carrying out investigations	Students develop and implement a study to learn whether or not the microorganisms in their tap water are safe to consume.
4	Analyzing and interpreting data	After implementing the tap water microorganism investigation, students use collected data to determine whether or not their water is safe to drink.
5	Using mathematics and computational thinking	Students use equations in their analysis process.
6	Constructing explanations and designing solutions	Students create a report of their tap water study explaining their findings and include ideas for how to improve the water quality, or how to share their safe water with others.
7	Engaging in argument from evidence	Students use their findings to argue for either safer water in their community or sharing their safe water with other communities.
8	Obtaining, evaluating, and communicating information	Students develop and implement plans for spreading the word about their community's tap water and include external sources.

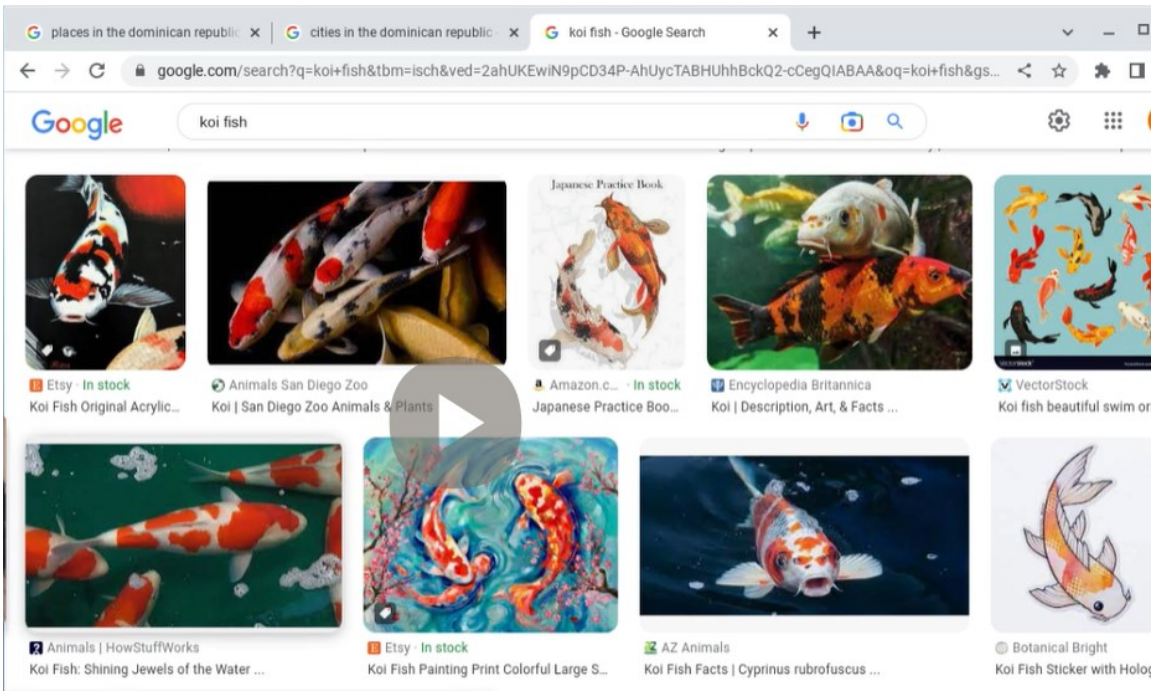


Figure 4-1. Screenshot from Gisele and Eduardo's laptop while they discussed fins for their fish model.

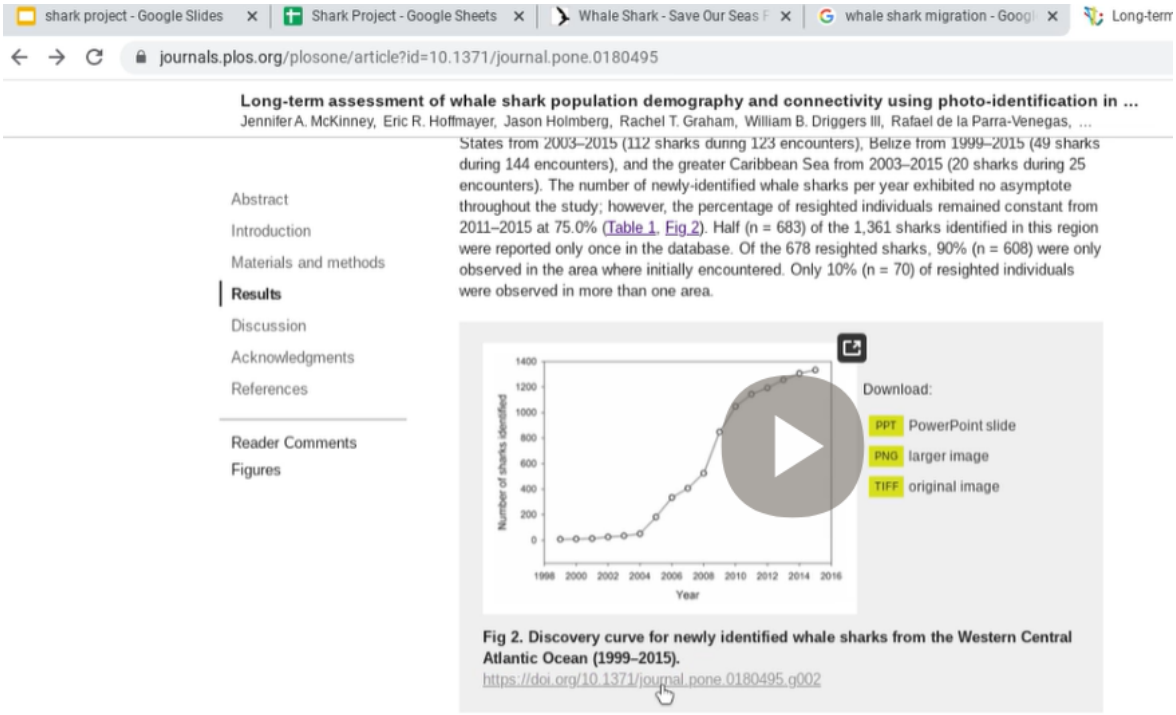


Figure 4-2. Screenshot of Gisele and Lauren's laptop while searching for data for a graph.

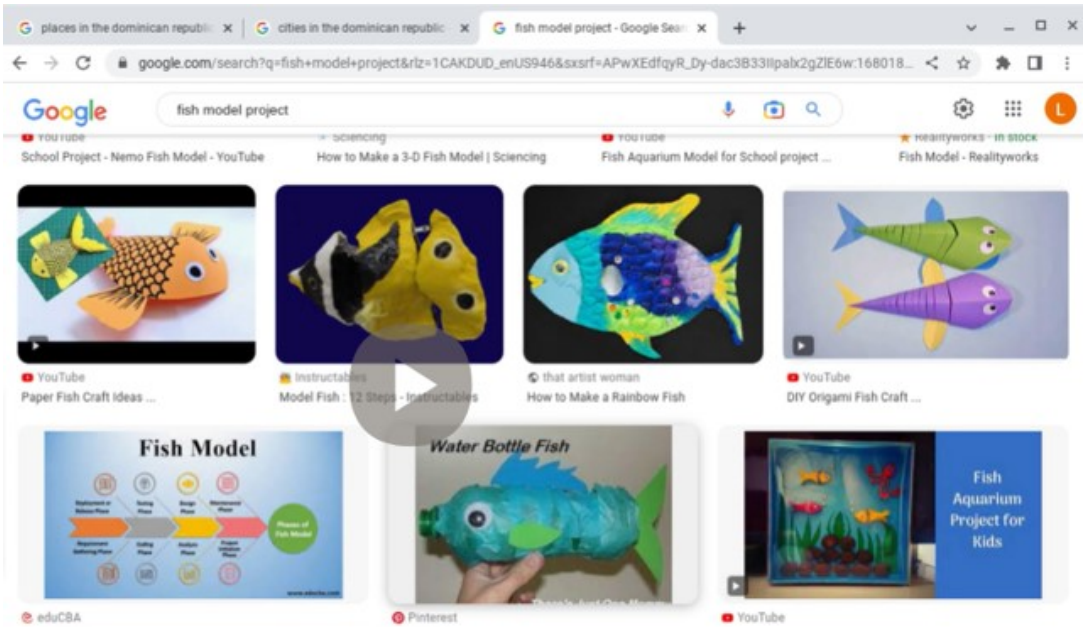


Figure 4-3. Screenshot of Gisele's search results.

