

Supporting Language-Minoritized Students in Science Practices  
within a Research-Practice Partnership

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**Abstract**

Supporting Language-Minoritized Students in Science Practices within a  
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This dissertation investigates the design and implementation of educational change efforts focused on supporting middle-school language-minoritized students in science learning. These chapters take as their units of analyses the shared activity of a research-practice partnership, the co-design of a discourse-based intervention and its outcomes for students, and finally the learning of students in discursive practice. In all, this study examines one problem space across multiple levels, from district-level decision-making and planning, to teacher implementation, to student learning outcomes in the classroom, yielding a coherent, multilevel view—from policy to practice—of the possibilities for building more equitable systems of science education within the vision of NGSS. Major

findings include that (a) multiple ideologies of “equity” may be present even within equity-focused partnerships, and these knotted to build axiological innovation, (b) that youths’ peer-to-peer interactions can serve to adversely position language-minoritized youth in science class, but youth are resilient to these positions, and (c) sense-making dialogue can be structured to support language-minoritized youth to deeply develop their ideas. Implications for educational spaces include the generative power of responsive, deep listening among partners in spaces that prioritize equity.

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Dedication

For my students: former, current, future, gone. You are not a problem.

## **Chapter 1: Introduction**

This dissertation sits within the intersecting problem spaces of implementation research, critical language pedagogies, and science education. In this introduction, I frame the social and research problem, outline the state of knowledge in those fields, describe my positionalities relative to them, and briefly frame the work of the ensuing empirical chapters.

### **Structural Inequality in Education**

Research has documented the systematic, pervasive structural inequalities in U.S. schooling contexts faced by students with status as an English language learner (ELL). These inequalities extend into seemingly every aspect of K-12 education systems, and they are instantiated in large-scale education policy in many ways: ELLs are subject to "English-only" mandates and dwindling support for native-language instruction (e.g., Wright, 2007), biased assessments of educational progress (e.g., Abedi, 2010), standards that mandate high-quality English instruction in content areas (Bunch, 2013), and curricula that proscribe "acceptable" versions of English rather than appreciating students' broad repertoires (Crawford, 2005; Enright, 2011; C. D. Lee, 2006; Nasir, Rosebery, Warren, & Lee, 2006). Issues for ELL students can also be attributed to matters of teacher preparation. Studies of teachers and teacher education indicate a lack of coherent support systems for in-service teachers of diverse youth (Athaneses & De Oliveira, 2009), and studies show that teachers often feel underprepared to teach "ELL" students in content areas such as math and science (Janzen, 2012; Rodriguez & Kitchen, 2005).

Finally, there are also issues of ideology that have contributed to structuring US education in ways that disadvantage linguistically diverse youth, including what languages are taught by districts down to teachers' instructional choices (Ricento & Hornberger, 1996). Ideologies are also implicated in the rhetoric of research, so much so that "ELL" students are themselves considered "a problem" instead of a resource even in contexts of service on behalf of these youth (Gutiérrez & Orellana, 2006).

Structural problems like these have resulted in an educational economy that, overall, allocates fewer resources to "ELL" students than to their native English-speaking peers (Gándara, Rumberger, Maxwell-Jolly, & Callahan, 2003). At the core of all of these policies is an emphasis on *subtractive* schooling that seeks to *remediate rather than sustain* children's native languages (Hakuta & McLaughlin, 1996; Ladson-Billings, 1995, 2014; Paris & Alim, 2014).

This system of inequalities forms the basis for the social problem addressed by this dissertation: youth who speak English non-natively face injustices in their classrooms and resulting complications in their learning of academic subject matter. In particular, I am concerned with the experiences of youth in science classrooms since the language demands of such classrooms are often very *particular and prescriptive* (Bazerman, 1984, 1988; Lemke, 1990, 2004), and this disciplinary pressure to "sound scientific" can result in further de-privileging of students' native language practices and compromising of students' sense-making (Hudicourt-Barnes, 2003).

### Science Education & "ELL" Students

However, ideologies which privilege academic scientific discourse over students' diverse language practices are still prevalent in science education research. Despite intentions of equity, science education researchers have for decades taken a stance of *remediation* towards English learners rather than working to better leverage their cultural practices in school spaces. These studies (and their corollaries in pedagogy) fail to build the heterogeneity in language and thought that can lead to transformative, rigorous, and productive scientific sense-making with diverse youth (Rosebery, Ogonowski, DiSchino, & Warren, 2010; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Leading researchers who work with students classified as "ELLs" and their teachers have deconstructed instructional practices and train teachers to support "ELL achievement. or remediation of some sort of gap (see Janzen, 2012, for a comprehensive review). The undergirding ideology of these studies is that ELLs are *deficient*: unable to achieve established academic goals, incompetent in English, dropping out of high school, and therefore not academically competent at all. Such studies in science education bear such goals to "align" students' language to the "content-area language used in the academic discipline" of science (Buxton et al., 2013, p. 349), or "enabling ELL students to learn science" to "increase student achievement" (Buxton, Lee, & Santau, 2008). Although much of this work does emphasize that the deficit framing is a problem, it still bears a problematic telos that English learners are somehow insufficient, and that it is the teacher's job to educate them to perform normative "scientific" practice and academic ways of speaking and writing scientifically.

I want to be clear that while I value the work of these research groups, I question the underlying ideology of this frame; it is not simply enough to teach "academic language" (e.g., Zwiers, 2008). Rather, I bear a commitment to examining and dismantling structures that assume children are not able to do science or that they are not doing science already in languages other than English—as these can alienate and minoritize nondominant youth. This brings me to the third corner of my problem space: that of critical language pedagogies.

### **Critical Language Approaches**

Critical language pedagogy comprises a vast number of scholars and fields of study, but it has been helpfully summarized as having three tenets: (a) locating English teaching in relation to systems of power and politics, (b) a commitment to transformation and change, and (c) continuous reflexivity on my own part as well as among structures (Pennycook, 1999). With this view, I interpret "English learners" as a deeply resourceful, resilient young people (e.g., Gutiérrez, 2004), counter to the body of literature that suggests they are altogether less able than their monolingual peers. I hesitate to describe such youth as "English learners;" such a term fails to acknowledge the systematic policies that oppress them and, again, highlights their "lack" of English rather than their sophisticated, cross-cultural, often multi-national capacities for language use (Flores & Rosa, 2015).

This critical language framing allows me to interrogate the power structures that language-minoritized students encounter in their lives at school while helping to design lessons that break these power structures down. In this dissertation, two chapters focus

on specific classroom practices and student activity, and a third examines the work of adults as we developed an equity-focused initiative together. The problematic structures addressed through critical design research in this dissertation are systemic (Chapter 1), microgenetic (Chapter 2), and pedagogical (Chapter 3).