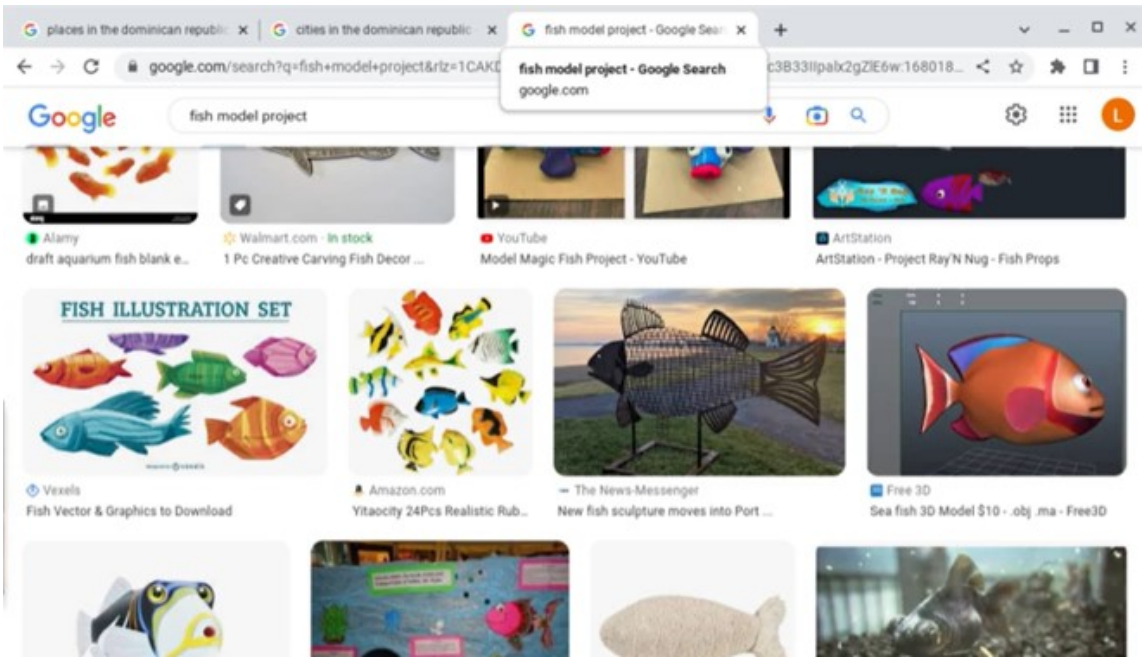


Figure 4-4. Screenshot from Gisele and Eduardo's laptop.

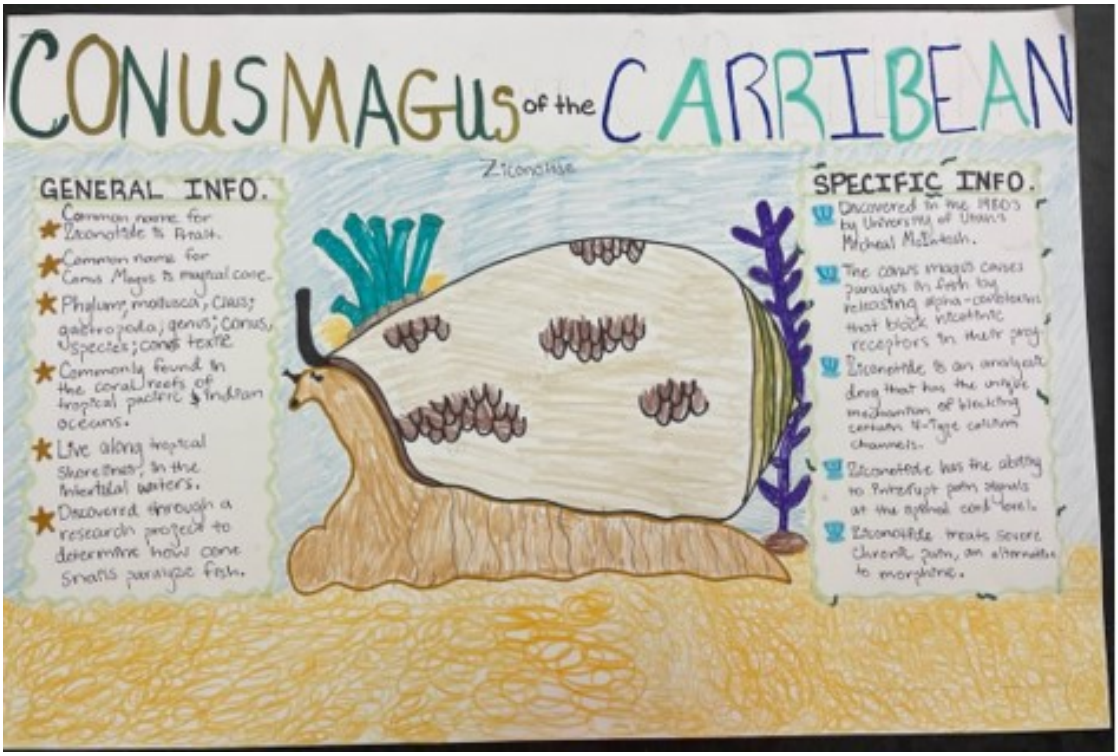


Figure 4-5. Poster composed by Gisele and Lauren. (Photo courtesy of author.)

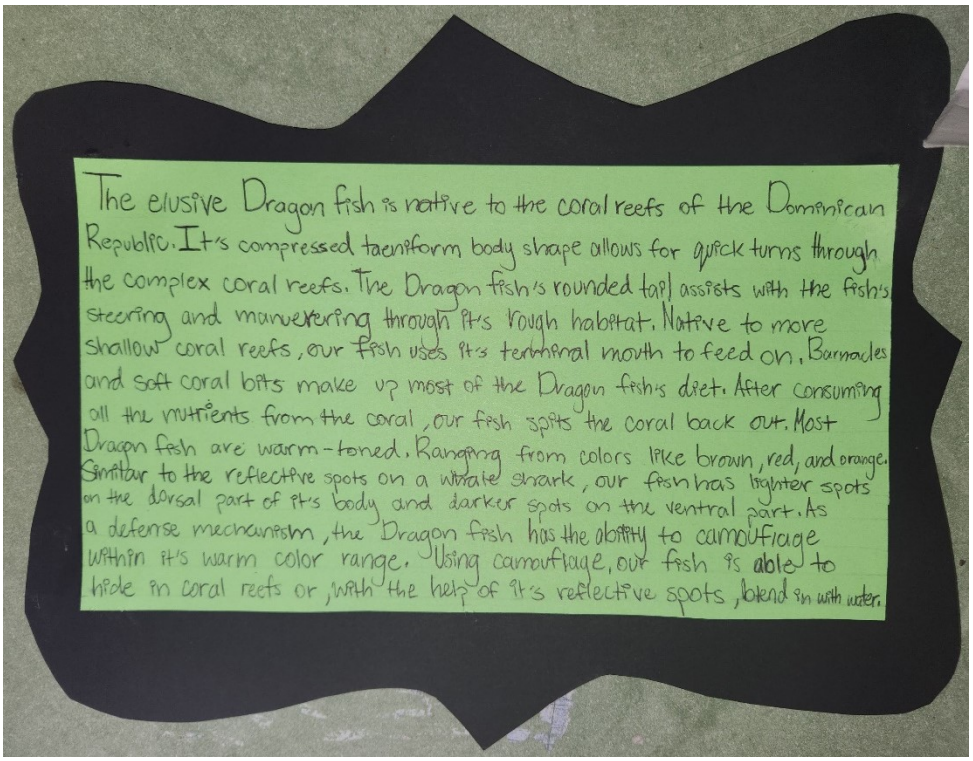
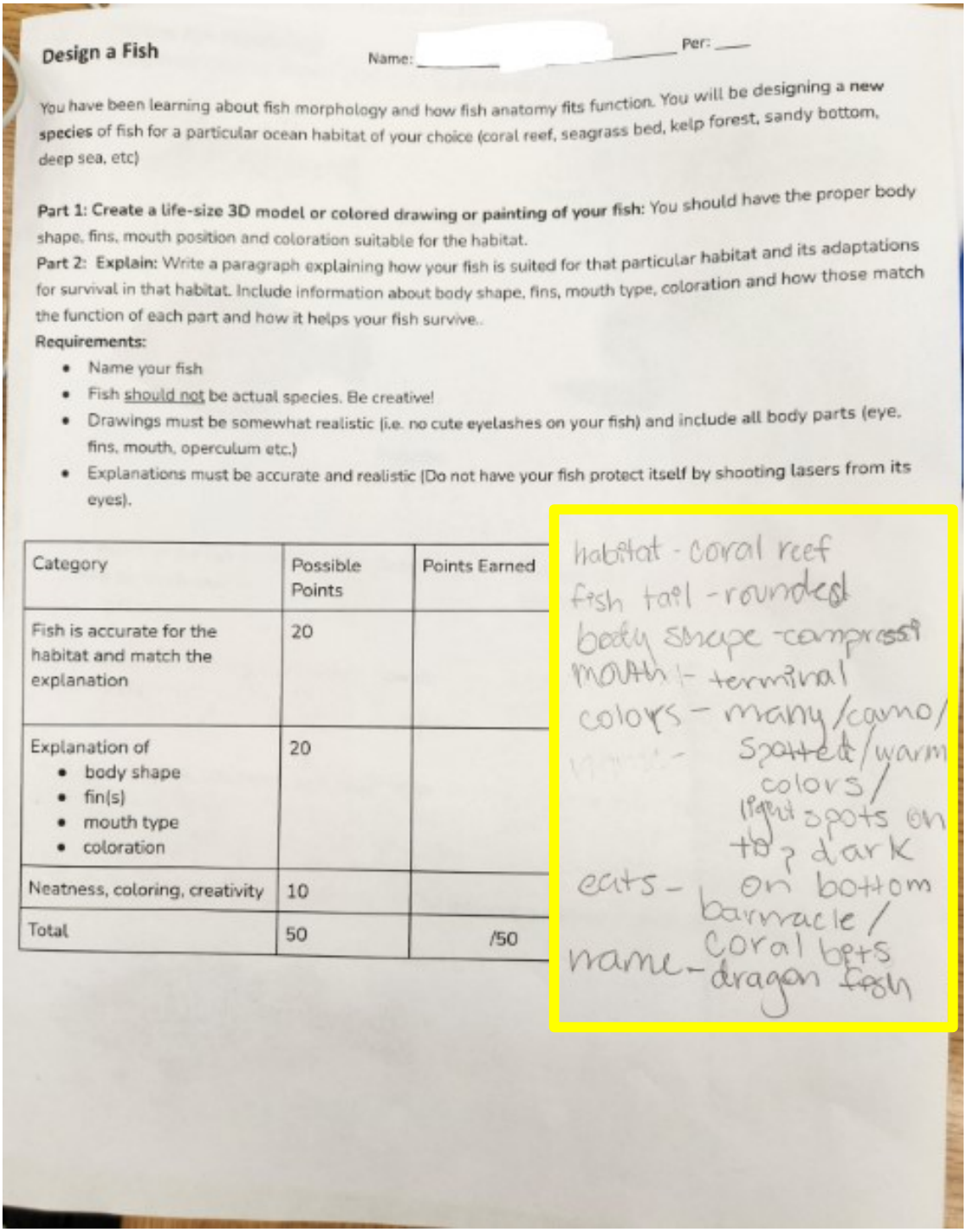


Figure 4-6. Photograph of Gisele and Eduardo's written text for their 3D model assignment. (Photo courtesy of author.)



Design a Fish

Name: _____ Per: ___

You have been learning about fish morphology and how fish anatomy fits function. You will be designing a **new species** of fish for a particular ocean habitat of your choice (coral reef, seagrass bed, kelp forest, sandy bottom, deep sea, etc)

Part 1: Create a life-size 3D model or colored drawing or painting of your fish: You should have the proper body shape, fins, mouth position and coloration suitable for the habitat.

Part 2: Explain: Write a paragraph explaining how your fish is suited for that particular habitat and its adaptations for survival in that habitat. Include information about body shape, fins, mouth type, coloration and how those match the function of each part and how it helps your fish survive..

Requirements:

- Name your fish
- Fish should not be actual species. Be creative!
- Drawings must be somewhat realistic (i.e. no cute eyelashes on your fish) and include all body parts (eye, fins, mouth, operculum etc.)
- Explanations must be accurate and realistic (Do not have your fish protect itself by shooting lasers from its eyes).

Category	Possible Points	Points Earned
Fish is accurate for the habitat and match the explanation	20	
Explanation of • body shape • fin(s) • mouth type • coloration	20	
Neatness, coloring, creativity	10	
Total	50	/50

habitat - coral reef
fish tail - rounded
body shape - compress?
mouth - terminal
colors - many/camo/
spotted/warm
colors/
light spots on
top? dark
eats - on bottom
barnacle/
coral bits
name - dragon fish

Figure 4-7. Printed directions for the 3D Model project. Gisele's notes indicated by yellow box. (Photo courtesy of author.)

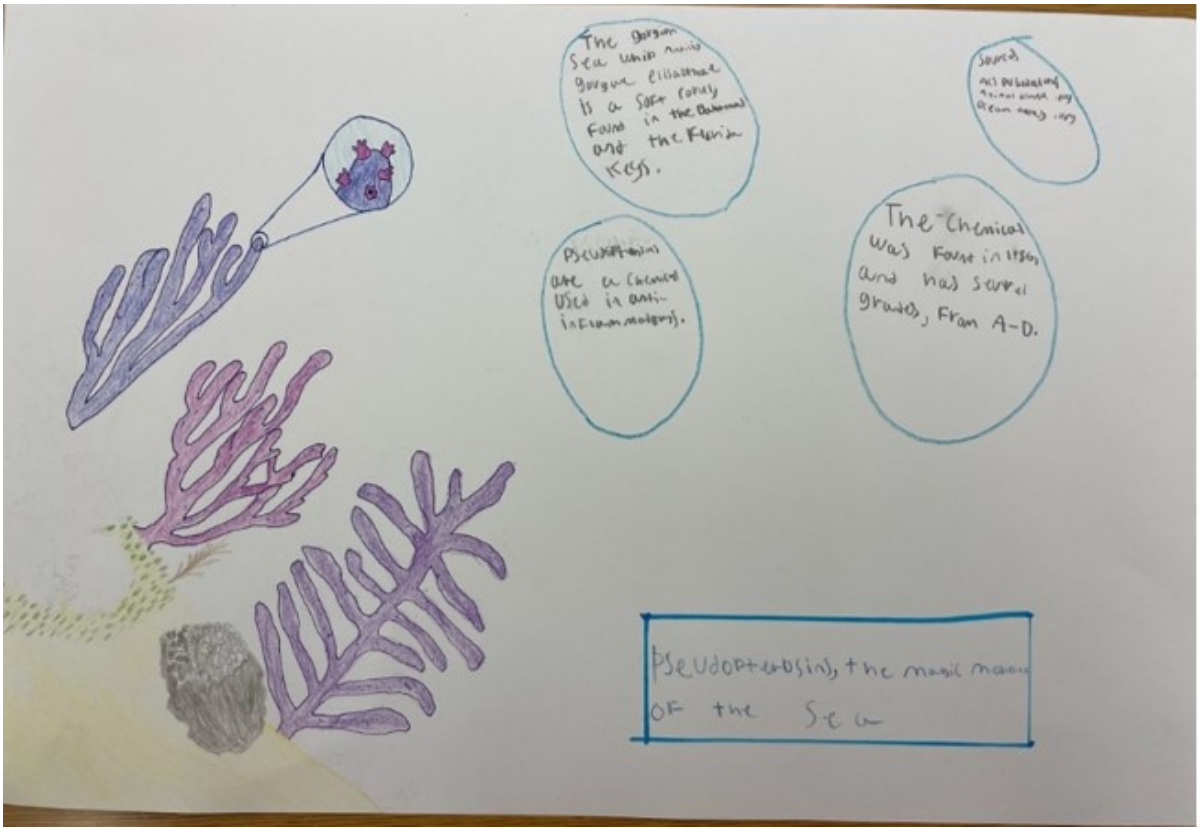


Figure 4-8. Non-digital poster composed by Eduardo and Owen. (Photo courtesy of author.)

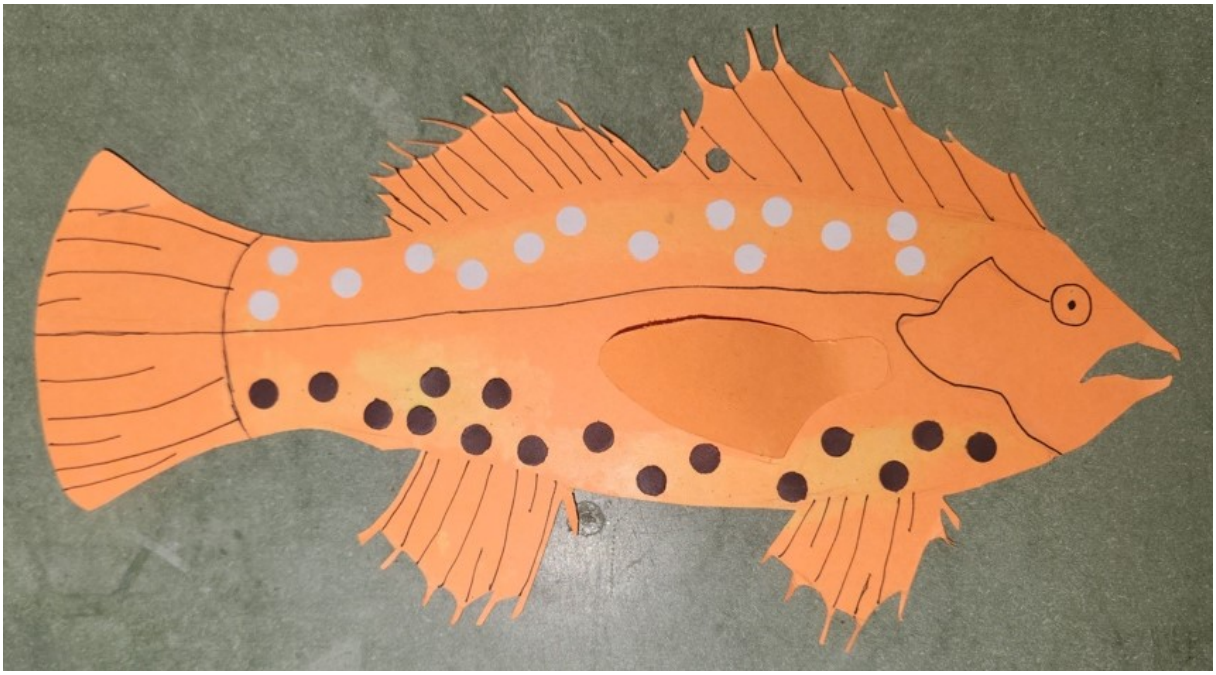


Figure 4-9. 3D model composed by Gisele and Eduardo. (Photo courtesy of author.)