### **Study Context**

The participants in this study are a subset of teachers and their students within an ongoing design-based implementation research study (Fishman, Penuel, Allen, Cheng, & Sabelli, 2013) that exists as a collaboration between the University of Washington and a nearby district's science department. This effort, funded by a National Science Foundation grant (SBE #1238253) and a U.S. Department of Education Math/Science Partnership grant, is focused on helping teachers and researchers develop capacity to teach the science practices of modeling, explanation, and argumentation. This design partnership is ongoing; we have engaged actively with this district since forming a partnership in 2013, and I was an active part of the design, research, and teacher development processes from August 2013 until September 2016. The partnership team has comprised between 8 and 15 practitioners and researchers.

The partnership's major activities included designing and implementing teacher professional development to support implementation of the Next Generation Science Standards (NGSS), which were adopted by our state in 2013. Our model of teacher professional development centered around a five-day summer institute, during which teachers adapted existing curriculum materials to incorporate the argumentation, explanation, and modeling practices. Then, teachers met for three release days throughout

the school year (in 2015-16: December, February, and May) to develop formative assessments, reflect on student work, refine the curriculum adaptations, and gather new strategies for NGSS-focused teaching. This model was adhered to by the two collaborating districts, Creston\* and Brentwood\*. The study design allowed for additional teachers to be added to the effort in year two, the entire contingency of middle school teachers to be added in year three, and the hope to expand PD to high school in years to come. At the time of this writing, approximately 180 teachers and practitioners had consented to the UW study, although the data for the two classroom-based studies was bound to the 2015-16 school year and only the middle school teachers in Creston Public Schools: approximately 70 in all. For the study of the research-practice partnership (Chapter 2), I study a smaller sample of practitioners over three years of engagement.

This dissertation focuses on data collected with the Creston Public Schools, a large urban district in the Pacific Northwest serving approximately 50,000 students. Of these, approximately 11% receive ELL services and ELL staff support students in each of the 98 buildings. According to data collected by CPS, 128 languages and dialects are spoken by students, and they represent 149 countries including the US. The district had approximately 20 middle schools and K-8 programs in the 2015-16 school year.

Teachers who have already given informed consent to be studied within this larger study of professional development chose whether to "opt in" to be considered for focal study at the classroom level—as part of a strategy to more deeply engage in the details of classroom-level inquiry and refinement of instructional practice. Because this “deep dive” focal study was an optional part of this professional development, sampling of both teachers and students was limited to teachers who explicitly indicated interest in

collaborating with me in their classrooms as we studied the participation of their students. I strategically sampled to include linguistically diverse classrooms. This sampling decision was made from research that all students arrive at school with diverse understandings about the natural world (Duschl, Schweingruber, & Shouse, 2007), and that young people have varied and culturally rooted practices for expressing these ideas (Hudicourt-Barnes, 2003). Given a broad sample of three geographically and culturally diverse schools, my conclusions should be both particularizable within different classrooms (Erickson, 1986) while permitting comparison "across" classrooms as to draw conclusions leading to larger design principles, making my design more relevant to educational practice as it relates to language-minoritized students (Gutiérrez & Penuel, 2014).

### **My Positionality**

This dissertation could not have been done this way by any other person, and the lens and stance that I take on my work is informed by my place in the world (e.g., Harding, 1988). My own positionality within the project, in my community, and in my social network of scholars and teachers enabled the perspectives herein. I describe these positionalities in this section.

In the pages that follow, I present my research study and findings as a graduate student and researcher. This is a positionality lent by my acceptance to the University of Washington in 2012 and the subsequent years of coursework, apprenticeship, and training in the Everyday Science and Technology research group (Philip Bell, director). Over four years of involvement in that group, I collaborated with approximately twenty other

scholars, all of whom were interested in equity-focused science education. Our perspectives within that field were quite broad, and I gained valuable perspectives on out-of-school learning, K-12 science policy, theories of human cognition, critical theories, and, of course, the learning sciences. I was also able to explore a wide array of research methodologies and methods: design-based research, ethnography of learning, interaction analysis, and social network analysis.

I must also credit two other research groups at the University of Washington for helping me find my scholarly voice. The English Language Pedagogy research group, founded by Manka Varghese in spring 2013, helped root me in a group of peers and scholars who shared my passion for supporting critical, reflective pedagogy in support of language-minoritized youth. Second, I worked with Heather Hebard's research group on writing and language instruction. I credit time with these researchers and peers as formative; not only did I come to deeply understand contexts of learning with the lens of a researcher, I was encouraged and apprenticed into research practice.

While I derived much of my stance as a researcher from participation in these research groups, I have also held my five years' teaching experiences close throughout my work as a researcher. I taught courses in English, English as a second language, social studies support, science support, sexual health, computer science, and reading, and this has further cemented a positionality of advocacy and care for students classified as "ELL" or marked by a nonstandard dialect of English. Taken together, this blended history of research and practice informs the words of this dissertation and the social actions I took in its generation.

## **The Research**

The empirical studies in this dissertation investigate the design and implementation of educational change efforts focused on supporting language-minoritized students. These chapters take as their units of analyses the shared activity of a research-practice partnership, the co-design of a discourse-based intervention and its outcomes for students, and finally the learning of students in discursive practice. In all, this study examines one problem space from district-level decision-making and planning, to teacher implementation, to student learning outcomes in the classroom. My hope is that it provides a coherent, multilevel view—from policy to practice—of the possibilities for building more equitable systems of science education within the vision of NGSS. In order, the empirical chapters answer the following questions:

1) Implementation Research Question: How can a research-practice partnership support more equitable implementation of NGSS?

2) Contextual Research Question: What characterizes the classroom-level interactions of language-minoritized students in this implementation?

3) Design Research Question: What instructional design approaches might support language-minoritized students to engage their cultural and linguistic resources?

I summarize each chapter briefly here.

## **Organizing for Equity: How a Science Research-Practice Partnership Developed an Equity Initiative to Support English Language Learner Students**

Large science education improvement projects which focus on supporting equitable outcomes for language-minoritized students tend to face challenges in

implementing at scale. As Rosebery, Ogonowski, DiSchino, and Warren (2010) point out, this "conundrum" lies in the tension between equity and scale: seeking equity demands that we provoke truly heterogeneous discourse and engage students' diverse backgrounds. Yet the kind of teaching that relies on students' spontaneous, rich contributions is very difficult to foster at scale. This study speaks to this tension in the context of large-district implementation efforts: the design of teacher professional development that amplifies student voice in relation to new science standards. It asks, "how can researchers and practitioners work together to design teacher learning that centers ELL students and their needs?"