Figure 4-10. Zoomed-in perspective of the 3D model's mouth design. (Photo courtesy of author.)

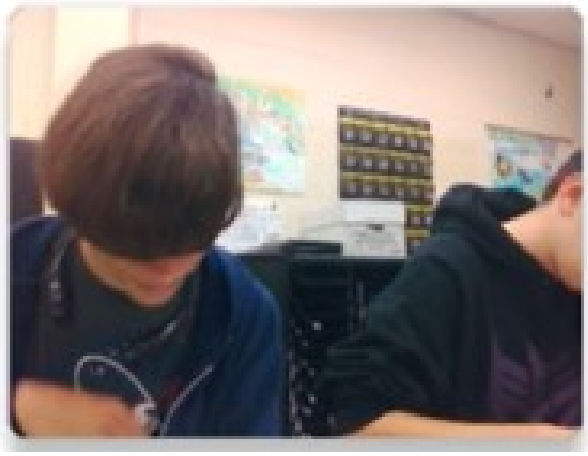


Figure 4-11. Screenshot from laptop, Eduardo (left) and Owen (right) during project two. (Photo courtesy of author.)

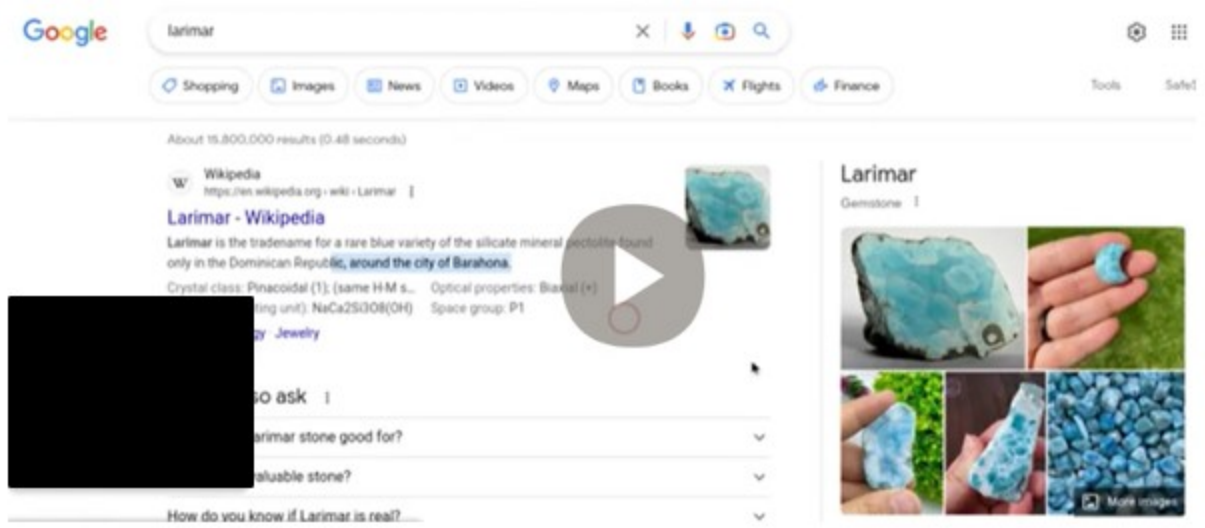


Figure 4-12. Screenshot of Eduardo and Gisele looking up information about larimar.

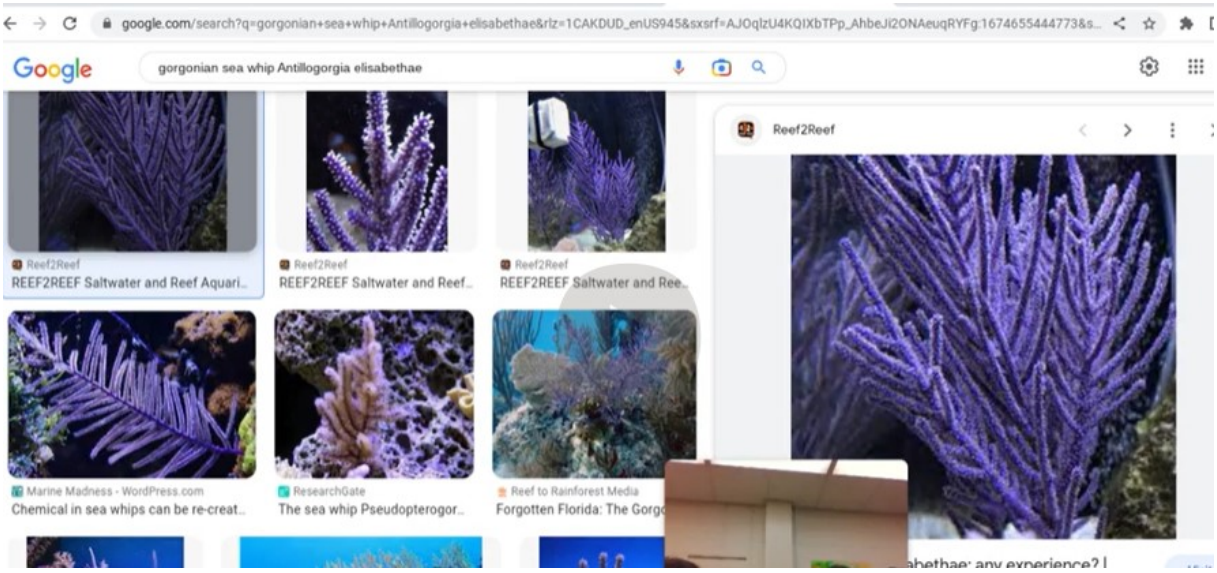


Figure 4-13. Screenshot as Eduardo and Owen looked at google image results of antillogorgia elisabethae

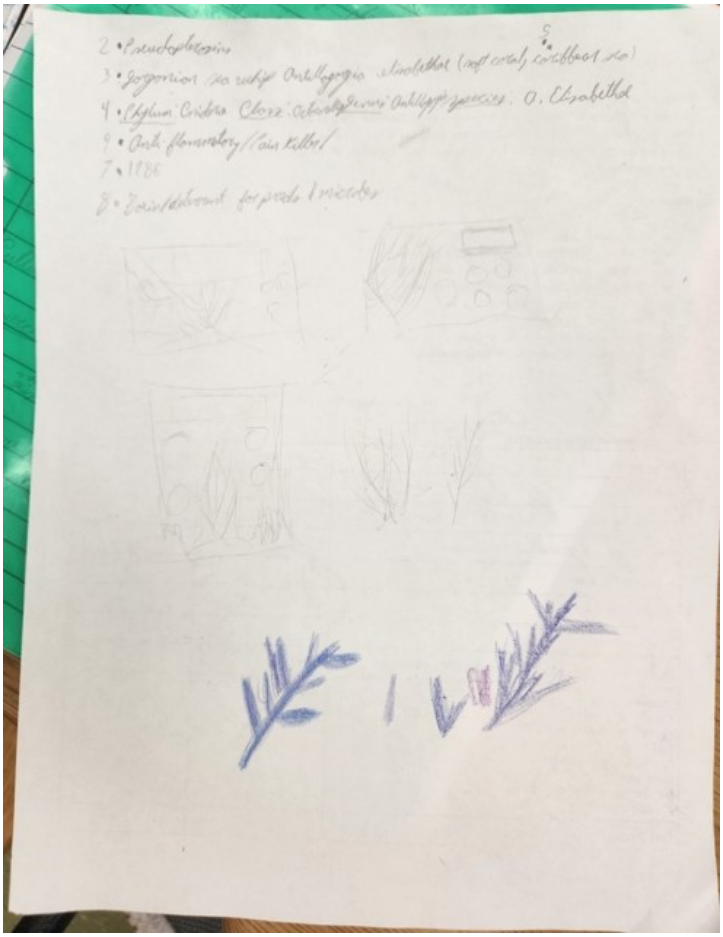


Figure 4-14. Sketches Eduardo shared with Owen for feedback. (Photo courtesy of author.)

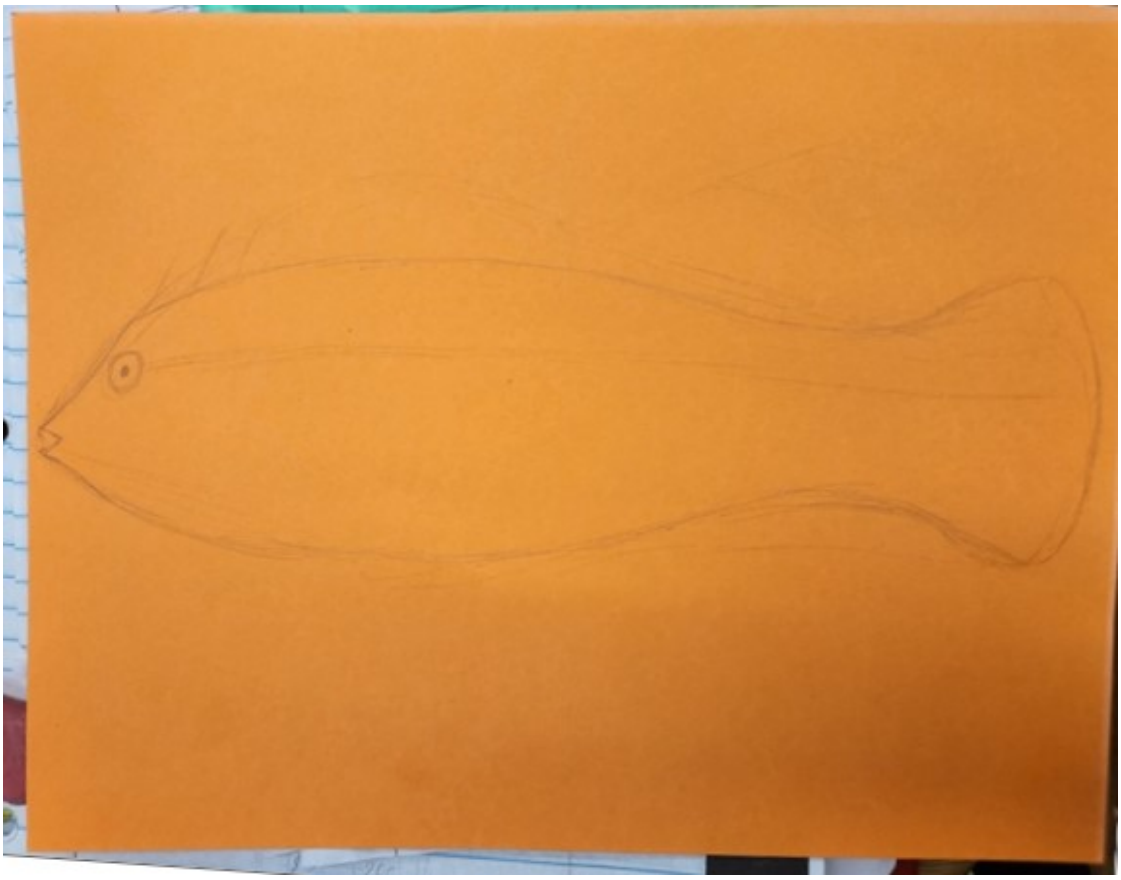


Figure 4-15. Sketch of Eduardo and Gisele’s 3D model. (Photo courtesy of author.)

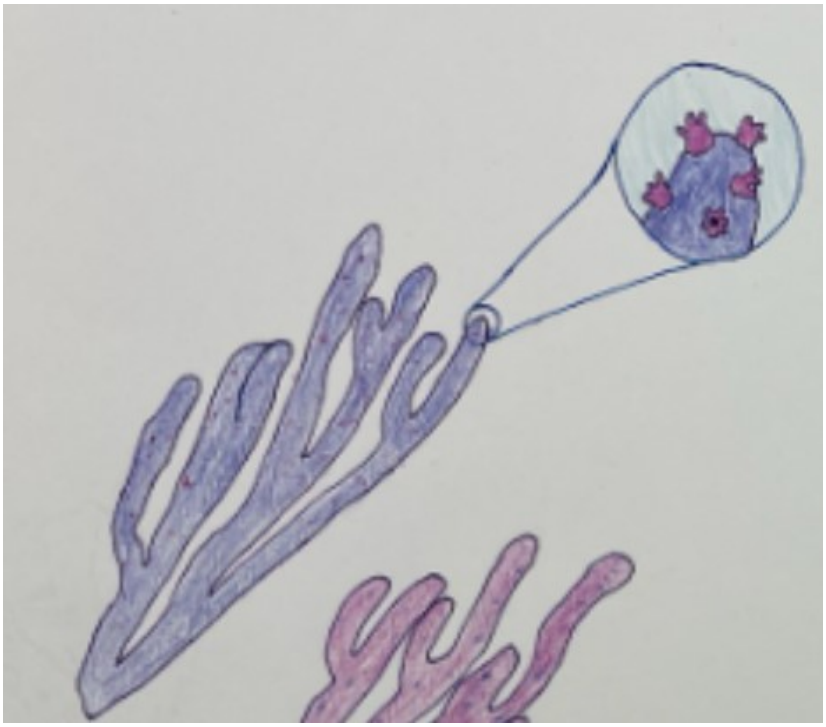


Figure 4-16. Close up photograph of Eduardo's drawing of polyps on the surface of coral. (Photo courtesy of author.)

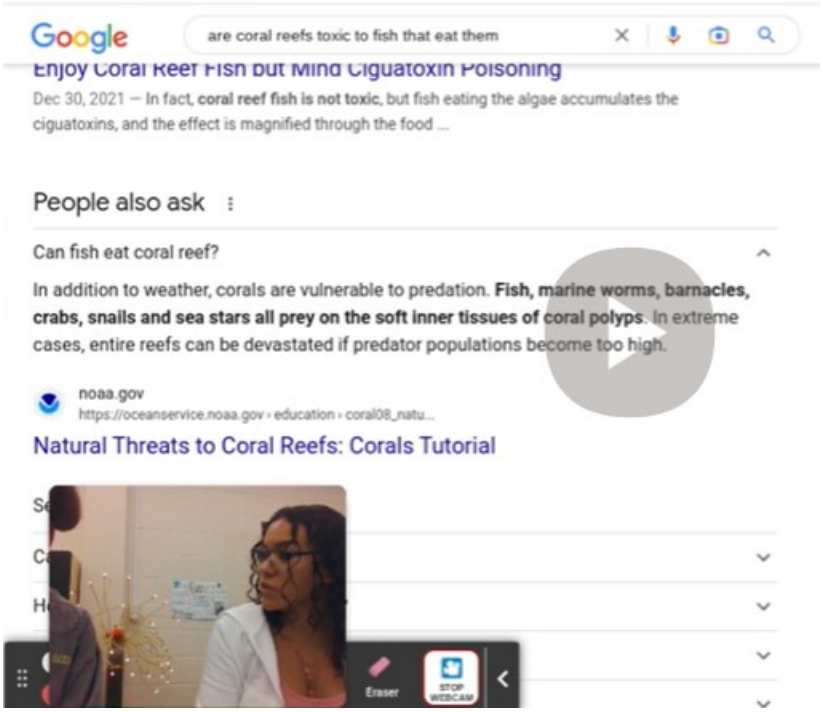


Figure 4-17. Screenshot of Google search results on Eduardo and Gisele's laptop. (Photo courtesy of author.)

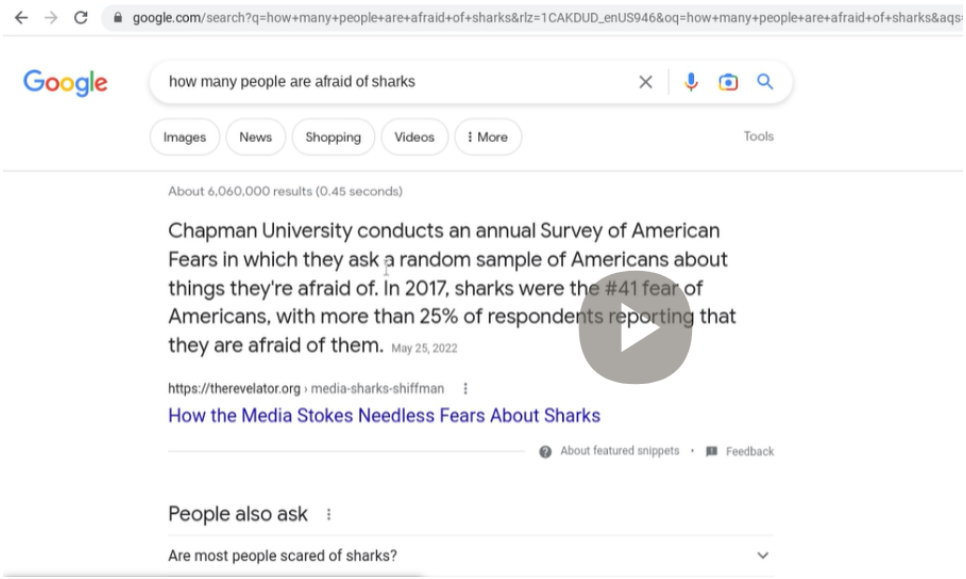


Figure 4-18. Screenshot of Eduardo and Owen's google search.