This study takes a design-based implementation research (DBIR) (Fishman, Penuel, Allen, Cheng, & Sabelli, 2013) approach to engagement with this problem space. With design-based implementation research, the research team and I worked in collaboration with practitioners (namely a group of several urban district leaders) to jointly solve problems of practice that emerged during our shared work over five years. This meant a bidirectional cultural exchange in which researchers engaged in the work of practice and vice versa (modeled on Palinkas et al., 2009), thereby altering the endeavors of both research and practice. For example, while I took fieldnotes, gathered transcripts, and conducted analysis as a typical graduate student, I was also regularly engaged in the work of practice: co-designing and delivering teacher learning days, visiting classrooms, coaching teachers, and supporting students in science learning.

I gathered, analyzed, and interpreted data related to this DBIR effort in an ethnographic fashion, attempting to make sense of members' meanings as we worked in

partnership to further the equity agenda. Findings were generated from over 500 pages of fieldnotes, audio recordings and transcripts, and retrospective interviewing.

Given a conceptual framing in expansive learning (Engeström & Sannino, 2010) and histories-in-person (Holland & Lave, 2009), I interpret key moments in the implementation of the equity initiative as *cycles of expansive learning*, as we jointly negotiated our work around shared objects of activity. Given that these cycles were messy, spiraling endeavors, I leverage Engeström's idea of "knotworking" to better understand how we made sense of English learner students.

This study has many practical implications. First, STEM education initiatives to support ELL students require constant attention and reflection. Second, the shared activity among researchers and practitioners can be accounted for simply by analyzing the activity, but it is helpful to consider the histories-in-person of the contributors as well when thinking about the mechanisms that move shared activity forward. Third, such dimensions of this work are especially important as we develop ways of implementing equity-focused educational interventions for English learner students at district-level scale.

### **"What Great Ideas": How Language-Minoritized Students Encounter and Counter Epistemic Injustice in the Third Space**

My second empirical chapter asks a pressing question about the nature of student-to-student discourse in the science classroom, particularly about how it is that students can come to be "minoritized" by their peers in classroom interaction. Many studies have addressed the nature of small-group learning in the classroom, but few have actually used

a framework for understanding how these micro-interactional moments of classroom life can be sites of injustice. To that end, I interpret language-minoritized students' interactions in terms of their participation structures (Erickson, 1982) and the ways that youth use discourse to position each other in relation to science content. I lean on studies of how youth are positioned relative to their peers in school (Leander, 2002) to argue that interactional moves matter in the construction of just learning spaces.

I used the micro-analytic methods of interaction analysis (Jordan & Henderson, 1995) to interpret video data of three focal students in one classroom over time. The findings are simultaneously hopeful and troubling. I found that Raqi, Ziling, and Pilar (all youth who have been minoritized in school because of their home language) *encountered* and *countered* adverse positioning from their peers in their classroom science learning; yet their resilience—despite being marginalized by their peers—broadened the scope of their learning opportunities. This study shows that peer-to-peer interactions in science class can be sites for injustice; language-minoritized students are especially vulnerable to unjust interactions. Yet they are resilient in ways heretofore not highlighted in research literature. Educators must be supported to attend to the ways micro-level interactions can minoritize youth, and this study recommends ways that teachers and adults can support youth to have positive, ethical interactions. My final empirical chapter works to summarize one instructional strategy for countering injustice by helping all students' voices be heard by a supportive peer.

## **Idea Coaching: A Pedagogy for Transformative Science Talk Among Language-Minoritized Youth**

Since teachers and I found that youth did not always engage with their peers in ethical ways, we sought to use design-based implementation research (Fishman et al., 2013) in order to systematically address this problem of practice. In this empirical chapter, I study what happened as researchers and teachers collaborated to design a formative intervention (Engeström, 2011) together in the local context of our research-practice partnership. Specifically, I analyze how language-minoritized students could come to engage readily in scientific practices, such as explanation and argumentation. This approach contributes to understanding the strengths of language-minoritized students in relation to discursive science practices; research on "ELL" students in science education often focus solely on the difficulties, lacks, and struggles facing linguistically diverse youth (O. Lee & Fradd, 1998; O. Lee, Quinn, & Valdés, 2013; Quinn, Lee, & Valdés, 2012).

For this study, the teachers and I took a design-based research approach that accounted for local instructional theory (Gravemeijer & Cobb, 2006) while systematically designing the tools and materials, discursive practices, and participant structures (Sandoval, 2014) that contributed to designed outcomes in each classroom. The teachers and I collaboratively implemented the intervention—called "Idea Coaching" or "Science Coaching"—in five classrooms and over eight total iterations in the 2015-16 school year. I gathered video data, audio recordings, student work, and fieldnotes from each iteration, and in all I analyzed 19 instances of idea coaching. This allowed me to

draw conclusions about how language-minoritized students were best supported to explain their scientific thinking.

I found that the designed intervention (idea coaching) allowed for a redistribution of authority and knower status. Authority and knower status is typically held by teachers in the classroom; the teachers are the ones asking questions, students typically sit facing the teacher, and students answer questions. However, the reconfiguration of this knower status as a result of idea coaching distributed power and knower status *among students*. Students participated as knowers in their dyadic conversations while the adults gave up floor time; this allowed a transformation of teacher, student, and researcher roles.

This study has ready implications for practice; unlike the other empirical work in this dissertation, this chapter directly answers the question, "How can I be a more equitable teacher with language-minoritized youth?" Pedagogies such as idea coaching fill a needed gap in supporting K-12 teachers to implement authentic, heterogeneous discourse, speaking directly to the "conundrum" laid forth by Rosebery et al. (2010).

In all, this dissertation broadens the empirical bases for sociocultural theories of learning in three directions: for socially just bilingual education, for science education, and for learning scientists. This study and its related project centered the local expertise of teacher-participants to conceptualize instructional practices that enact sociocultural and critical theories for language-minoritized youth.

Together, this body of work seeks to be more than a sum of its three empirical parts by intertwining investigations of multiple elements of a long-term and complex project. In all, these chapters deeply investigate an equity-focused science implementation project in an urban district. By attending to three components of the

project: how adults organize themselves in service of youth, what problems face linguistically minoritized youth, and the pedagogies that might ameliorate these problems, it is my hope to shed light on questions that may face others interested in similar aims of more equitable learning spaces for minoritized youth. I hope to help others in justice-focused implementation projects predict and respond to challenges similar to those we faced in doing such work. The most heartfelt purpose of this dissertation is to help researchers and practitioners answer pressing and practical questions, such as “What are the challenges and benefits to working in a research-practice partnership focused on equity?” “How might I teach my students to engage in scientific discourse?” and “What strategies could help my ELL students better explain their ideas?”

These three studies also seek to contribute to sociocultural learning theory, particularly those which focus on fostering more just learning environments for students who have been historically minoritized. In particular, they take up questions about the nature of human learning through dialogue (e.g., Bakhtin, 1982; Vygotsky, 1978) in a context that is laden with power differentials and social stratification, such as those between researchers and practitioners. I attempt to answer question about the nature of learning in complicated knots of human activity (Chapter 2), how discourse can be used to counter adverse positioning in learning environments (Chapter 3), and what design features might expand opportunities for youth to engage in sense-making discourse (Chapter 4). Together the studies articulate the importance of *responsive listening* in building transformative learning spaces for youth and adults.

## Chapter 2

### **Organizing for Equity: How a Science Research-Practice Partnership Developed an Equity Initiative to Support English Language Learner Students**

#### Abstract

The new vision for science education calls for the cultivation of science classroom environments where English-learning students have opportunities to reason and construct their understandings of the natural world as part of a supportive community of learners. Yet these supportive environments have proven problematic to promote at scale. This limited success can be attributed, in part, to limited understanding of how science teachers can be professionally supported in regard to teaching English learners within the context of systems-level educational improvement projects. Toward this end, an in-depth longitudinal ethnographic study of a science-focused research-practice partnership was undertaken guided by the following broad question: how did a research-practice partnership implementing a district-wide improvement initiative develop its focus on and approach to equitable teaching for English language learners—and to what effect? With a lens of cultural historical activity theory (Engeström, 2011), I interpret the findings in light of the expansive learning cycle being developed through a design-based implementation research effort. The findings point to two patterns of collective conceptual formation in the tangled "knot" of the ELL support initiative: (a) the importance subject positions within the shared knot of activity within the research-practice partnerships and (b) the "spiraling upward" of initiatives that brought about a

new axiology out of competing theories of language learning. This study concludes with implications for justice-focused partnerships concerned with systems-level scale.

## Introduction

Research-practice partnerships—in which researchers and practitioners in education work together to identify and solve problems (Coburn, Penuel, & Geil, 2013)—are a promising approach to organizing for equitable change in learning environments. Empirical work has provided evidence on how various collaborations among researchers and practitioners can, in partnership, accomplish meaningful designs for learning (Linn, Shear, Bell, & Slotta, 1999). Such findings include designing equitable out-of-school learning spaces (Vossoughi, Escudé, Kong, & Hooper, 2013), improving large-scale mathematics reform efforts (Cobb et al., 2013), supporting community-based design (Bang, Faber, Gunneau, Marin, & Soto, 2015), and re-organizing instruction around interest and identity in science classrooms (Coburn et al., 2013). By using the approach of design-based implementation research, such partnerships have been systematically studied in ways that benefit practice while contributing to research (Penuel & Fishman, 2012).

Despite these advances, little is known about how researchers and practitioners, in partnership, attend to one of the most pressing problems in K-12 educational reform in science: the inequitable distribution of resources, capital, and learning opportunities within and across school districts. In many settings, these inequities are particularly stark for immigrant and non-native speakers of English in the middle and upper grades, who bring tremendous resources to their U.S. schools (Campano & Ghiso, 2011). Yet they are often only understood as "limited English proficient" (LEP) (Suárez-Orozco & Suárez-Orozco, 2002) or simply as "a problem" (Gutiérrez & Orellana, 2006) in need of remedy. This deficit-focused thinking undergirds much of K-12 policy, in particular policies that

specify that “LEP” students receive instruction in English language through some form of pull-out instruction in English. In these policy contexts, learners are physically isolated from their peers for instruction in English reading, writing, and grammar for part of the school day. This was the case in the context of the present study with one important caveat: in the focal district, the “LEP”-designated students (or English learners) attended middle-school science classes along with their native-speaking peers. This practice of “mainstreaming” for science class is more favorable than the segregating effects of pull-out English programming. However, mainstream science teachers have been found to be less confident and less prepared to teach English learners (Rodriguez & Kitchen, 2005), which can lead to inequities in instruction. The present study takes on these intersecting policy planes, where English is the only language of instruction, where English learners are relegated to ESL classes for most of the day *yet* included in mainstream classrooms for science, and in which their science teachers have limited opportunities to develop their instructional practice related to ELLs. This study seeks to provide knowledge about how a research-practice partnership functioned to afford or constrain the possibilities for language-minoritized students through the development and enactment of an educational improvement initiative within this complicated context.

The research approach of design-based implementation research (referred to as DBIR hereafter) (Cobb et al., 2013; Penuel & Fishman, 2012) is accomplished through a research-practice partnership approach. DBIR makes the work of researchers more rigorous, relevant, and timely to the needs of educators through its commitment to collaboratively recognizing and addressing problems of practice encountered daily by practitioners (Gutiérrez & Penuel, 2014). It maintains the deep commitment to designing

locally-relevant interventions of traditional design-based research (e.g., Brown & Campione, 1992; DBRC, 2003). However, DBIR calls for a deep investigation of *how* multi-sector partners come together to do their work, and how shared practices and human capacity for equity-centered educational improvement can develop in these partnerships over time (Penuel, Coburn, & Gallagher, 2013). Similarly, researchers in the field of language-learning in particular have called for more collaborative efforts among researchers and practitioners in order to bring about deeper, more lasting change (Hakuta, 2011), and the present study is situated within such an effort.

### **Conceptual Framing: Learning in Knotworking**

This study is grounded in sociocultural theories of human learning, which assume that learning is a cultural phenomenon achieved by and within groups of people engaged in joint activity together (e.g., Gutiérrez & Rogoff, 2003). With this assumption, my study focuses on two units of analysis: (a) the collaborative activity within a large-scale research practice partnership, and (b) the design and enactment of the intervention for English learners. First, I explain how I framed the work of our research-practice partnership across five organizations over five years and the geographically dispersed practitioners that were the focus of the improvement initiative.

Within such a complex organization of multi-sector partners, I first conceptualize that organizations of people can learn together in expansive ways and through shared objects of activity focused on collective concept formation (Engeström & Sannino, 2010). As described below, I focus on Engeström's ideas of knotworking (Engeström,

2008) and the related concept of spiraling (Foot, 2001). I will detail these concepts and how I applied them to my study in turn.

### **Knotworking**

I leverage cultural-historical activity and in particular, Engeström's (2008; Engeström & Sannino, 2010) concept of expansive learning "in knots" around objects of activity. In studies of how teams of professionals across organizations do their work together, he posits that it is in these complex "knots" of activity that the work of organization for change can take place (Engeström, 2008). He uses the metaphor of the knot because an actual knot, made of rope, does not have an identifiable center, and similarly, work in the knots of partnership involves continuous shared effort to maintain joint focus. This is a particularly useful conceptualization for this study of research-practice partnership because our "loosely connected actors and activity systems" continually worked to construct a language and science learning initiative, often by engaging in processes of "tying, untying, and retying" (p.194) in relation to our focus on equity. This framework is suitable for our engagement in a research-practice partnership because the individual subjects in an RPP have differing backgrounds and standards for quality in their work, yet they are engaged in a mutual activity with a shared object. This shared object makes knotworking a helpful conceptual and analytical framework for the present study.