CHAPTER 5
DISCUSSION AND CONCLUSION

Findings of this dissertation study demonstrate how multilingual learners used various modes while multimodal composing to: (1) interact with classmates, (2) position themselves, and (3) enact their vision of engaging in science. Further, findings also show how multilingual learners participated in science and engineering practices: (1) by leaning into their strengths, (2) in accordance to how they positioned themselves, (3) and in accordance with their understandings of science. These findings have implications for current conversations in multimodal composing research, science education for multilingual learners, and language education. In the following sections, I discuss contributions to research on multimodal composing in content area classrooms, science for multilingual learners, and language education before describing the implications for practice, limitations, directions for future research, and finally the conclusion.

Contributions to Research

This dissertation study presents understandings in multiple areas of education research. In particular, the findings presented in the previous chapter contribute to conversations around multimodal composing, K-12 science education for multilingual learners, and language education. The following sections discuss the contributions of this work within those areas.

Multimodal Composing in Content Area Classrooms

An ongoing challenge in the field of multimodal composing is a preoccupation with digital literacies. For example, Nash's (2018) review of multimodal composing within secondary English classrooms found that a majority of literature has centered

digital composing practices. Other large systematic reviews of the literature on multimodal composing with multilingual learners have included only students' digital composing practices (Smith et al., 2021; Zhang et al., 2023). Jiang's (2023) work even defined multimodal composing as an exclusively digital practice (p. 21). This dissertation study shows the power—as well as the need to reconsider—non-digital multimodal composing. For example, Eduardo who had extensive experience with digital composing in online gaming and graphic design chose to participate in an essential science practice, *developing models* by using his artistic skills through drawing on paper. This study also highlights how Gisele used the digital composing project in this study as an opportunity to complete the assignment early. She accomplished this by copy and pasting information from the internet without evaluation, missing opportunities for meaningful participation in science practices and the development of literacy practices (Kohnen & Saul, 2018). Though digital literacy practices are relevant within 21st century classrooms (Jewitt, 2005), the field should not overlook the benefits of non-digital composing practices because in some instances, it may be preferable to digital composing.

An ongoing conversation in the field is the use of other literacy practices around multimodal composing and their utility for productively engaging students. For example, the use/requirement of student presentations of multimodal compositions. Hellmich and colleagues' (2021) found that students' presentation of their multimodal compositions was a source of stress within the classroom. Other work, like that of Hafner (2014) and Jewitt (2008) suggested that presenting their work was enjoyable for K-12 students. This study adds to the conversation by illustrating the importance of how this ancillary

practice shaped student composing. Specifically, I found that the lack, or rather the assumed lack, of a presentation requirement lead a participant, Gisele, to compose digital slideshow that included information she felt was “technical and like hard to read, kind of, or digest.” Analysis found that as she and her partner composed the slideshow, they copy and pasted written text directly from the internet and were not able to discuss it when questioned by Ms. Pearson. During the final interview she explained that she hadn’t realized during composing that they would be expected to present to the class. As she put it, “If I knew we were gonna present, like it would've been kind of a way different format.” Though not a major theme of the study, this finding suggests that more nuanced understandings of the conversation around classroom presentations of compositions are possible and needed.

Lastly, emerging work has begun to show the power in multimodal composing for inviting students to explore aspects of their cultural and linguistic heritage (Cun, 2023; Honeyford, 2014; Smith et al., 2017; Smith et al., 2021; Yi & Hirvela, 2010), connect with their communities and family members (Pacheco et al., 2017). and draw upon shared experiences with classmates as individuals of “similar cultural and linguistic communities” (Martin-Beltrán et al., 2017a, p. 163). This dissertation study adds to this conversation by showing some of the mechanisms that make this exploration possible. For example, Gisele viewed composing with Eduardo as a space for her to explore her heritage. She took advantage of the opportunity to ask him questions about cities in the Dominican Republic, what the schools there were like, and other details about his experiences growing up there. Similarly, Eduardo also benefitted from composing with Gisele as the experience provided opportunities for him to establish a new friendship,

which he expressed was a priority for him. However, this was not without complication. For instance, Gisele openly expressed a desire to compose with Eduardo so they could use Spanish together, but this did not come to fruition. Though Eduardo answered all of Gisele's questions and later stated that he enjoyed speaking with her, he used only English, with very few exceptions and Gisele seemed to follow his lead. She stated that on a few occasions she explained information to him in Spanish, and though she believed this supported his understanding, but he always responded in English. Gisele's use of language was guided by the linguistic choices of her peers, which is consistent with prior findings (Daniel & Pacheco, 2016). Through their collaboration, Eduardo reaped the benefits of forming a friendship through cultural connections, as did Gisele, but her access to Spanish, her heritage language, was limited by his use of English.

Science for Multilingual Learners

While the use of multiple modalities has long been a feature of science classrooms (Jaipal, 2009; Yeo & Nielson, 2020), this study furthers understandings of the potential of these modalities by illustrating their power in inviting the participation of MLs. Multimodal composing can present appealing ways for learners to draw upon their cultural experiences and personal interests for academic purposes (Hull & Katz, 2006) and it allows learners to flexibly select modes within their comfort zones for expression (Anderson & Gregg-Harrison, 2013). Eduardo brought science knowledge and an extensive artistic repertoire and Gisele possessed strong aesthetic, language, and social skills. As they composed multimodal artifacts, Gisele and Eduardo were able to focus on knowledge- and language-in-use (Buxton & Lee, 2023).

Second, this research demonstrates that multimodal composing has the potential not only to engage students in the science classroom, but to encourage robust

participation in the SEPs. Prior work has found that multimodal composing can serve as a supportive space for students to learn STEM practices (Jiang, 2023; Smith et al., 2021) and participation in particular SEPs. For instance, Walsh and McGowan (2017) found that multimodal composing created opportunities for engagement in disciplinary argumentation which relates to *Practice 7, engaging in argument from evidence* and Pierson and colleagues (2021) explored MLs participation in developing models, which relates to *Practice 2, developing and using models* (Pierson et al., 2021). This dissertation study expands upon these findings by exploring case-participants' participation in all eight of the NGSS's SEPs. Findings demonstrated that both case-participants leaned upon their unique strengths for participation *Practice 2, developing and using models*, and *Practice 8, obtaining, evaluating, and communicating information*. For example, Eduardo participated in *Practice 2* as he created visual representations of coral and designed a model of a new fish species by drawing. Gisele participated in *Practice 8*, specifically to *communicate information* as she selected appropriate images online to communicate her ideas with her composing partners and their audience. In this study, multimodal composing was a space where multilingual learners leveraged their strengths for participation in SEPs while developing disciplinary ideas as well as ways of knowing and communicating that align with practicing scientists (Mehta & Fine, 2019).

However, this study also suggests some of the limitations of multimodal composing for scaffolding students' participation and understandings of science within marine biology. Past research has shown its potential to support students' critical responses to socio-scientific issues, make connections between topics of science, and

create narratives that tell the stories of characters who are scientists, including marine biologists (Ran et al., 2023). However, findings from this study demonstrated multimodal composing didn't solve all challenges, as case-participants' understandings, or misunderstandings, of science went unchallenged. For example, Gisele viewed science as a bound and comprehensible body of knowledge, which she had only to memorize and reproduce through classroom assignments. Gisele's view was not challenged within her composing processes and remained unchanged.

Eduardo, on the other hand, viewed science as an endeavor that should be driven by genuine curiosity. Curiosity and its role in learning has long been of interest within psychology (Berlyne, 1978) and education (Deci & Ryan, 1981). More recent findings have suggested its importance for intrinsic motivation (Grigorescu, 2020), improved learning outcomes (Stahl & Feigenson, 2015), and connections to science achievement when stimulated by parents at a young age (Gottfriend et al., 2016). However, what Eduardo described as curiosity seemed to lead him to prioritize his interests over effort. Though he composed detailed drawings that were critical to his participation in SEPs, when he was unable to draw as part of his composing practice, he went off task to draw unrelated images for fun. In the end, Eduardo's pursuit of curiosity and all that he found interesting lead him away from the aspects of participating in SEPs that he found less fun, such as evaluating information.

Eduardo considered looking up information that he believed he knew already as tedious and unimportant. There is a growing body of research emphasizing the importance of encouraging multilingual learners' science identities (Brown, 2019; Buxton & Lee, 2023; MacDonald et al., 2020; Staggs & Brown, 2023; Tripp & Waight,

2022), but this study contributes a nuanced perspective. Eduardo held strong beliefs about science and considered himself knowledgeable about content and experienced with disciplinary practices. However, while multimodal composing, these ideas seemed to sometimes cause his misconceptions to persist, such as his belief of the inability of fish to eat coral (Cole et al., 2008).