This theory of joint work as knotworking sits within larger theories of expansive learning (e.g., Engeström & Sannino, 2010) which have posited that the learning that happens within an organization is not a linear process with an ascribed telos, such as

some type of professional-level “expertise.” Rather, theories of expansive learning describe learning as a process that occurs across boundaries, such as those of research and practitioners of education. Expansive learning places “the primacy on communities as learners, on transformation and creation of culture, on horizontal movement and hybridization, and on the formation of theoretical concepts” (Engeström & Sannino, 2010, p. 2). This is an apt conceptualization of learning within a research-practice partnership, where researchers and practitioners, with their respective social objects, sit down with a shared problem of practice in an attempt to address it using their collective resources. Specifically, Foot (2001) gives this helpful summary of seven processes within an expansive learning cycle:

- “1. questioning; criticizing some aspects of the accepted practice and existing wisdom;
2. analyzing the situation in order to find out causes or explanatory mechanisms (...)
3. modelling the newly found explanatory relationship in some publicly observable and transmittable medium;
4. examining the model in order to grasp its dynamics, potentials, and limitations;
5. implementing the model through practical applications and conceptual extensions;
6. reflecting on and evaluating the process;
7. consolidating its outcomes into a new, stable form of practice.” (p.65)

My analysis hinges on these seven processes within the expansive learning cycle, by which subjects move in object-based circles around an object of activity without ever coming to rest perfectly on a center. Foot (2001) also argues that these cycles progressively *improve* in their shared endeavor, and the cycles of improvement take on a spiral shape; the movement inward signifying a more tightly focused shared endeavor, or object. Engeström also argues that these spirals move multi-directionally, upward, across

boundaries, forming knots in which there is no tangible center (Engeström, 2008; Engeström & Sannino, 2010; Foot, 2001).

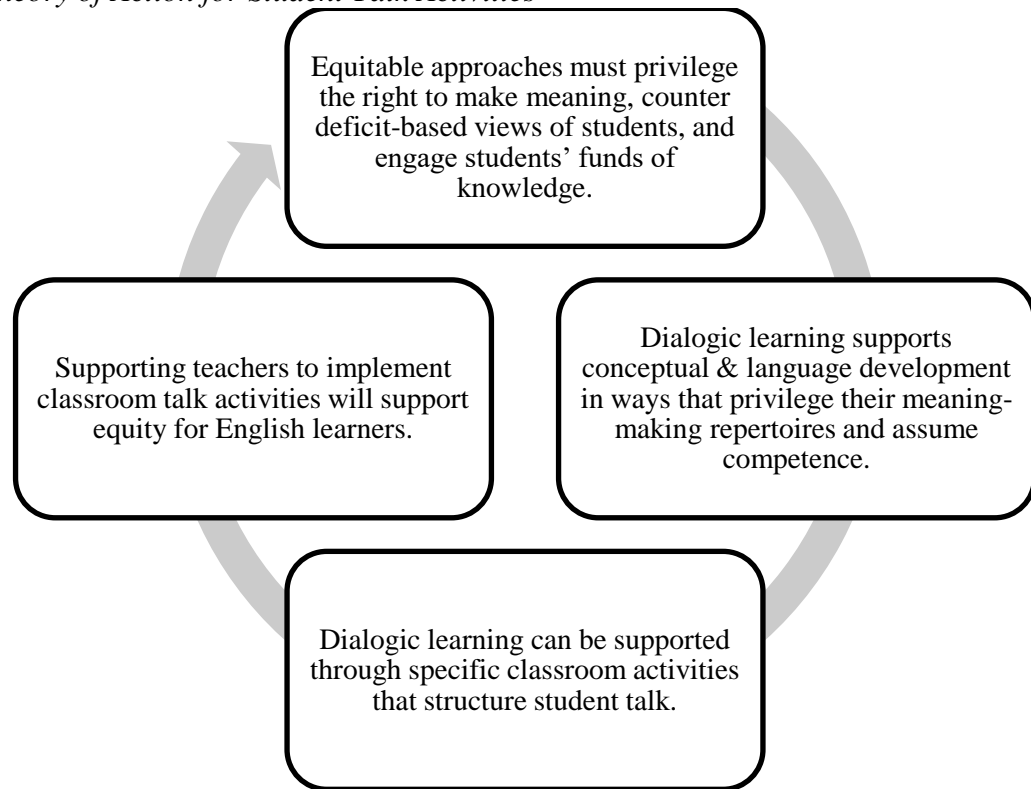
To what end did our shared work spiral upward? Together with district leaders, scientists, and a local biology nonprofit, we knotted our initiative around a project with six goals: (a) developing a set of core scientific models, (b) integrating modeling into existing science teacher practice though (d) continual reflection, supporting science practices, core ideas, and crosscutting concepts, and (e) supporting ELL students in developing science and language proficiency, and (f) building administrative support (150618 “Project Goals”; “Grant Complete”). Here I focus specifically on the pursuit of one of these knots: negotiated and enacted the ELL initiative. I asked the following broad research question about our joint work: "How can a design-focused, district-level research-practice partnership in science education build capacity for, develop, and implement an educational initiative in keeping with a shared commitment to equity for English language learners?" Given the theoretical lenses of expansive learning in the knots, I took up the following conceptually framed analytical questions: "How did a science-focused research-practice partnership follow the cycle of expansive learning related to the needs of English learner students? What are the affordances and constraints of such an arrangement?"

### **Theory of Action for Supporting English learners**

A separate set of theories informed our design process as we worked to support language learners in science instruction. The theoretical roots of these activities lay in

Vygotsky's and Bakhtin's theories of dialogic learning, and this theory of action and its relationship to our goals for equity is illustrated in Figure 2.

*Figure 1. Theory of Action for Student Talk Activities*



First, it is well-documented that equitable approaches to educational design must privilege students' meaning-making processes (National Research Council, 2012; Rosebery et al., 2010), counter deficit-based views of minoritized students (Gutiérrez, Morales, & Martinez, 2009), and engage students' funds of knowledge (Moll, Amanti, Neff, & Gonzalez, 1992). One way to enact these mandates for equity is to keep student-to-student dialogue at the center of pedagogy, thus prioritizing their language and their experience as sense-making tools: “The students’ voice should never be sacrificed, since it is the only means through which they make sense of their own experience in the world” (Freire & Macedo, 1987, p. 152). Although a difficult process, teaching students to use

scientific discourse in the classroom has been found to support this vision for transformative teaching and learning for language-minoritized youth (Rosebery, et al., 2010). Finally, we understand that a professional learning environment that supports teachers to implement dialogic learning should result in improvements to their pedagogy, eventually translating to better opportunities for ELL students to engage in science talk, thereby supporting their facility with scientific practices as well as the English language. In the design of our professional learning environment, we worked to enact this logic model. One might say this model grew into the object of activity that we "knotted" around, yet the process was far from straightforward.

### **Context: A Design-Based, District-Wide Implementation Research Project**

I selected my data from a corpus developed during a large-scale science education improvement project that focused on supporting the implementation of the Next Generation Science Standards (NGSS Lead States, 2013b) with specific attention to more equitable instructional practices related to modeling, scientific explanation. Our long-term, ongoing study occurred over five school years (2013-2018) in an urban district in the Pacific Northwest. In particular, I focus on year three (2015-16) in which we began to work with middle school science teachers, and this effort contained an explicit focus on supporting ELL students. The project had multiple contexts where collaborative activity occurred, including leadership team design meetings, cross-district collaboration meeting, and classroom-level instruction involving support and research. This study takes into account our collaborative work as it developed across these contexts, and data collection resulted from a "participant observer" stance in the effort over four years. As a researcher

in collaboration with science education practitioners, I contributed directly to the design, interpretation, and curriculum of both professional development (PD) design and classroom life, and my role kept me actively involved in the development of the project and simultaneously attentive to the work of fieldnoting and data collection. Across multiple years of the project, our research team has engaged in thousands of hours of such design work with practitioners with the long-term focus of developing the NGSS vision across the district. Specifically, our partnership seeks to accomplish an instructional shift focusing on implementing *equitable* modeling, argumentation, and explanation practices in conjunction with the state adoption of the NGSS.

Over the first three years of collaboration, we have taken a curriculum adaptation approach (DeBarger, Choppin, Beauvineau, & Moorthy, 2013; Penuel, Harris, & DeBarger, 2013; Squire, MaKinster, Barnett, Luehmann, & Barab, 2003) which supports teachers to learn about and incorporate elements of the NGSS into their existing curricula. However, during the 2015-16 year, we added a new initiative to our focus on curricular adaptation: a focus on supporting English language learners to engage in the science practice of modeling. In addition to this "equity initiative," we also added 68 new teachers to the effort in the 2015-16 year: the entire population of middle grades science teachers within the district who met for one week in summers 2016-18 and three separate release days during each school year. We shared several initiatives related to developing new science standards, including developing core models that could be taught in middle grade science, bringing administrators into the PD effort, and changing science instruction to include modeling and explanation.

**The equity initiative.** Despite these multiple foci, the objective of focus in this study is the effort to support English language learners as it played out in the context of our designs and development of the NGSS vision. This initiative was defined in the supporting grant proposal as an "equity strategy" with the goal of supporting "English language learners" with both science content and in development of their English language proficiency. The partnership had considered multiple, possible equity strategies to focus on in the proposed work. In the known history of the school district, this effort marked the first time that the science department at the district level had paid systematic attention to the needs of English language learner students in middle grades. The efforts to develop this goal, including the efforts toward teacher PD development, are hereafter referred to as the "equity initiative."

### **Methods of Analysis**

This analysis of the large-scale educational intervention is a qualitative study in the tradition of ethnographic field research in which members' meanings are derived from careful preparation and close analysis of fieldnotes, participant interviewing (often "semi-structured" or ethnographically responsive in structure), and content logs/transcriptions of audio and video recordings (Emerson, Fretz, & Shaw, 2011; Heath & Street, 2008; Walford, 2008). In this way, we engaged in the field as participant-observers (Atkinson & Hammersley, 1994; Emerson & Pollner, 2001), and, as it could easily be argued, participant-*designers* of this design-based research in science education. This study also includes notes, interviews, and memos contributed by other university team members. This endogenous approach (Stevens, 2010) affords my study a great deal of

particularizability and the development of situated knowledge (Erickson, 1986); that is, this study offers a refined understanding of the context of our study and the intersecting social and interactional factors that help it function with the goal of understanding the interacting social practices, or knotworking, that influenced the settings in desired and undesired ways. In this way, studies such as this one seek to inform others about *how* partnerships *can* support language learners in a large implementation project.

### **Setting and participants**

This study extended across twelve months of engagement and across multiple levels of a partnership. In this section, I will describe the participants in the present study and the contexts in which we conducted our joint work to plan teacher professional learning.

The data for this study were collected over a three-year series of design meetings, professional development days, and at debrief meetings for Creston Public Schools, a large, urban district in the Pacific Northwest. Participants from multiple organizations in multiple sectors were involved across these kinds of meetings. Of the twelve focal participants in the Creston Public Schools design meetings, four had teaching experience within the district, ten had formal (K-12) teaching experience, and three had experience working in STEM fields. An additional partner represented a local biology research nonprofit. All but one were White, and our years of experience working in education ranged from two to thirty years. The diverse experiences of the participants involved in such a study is recommended for both a research-practice partnership and for the studies that emerge from it: engagement across the various levels of the system can increase

mutualism and the productive understanding of actors' work across all levels (Scherrer, Israel, & Resnick, 2013).

*Table 1. Participants*

	<b>Role</b>	<b>Experience Teaching K-12</b>	<b>Experience in STEM</b>
Mark	Science Program Manager 2013-2015	Yes	Yes
Amelia	Science Program Manager 2015-18	Yes	No
Judy	Project Manager	No	Yes
Naomi	Middle School Science Manager	Yes	No
Wyatt	Nonprofit consultant	Yes	Yes
Phil	Researcher, tenured faculty	No	Yes
Shelley	Postdoctoral Scholar	No	Yes
Heena	Research assistant	No	Yes
Kerri	Research assistant	Yes	No
Tana	Research assistant	Yes	No

This study takes as its unit of analysis the *activity* of these individuals whose shared goal was to develop the new vision for science education as outlined in A *Framework for K-12 Science Education* (National Research Council, 2012). Specifically, the project had three goals for teacher learning and improvement: (a) supporting the learning of science content knowledge, (b) designing and enacting "three-dimensional" science instruction through curriculum adaptation and professional learning, and (c) supporting the participation and learning of English language learners (see Figure 2). The participants produced many of the documents in the data corpus as part of their shared activity.

**Data collection**

Data for this study was collected continuously throughout the equity-focused partnership, from June 2013 through June 2016. In order to study how routines developed around an equity initiative, I focused this study on data from the first 18 months of our pursuit of equity for English learners. During this time, our research team and I collected fieldnotes, audio recordings, agendas, and emails relating to the design. I also wrote interim memos to make sense of the ways our routines and practices supported the professional development. Retrospective interviewing within the research team and with collaborating practitioners was conducted as a form of member checking to support triangulation of major claims and to add perspectives to my interpretation of events and data corpus.

**Data Analysis**

I utilized two phases of coding as described by Miles, Huberman, and Saldaña (2014): a primary, summarizing phase that focused on describing the data and binding my dataset, and a second, "explanatory" phase to look for emerging themes. Although my approach to analysis contained elements of basic qualitative research, my relationship to the data was ethnographic; I maintained a focus on members' meanings as they worked through activity systems over time and across contexts.