Language Education

This study's attention to MLs who are not receiving English language services helps us understand the need for pedagogies that position them as multilingual and promote their use of their unique strengths. Recent work shows that MLs, regardless of their status as English learners, as defined by schools, districts, and states, have distinct capabilities and needs that distinguish them from their non-ML peers (Huitzilopochtli et al., 2021; Martínez, 2018; Meyer, 2020). For example, Curran and colleagues (under review) found that multilingual learners made more swift gains in science achievement during elementary grades when compared with English monolingual peers. My study shows that multimodal composing created space where multilingual learners leveraged their unique strengths within a science classroom for participation in science practices. Findings contribute to an asset-based perspective of multilingual learners within K-12 content area education. Multimodal composing created a space for Gisele to bring in her linguistic, cultural, and aesthetic strengths and for Eduardo to bring in his science knowledge and artistic skills in ways they had not previously within the science classroom. Though there has long been evidence of the benefits of multilingualism (Peal & Lambert, 1962; Cummins, 1974; Adesope et al., 2010; Bialystok, 2020; Diaz, 1983) K-12 language education research in the US has continued to privilege only English language proficiency. Though supporting multilingual

learners' English language proficiency is a worthy purpose, we should not lose sight of the resources multilingual learners continue to possess even after they develop proficiency in English, however that is defined within school contexts.

Lingering Challenge, Constrained Participation

Multimodal composing allowed Gisele and Eduardo to leverage their academic, aesthetic, artistic, and social strengths within the science classroom in ways they hadn't previously. Still, distinct challenges remained, as at times during composing, Gisele and Eduardo's participation in science and engineering practices was constrained. These challenges are explored within this section and divided in to three groups: (1) those relating to the role of teacher, (2) those relating to time, and (3) those relating to project design.

Role of teacher

Eduardo participated in SEPs including *Practice 8* from his position in the science classroom as a skilled artist by drawing detailed images to communicate scientific information through multiple formats (i.e., written text, image) (NGSS Lead States, 2013b). However, his positioning as a knowledgeable student sometimes constrained his communication of information. For instance, he selected to share his own misunderstanding, that a fish could not eat coral, rather than reading scientific information from multiple appropriate sources, synthesizing it, and assessing their credibility (NGSS Lead States, 2013b). Even when Eduardo's composing partner questioned his misunderstanding and conducted an online search, he insisted he was correct and in the end, their model was shaped by his misunderstanding. While multimodal composing, there was no effective challenge to the incorrect information nor sufficient reason to evaluate the idea for him. Perhaps, Ms. Pearson might have been

able to prompt Eduardo to obtain, synthesize, and evaluate information from multiple sources. Within this project, multimodal composing was a student-centered activity, but there were times, such as this, when teacher support might have strengthened the pedagogical potential. Perhaps, in moments such as this, Ms. Pearson might have successfully scaffolded Eduardo's participation in SEPs.

Time

Findings indicated that Gisele preferred to get things done over following curiosity, in that she prioritized submitting classroom assignments and earning high scores over exploring new scientific information that she found interesting. However, there was one major exception to this within the three projects, during the initial day of the first composing project. On that day, as Gisele worked alongside Lauren, she expressed curiosity about and interest in the potential of South Indian green seaweed for the development of a neuroprotective medicine. They also invited Ms. Pearson into their information gathering online for her support, as they worked to comprehend complex journal articles. Ms. Pearson scaffolded the information for them, by restating it through less complex but still accurate terms, thereby modeling participation in *Practice 8* (NGSS Lead States, 2013b). However, in the end, Gisele decided that the time she estimated it would have taken to gather, synthesize, and communicate the information through multiple formats in their poster would exceed the time allotted for the project.

This was a fair consideration, as time is often a challenge within K-12 classrooms (Pollock & Tolone, 2020). However, it is worth noting that rather than explore a new and interesting neuroprotective medicine, Gisele and Lauren elected to select a well documented medicine, one that was also presented by numerous other students within Ms. Pearson's classroom. Had Gisele felt she had sufficient time, she and Lauren might

have been able to dive into the scientific information to, “gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source” (NGSS Lead States, 2013b, p.15) while driven by their interest in the neuroprotective potential of seaweed. Though time may be a permanent challenge within K-12 classrooms, perhaps classroom adjustments and scaffolds could have served to support Gisele and Lauren. For instance, the written directions might have been adjusted to include fewer requirements so that these participants could have conducted a deep rather than broad exploration. Alternatively, perhaps the journal articles could have been adjusted to a grade-level appropriate format or alternative sources could have been found. Though, adjustments such as these would have required additional time of the teacher outside of instructional time, which presents additional time-related challenges.

Design of projects

Finally, the design of the 3D model project within this study might have contained inherent constraints for certain types of participation in *Practice 2*. Specifically, the 3D model within this study allowed participants to “show relationships among variables between systems and their components in the natural and designed worlds” (NGSS Lead States, 2013b, p. 6) as well as represent “phenomena that are too big, too small, too fast, too slow, too far away, or too long ago to experience first-hand” (Miller & Kastens, 2017, p. 642). While this represented strong participation in *Practice 2*, the NGSS (2013b) also suggests students in grades 9-12 design and use runnable models. Runable models can be used to test ideas, create new understandings, and make predictions (Kastens, 2015; Nersessian & Patton, 2009, Miller & Kastens, 2018). Though this 3D model project allowed participants to participate in Practice 2, it could

have been further promoted in a grade-level appropriate manner, by having students design and use a runnable model. For instance, their 3D fish could have been created using water resistant materials so that the body shapes could have been tested for their hydrodynamic designs in a classroom water tank.

In conclusion, though multimodal composing offered Gisele and Eduardo numerous benefits, some challenges persisted. These challenges underscore the importance of continued exploration of multimodal composing's potential and challenges for multilingual learners within science classrooms. In particular, this work highlights challenges relating to (1) the role of teacher, (2) time, and (3) design of multimodal composing projects.

Implications for Practice

This dissertation's findings shed light on important considerations for practitioners who undertake multimodal composing activities with secondary multilingual learners. While prior work has found that multimodal composing is engaging (Miller & McVee, 2013), this study identified caveats. For example, while both case-participants had strong modal preferences (Smith, 2017), Eduardo was observed to disengage when he was unable to use his preferred composing skill of drawing. While Eduardo's composing partner, Owen, composed their slideshow on Sharks in the Media, Eduardo focused on creating off topic images. Though composing the non-digital poster and 3D model did seem to be engaging for him, composing a digital slideshow did not. Interestingly, Eduardo possessed extensive coding and digital graphic design skills and stated during an interview that he enjoyed using them. His disengagement during the digital slideshow project might have reflected an unwillingness on his part to participate without drawing. Alternatively, he might have been reluctant to bring in more advanced

tools that were outside those presented by Ms. Pearson, which would align with prior work demonstrating teachers' role in mediating students' composing choices (Shanahan, 2013). Therefore, practitioners should consider students' individual strengths as well as the tools they include within demonstrations or suggest for use. Still, Eduardo was not the only case-participant with untapped strengths.

Prior findings have shown that MLs' language use may be guided by their peers' language use (Daniel & Pacheco, 2016). Gisele created multimodal and multilingual artifacts via social media outside of school to express her views. However, during data collections, her compositions included only English even though she stated a clear desire to include Spanish with Eduardo. Gisele's access to Spanish was limited by Eduardo's linguistic choices. This finding leads me to suggest practitioners, including English monolinguals, consider how to promote MLs' use of their full linguistic repertoires. For instance, existing studies have shown how English monolingual teachers can use multilingual materials and include students' home languages in discussions (Menken & Sánchez, 2019; Shi & Rolstad, 2023). Strategies such as these could help MLs reap the clear benefits of using their full linguistic repertoires in science (Lemmi & Pérez, 2024).

Next, there is an ongoing conversation within the multimodal composing literature on the potential benefits of classroom presentations of student-composed artifacts. Some have found that student presentations created stress (Hellmich et al., 2021) while others have found students enjoy presenting their compositions (Hafner, 2014; Jewitt, 2008). This study found that the knowledge that a presentation was required, or lack thereof, seemed to influence at least one case-participants' composing practices.

Practitioners should consider whether classroom presentations might facilitate students' composing in ways that encourage participation in science practices while minimizing the potential stress they have been known to cause. As always, teachers should also keep in mind the strengths and needs of their individual students.

Finally, the issue of time is always a consideration within K-12 classrooms, and during multimodal composing is no exception (Van Rooy, 2012). The three composing projects included within this study were completed over the course of four to six days each. Each composing session lasted one class period. Within a secondary science classroom, this is a significant investment of time. In order to make that investment valuable for the learners, opportunities for participation in science and engineering practices through students' strengths should be emphasized.

Limitations

The first limitation of this work is the size and scope of the study. This dissertation presents a comparative case study that was conducted within one classroom over the course of one year with two case-participants. As described in the findings, Gisele and Eduardo brought unique strengths, experiences, and preferences into their composing practices. If this work were to be replicated in the future with other participants, further insights could be obtained.

Second, this study explored how two case-participants used various modes to tap into their identified strengths for particular purposes within a secondary science classroom. While certain strengths were evident during data collection, it is important to note that Gisele, Eduardo, and all learners, have extensive strengths and resources all of which are not possible to be identified and understood within any single study.