**Phase 1.** I began by importing the corpus of fieldnotes, agendas, and other documents described above (approximately 500 pages) into Atlas.ti (2013), and I applied initial codes to each document related to its (a) source, (b) creator, and (c) its attention to our shared strategy for equity. I selected for further analysis only the documents that

contained information that explicitly focused on our equity strategy: to build teacher capacity to provide "unwavering support" (*Grant proposal, 150303*) to English learning students in science class, resulting in a corpus of approximately 98 documents from the following events: fieldnotes at each of fifteen design meetings, seventeen days of teacher professional development, and at three debrief meetings throughout the effort. Additional data included agendas for professional development days, several teacher-produced artifacts from professional development, audio recordings of design meetings, fieldnotes from meetings with district ELL/migrant staff, photos and audio from teacher PD events, and fieldnotes of events with other research-practice partnerships in the area. In all, this corpus amounted to 98 documents and photos specifically related to the equity initiative for supporting language learners. I then organized relevant documents and quotations chronologically and wrote several memos describing major phases of the work in an effort to "write my way into" a cohesive narrative of this complicated and multidimensional effort. Most critically, I compiled the cross-setting project timeline for the initiative. I used this timeline to verify my findings with other researchers and add perspectives to the events and fieldnotes through semiformal interviewing.

**Phase 2.** After gathering broader perspectives around our equity strategy, I reread the chronologically organized codes and returned to the literature in an attempt to better understand how organizations with diverse human resources made sense of and solved complicated social problems. I generated additional codes based on my conceptual framework related to expansive learning (Engeström & Sannino, 2010) to better illuminate patterns related to my conceptual framing, and the findings emerged from this organization. My final stages of coding consisted of tagging the long-term timeline with

cycles of expansive learning as well as documenting moments where individuals referenced their salient histories in person and histories in relation to larger struggles.

**Positionality & limitations.** As with ethnographic studies that rely primarily on fieldnotes, artifacts, and interviews, this study is limited specifically to what my research team and I have seen, done, and written about to remember—or what can be inferred or recollected by team members. That is, this study is limited by my positionality within the complex system we've described, namely, as a graduate student with a background in English learner pedagogy and advocacy working within a research institution. Although we took steps inside our research group to interpret the meanings of our engagement through others' positions, continued work is needed to seek the endogenous meanings (Stevens, 2010) of all involved in our partnership.

I also bring to this work my positionality as a White woman, a status which afforded me relative privilege as I moved across design, professional learning, and school spaces. For example, when I was present in science classrooms, I was introduced to youth as someone from the university, and students often asked me questions about coursework and allowed me to join into their conversations, activities which are regularly directed toward teachers.

My own history as a teacher of English learners also allowed a unique position in this work. In particular, my experience as an English as a second language (ESL) teacher in a large urban school allowed me to predict the types of opportunities that would be helpful for teachers to use with their students. For example, my own students benefited when I incorporated discourse-based strategies as part of my own instructional practice, and so I leaned on this experience heavily as I designed opportunities for teachers to

practice discourse. In this way, my experience regularly influenced the positions I took up in the partnership work. And yet, these positions also obscured meanings that others in the settings I studied might recognize most acutely.

## **Findings**

### **Spiraling**

The process of learning to support English learners within our science RPP was expansive and thus complicated. I use the metaphor of conjoining spirals to model our activity as a dialectic and also as a trajectory. As each cycle of expansive learning began in this collaboration, another cycle often spiraled off of it. As in Foot (2001), learning was enabled by continuous cycles of expansive activity, and some of these cycles enabled other, smaller-unit cycles. As I will show, these cycles allowed us to collectively progress toward becoming advocates for English learner students and their teachers. I will describe three cycles of expansive learning here, each of which occurred over a span of several months and which included a number of subjects/individuals who were each working to reconcile their individual histories-in-person with larger histories in institutional struggles (Holland & Lave, 2009, p.3). These cycles had to do with (a) incorporating a focus on ELL students within the professional development (PD) effort over the first year, (b) focusing the PD on a specific teacher-learning outcome, and (c) resolving emergent conflicts when building out a longer-term strategy. I conclude with a recommendation for social theory in design-based implementation research as well as a dilemma facing radical change-makers in dialogic spaces.

**Cycle 1: "Integrate the possibilities"**

The first cycle of expansive learning related to the initiative to support English learners resulted in a specific commitment of professional learning time to our equity strategy. Although our grant contained significant wording about our intentions, and included ELL-focused researchers and partners, it was still a new object of our activity and we underwent a cycle of expansive learning to build teacher-learning opportunities originating in the grant language. Specifically, we wrote:

"We are deeply concerned with the education system's current lack of sufficient attention to ELL students, as evidenced in the egregious opportunity gap, and at current trajectories, we will leave these students further behind, failing in the core of our responsibility to our youth. The NGSS (and CCSS) bring increased demands for disciplinary discourse, which will widen existing opportunity gaps for ELL students if not attended to (Lee, Quinn, & Valdes, 2013). Furthermore, with current and projected demographic trends, an increasing number of our students will suffer this inequity of opportunity (Batalova, 2015). We choose, without reservation, to wholly own our responsibility and will not sweep our accountability to these students under the broad coverage of "best practices" in science education. (...) We recognize this stance unwittingly absolves us of responsibility to responding to what the data show us. No longer will we take this stance. With this project, we commit to our own transformed perspective as we work to transform the education of our youth" ("Grant Proposal", 150303)

Further, we operated with the concern that "best practices" in science education were not necessarily considered "best practices" for supporting language learners. In the earliest weeks of the project, the science program manager leveraged the language used in the grant to provide an overview of the equity initiative within the grant to stakeholders, including the rest of the design team (fieldnote 150615), teachers (fieldnote 150618), and grant supporters (fieldnote 150225, 150611). This language varied somewhat, but in each of these situations, the program manager shared that we held a commitment to supporting language learners through improved pedagogy. This was

presented with differing angles of focus, including "supporting ELL students in developing proficiency in science and the English Language Proficiency Standards," a "commitment to equity and unwavering attention to ELL students," and a "focus on equity (ELL)" (Grant 160301). In this way, the team summarized and previewed the complex equity initiative in differing ways, beginning with the program manager's decision-making and moving outward to other stakeholders.

Thus, the grant served as a stated, overt motivation for activity, a way for us to focus our work together and to begin to "knot" our activity around. The language of the grant helped us begin to move toward an *object of activity*. The proposal provided resources to involve the ELL staff of the school district in the work—as they were part of the proposing team—but they were unable to initially engage in this new program work given their responsibility with other competing district initiatives. As we prepared to work with teachers during the first one-week summer institute, however, we faced a bit of a dilemma. Since we had already agreed to six facets of work, supporting ELLs being one, we were faced with a need to narrow or consolidate our work for the first year of the project. Since the same 70 teachers would continue with us through the full three years, we felt that we could add other elements as teachers became comfortable with scientific practices. In a June 2015 meeting, the science program manager specifically addressed the six commitments of the grant, saying that they might be too much to focus on in the first year. He suggested that the ELL initiative may need to be postponed during the first year of the study because it might "not be done well enough," and he was concerned about providing adequate time and attention to this initiative. At a meeting in June 2015,

he suggested that we think about delaying the start of our equity initiative until the second year of the initiative, or the 2016-17 school year.:

"We spent a few minutes getting clear about what was meant by the E bullet on ELLs and what was lowest-hanging fruit. KW said she was "disappointed" by this (ELL initiative) being on the chopping block for the first year and argued that the Talk Science Primer is the first step toward instruction that works for ELLs and that could be an easy target for us that we can hit. SDG's concern is not doing something well enough" (fieldnote, 150714).