Directions for Future Research

First, this dissertation study offers new insights into multimodal composing in content area classrooms through digital and non-digital composing practices. Findings illustrate benefits of composing using the most basic classroom tools (e.g., poster paper, colored pencils) for a learner who possessed extensive digital composing strengths. Within these findings, digital composing was an opportunity to copy and paste information directly from online search engines into a slideshow without discussion. However, this study does not seek to negate the benefits of digital composing, only emphasize a need within the field to ascertain in which contexts each should be selected and for whom. To progress our field, we must seek to understand the potentials of *composing*, rather than only the potentials of composing via impressive technological tools. Currently, access to technological resources is often presented as a decising factor, but this work hightlights a need for consideration beyond simple matters of access.

Second, though multimodal composing can create space for students to use their full linguistic repertoire (Pierson et al., 2012), this dissertation demonstrated that it does not do so automatically. Though the teacher stated her approval of multiple languages for composing, it was not enough to promote these participants' use of Spanish, apart from a few brief instances. As multilingual learners' use of language in classrooms can be guided by their peers' use of language (Daniel & Pacheco, 2016), future work in science classroom should explore learner grouping and teachers' roles for promoting multimodal composing through multiple languages.

Finally, this study found that multilingual learners leveraged their unique strengths for participation in science practices through multimodal composing. These

two multilingual learners leveraged their artistic, social, academic, and at times linguistic strengths in ways that they hadn't previously in the science classroom. Further research should continue to explore multilingual learners in science, and all content areas, as students who bring considerable strengths from which to draw upon. Further, participants in this study leveraged various modes to support not only their own participation, but also their peers. As we continue to explore the benefits of multimodal composing for multilingual learners, we should also emphasize their contributions to their science learning contexts and beyond.

Conclusion

In conclusion, this dissertation study has emphasized how, while multimodal composing, multilingual learners drew upon their strengths for multiple purposes, including participation in science and engineering practices. Though multimodal composing is a linguistically responsive pedagogy for multilingual learners (George, 2022), this study demonstrates that it goes beyond this label. These findings demonstrated that multilingual learners leveraged more than their extensive linguistic strengths while multimodal composing in science, by bringing in their other unique resources. For instance, Gisele leveraged her social, communicative, and aesthetic strengths via multiple modes for multiple purposes, including participation in SEPs. Eduardo, on the other hand, leaned upon his scientific, academic, and artistic skills. Though multimodal composing is certainly responsive, it's open-ended and student-centered nature responds to so much more than students' linguistic backgrounds. Perhaps it would be best to label it as simply responsive to the unique backgrounds and experiences of diverse learners.

Findings of this work contribute to ongoing conversations in research concerning multimodal composing in content area classrooms, science education for multilingual learners, and language education. This work has implications for both practice and research. Future research should continue to position multilingual learners as knowledgeable students who bring numerous strengths to classrooms.

APPENDIX A
INITIAL STUDENT INTERVIEW PROTOCOL

Initial Student Interview Protocol

Planned time: 30 minutes

Student Name	Date	Interviewer

Introduction: Thank you for participating in this project. First, I would like to learn more about how you feel about language and science. I have a few questions to ask you. Is that all right with you?

If yes, I want to remember what you say, so I'm going to audio record this interview and also take some notes. I'm interested in your thoughts and ideas, so there are no right or wrong answers. What you say will not affect your grade.

Openers

1. How are you today?
2. Can you tell me about what you like to do in your free time?

Composing

3. Do you ever make videos or other posts? (Snapchat, YouTube, or TikTok videos, Instagram posts, etc.)
   - 3.a If so, what language(s) do you typically use?
4. Do you like to view videos/posts on social media or online?
   - 4.a If so, what types of videos/posts do you like?
   - 4.b If so, in what language(s) do you typically view these videos/posts?

Communicative Resources

5. How do you use [insert language] at home?
6. How do you use English at home?
7. How do you use [insert language] at school?
8. How do you use English at school?
9. How do you talk with your friends? (Online, in person, text, DM, etc.)
10. When you want to talk to a friend in class, how do you do this?

SEPs

11. What kinds of things do scientists do?
12. How do scientists study the world?
13. Do you ever ask questions and define problems?
14. Do you ever make or use models?

15. Do you ever plan and carry out investigations?

16. Do you ever analyze and interpret data?

17. Do you ever use mathematics and computational thinking?

18. Do you ever construct explanations and design solutions?

19. Do you ever engage in argument from evidence?

20. Do you ever obtain, evaluate, and communicate information?

APPENDIX B
FINAL STUDENT INTERVIEW PROTOCOL

Final Student Interview Protocol

Planned time: 40 minutes

Student Name	Date	Interviewer

Introduction: Thank you for participating in this project. I have a few questions to ask you about your participation. Is that all right with you?

If yes, I want to remember what you say, so I'm going to audio record this interview and also take some notes. I'm interested in your thoughts and ideas, so there are no right or wrong answers. What you say will not affect your grade.

Openers

1. How are you today?

2. Can you tell me about your experience making an infographic, poster, and website?

   2.a What did you like?

   2.b What could have made it better?

Composing

3. Did anything in class help you make your infographic?

4. Did anything in class help you make your poster?

5. Did anything in class help you make your website?

6. Did anything in class make it difficult for you to make your infographic?

7. Did anything in class make it difficult for you to make your poster?

8. Did anything in class make it difficult for you to make your website?

Communicative Resources

9. How did you use [insert language] while making your infographic?

10. How did you use English while making your infographic?

11. Besides language, what helped you communicate your thoughts and ideas while you made your infographic?

12. How did you use [insert language] while making your poster?

13. How did you use English while making your poster?

14. Besides language, what helped you communicate your thoughts and ideas while you made your poster?

15. How did you use [insert language] while making your website?

16. How did you use English while making your website?

17. Besides language, what helped you communicate your thoughts and ideas while you made your website?

SEPs

15. What kinds of things do scientists do?

16. How do scientists study the world?

17. Do you ever ask questions and define problems?

18. Do you ever make or use models?

19. Do you ever plan and carry out investigations?

20. Do you ever analyze and interpret data?

21. Do you ever use mathematics and computational thinking?

22. Do you ever construct explanations and design solutions?

23. Do you ever engage in argument from evidence?

24. Do you ever obtain, evaluate, and communicate information?

APPENDIX C
TEACHER INTERVIEW INTERVIEW PROTOCOL

Teacher Initial Interview Protocol

Planned time: 20 minutes

Teacher Name	Date	Interviewer

Introduction: Thank you for participating in this project. I have a few questions to ask you about your participation. Is that all right with you?

If yes, I want to remember what you say, so I'm going to audio record this interview and take some notes. I'm interested in your thoughts and ideas, so there are no right or wrong answers.

Openers

1. How are you today?
2. Can you tell me about what you hope to gain from participating in this project?

Instruction

3. Can you share a bit about your instruction of MLs?
   - 3.a How do you support MLs' use of language?
   - 3.b How do you support MLs' participation in SEPs?
   - 3.c How do you support MLs' multimodal composing?
   - 3.d Is there anything you would like to add about your instruction for MLs?

General

4. Can you describe your use of language in the classroom?
5. Can you describe your use of SEPs in the classroom?
6. Can you describe your use of multimodal composing in the classroom?

APPENDIX D
TEACHER DEBRIEF INTERVIEW PROTOCOL

Final Teacher Interview Protocol

Planned time: 20 minutes

Teacher Name	Date	Interviewer

Introduction: Thank you for participating in this project. I have a few questions to ask you about your participation. Is that all right with you?

If yes, I want to remember what you say, so I'm going to audio record this interview and also take some notes. I'm interested in your thoughts and ideas, so there are no right or wrong answers.

1. How are you today?

Openers

2. Can you tell me about your experience participating in this project?

   2.a What did you like?

   2.b What could have made this a better experience?

3. How has this experience shaped your instruction of MLs?

Instruction

   3.a How did you support MLs' use of language?

   3.b How did you support MLs' participation in SEPs?

   3.c How did you support MLs' multilingual composing?

   3.d Is there anything you would like to change moving forward?

4. Has this experience shaped how you use language in the classroom? If so, how?

General

5. Has this experience shaped how you support students' participation in SEPs? If so, how?

6. Has this experience shaped how you support students' multimodal composing? If so, how?

APPENDIX E
STUDENT WRITTEN REFLECTION 1: POSTER

1. What languages did you use while making your poster?

2. How did you *obtain, evaluate, and communicate information* while making your poster?

3. Did anything help you compose in class?

4. Did anything make composing in class more difficult?

APPENDIX F
STUDENT WRITTEN REFLECTION 2: DIGITAL SLIDESHOW

1. What languages did you use while making your slideshow?

2. How did you *obtain, evaluate, and communicate information* while making your slideshow?

3. Did anything help you compose in class?

4. Did anything make composing in class more difficult?

APPENDIX G
STUDENT WRITTEN REFLECTION 3: 3D MODEL

1. What languages did you use while making your model?

2. How did you *develop and use models* & *obtain, evaluate, and communicate information* while making your model?

3. Did anything help you compose in class?

4. Did anything make composing in class more difficult?

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