As the primary investigator and lead grant-writer with a history of directing teacher learning efforts, he had come to acknowledge that a "half-baked" initiative constituted a political threat (i.e., teachers could opt out of this non-mandatory PD work, the ELL staff might increase their support of the science program, etc.). This history manifested in our initiative when he focused our discussion on cutting back on the first-year goals in order to have some fast successes.

In response to his proposal to postpone any direct attention to ELL students' needs, I countered his suggestion in the design moment. I offered that we instead pursue the ELL initiative but with a narrower focus: supporting dialogic learning through science talk activities. I argued that this course of action met the requirements of the grant through its goal of providing teachers explicit instructional tools to support ELLs, but it also cohered with our other initiatives, especially our attention to instructional improvement. My subject position that was *historied*; my experience supporting ELLs as a teacher, my experiences with the district's ELL staff, a good relationship with the program manager, and my research focus on English learners all contributed to the way I responded in this moment. The move also built upon the prior work of other district

practitioners which used a scaffolded approach to learner-centered discourse for making sense of natural phenomena. Further, discourse in the science classroom had come to be regarded a “best practice” (NRC, 2007) recognized by the knot-workers. These are things the science program manager was familiar with, and it likely provided logistical and research-based reason to pursue a focus on discourse. This micro-moment contained our differing perspectives, but also a rich cultural and historical site for learning.

With these specific histories engaged in the knots, we negotiated a focus on supporting equitable student discourse as a PD strategy for the year. The next time we met, the district director acknowledged that he was glad I helped him "integrate the possibilities" of the science initiative and the ELL initiative. In this way, our knotworking led to a revised object of activity: a year-long focus on supporting classroom discourse for ELL students. I interpret this complex, interdisciplinary decision-making as pivotal for the equity agenda; the shared object of our work "in the knots" came into focus as a result of an expansive learning cycle that contained tension among subjects due to their histories relative to the effort: in this case a former teacher's and the science program manager's.

To date, the resulting discourse strategy has remained as a long-standing, expanding element of the equity initiative within the project, and it has seen considerable uptake including three focal schools described in Chapter Three and more broadly in the

science education field<sup>1</sup>. The result of our activity in the local, contentious practice was a blending, hybridized version of the original object of activity stated in the grant. This hybridization, as Foot (2001) describes it, an example of a continued spiral of activity whereby both partners' values and goals are represented as we continually negotiate the object of activity in the knots. We moved forward with this hybridized object into the design of the first teacher learning moments.

I will pause here to comment on what was striking about this cycle of expansive learning in relationship to the research question. This case, in which an equity initiative for ELLs begins to take shape in a partnership, illuminates one of the strengths of research-practice partnerships: an expansion of possibilities when multiple subject experiences are knot-worked. In this case, there were *logistical* and *ethical* concerns weighing on the knot, especially related to whether or not we had capacity to fully develop the initiative versus whether it was fair to let a year of the grant pass without any overt work towards equity. Each of these concerns was tied to the histories that subjects brought to the moment, and anchored in the language of the grant (a tool). However, this was not a simple chain of cause-effect interactions, but through this complex interaction we arrived at a path forward that addressed both concerns. When we agreed upon a strategy of incorporating opportunities for youth discourse into science curriculum, we were able to address all of the value-based concerns of the partners. In this way, we were

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<sup>1</sup> One such resource is available at [www.stemteachingtools.org/sp/talk-activities-flowchart](http://www.stemteachingtools.org/sp/talk-activities-flowchart).

able to realign our axiologies, or value systems, in ways that propelled us forward into the initiative.

### **Cycle 2: Imagining the Professional Learning Activity**

As I have described, I do not conceptualize expansive learning cycles as linear, collated events that line up neatly one-after-another. Our first cycle of expansive learning was no exception. We found that once the cycle was initiated with questioning and proposing of solutions that new cycles of learning were launched. This phenomenon has been called "spiraling":

"As spiraling cycles, the second is contingent upon the first, though not strictly successive to it. The introduction of the indicator model [a new tool for the network] occurred in the evaluation phase of the first cycle and in the analyzing phase of the second cycle. In other words, the introduction of the indicator model was an action with dual meaning. On the one hand, it was an action of evaluation and consolidation. On the other hand, it was an action that led to the modeling of a new form of activity." (Foot, 2001)

In this way, our second cycle of expansive learning was a direct result—e.g., it spiraled off—the analysis and modeling phases of the summer design work described above. As Foot indicates (above) it is common for the spiraling circles to be contingent but not strictly successive. This case describes a cycle of expansive learning that specifically knotted around the formation of a tool for supporting student-to-student discourse.

After we decided together that scientific talk would be part of work for the 2015-16 school year, it took another cycle of expansive learning to specify the focus of the professional development. As knotworkers, we needed to specify what teachers would *do*

and *learn* during our PD time. I describe this cycle and how our subject positions were made salient therein.

After the district leader and I modeled a solution of including the ELL initiative in the summer, another graduate student and I were tasked with developing an initial learning opportunity for local teachers to engage in. We had initially planned to use the *Talk Science Primer*<sup>2</sup> (Michaels & O'Connor, 2012) and were planning to distribute it in June at the first day of professional development. We felt the *Talk Science Primer* was pivotal for supporting instruction of science practices, particularly helping teachers encourage deep explanation. We planned to build around this document for the next nine months of professional development.

However, we confronted our need state of this "spiraled-out" cycle of learning when our science planning team sat down with the district's ELL team—who were now available to consult with. At that meeting, the ELL professionals identified a key shortcoming of the *Talk Science Primer*. Simply, the *Talk Science Primer* focuses on teacher talk, and the ongoing mission of the ELL department was to improve the quality of *student* talk. This led to a contradiction, a moment of questioning our object in order to manage competing values in service of our desired improvement goals.

This moment of questioning in the *need state* launched a second cycle of expansive learning. Since all of us—the district ELL and science staff, the University

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<sup>2</sup> The *Talk Science Primer* is a research-based, teacher-directed document that explains the importance of talk in science classrooms and focuses on helping teachers implement probing and clarifying questions directed from teacher to student.

partners, and the science nonprofit—wanted teachers to have coherent professional development opportunities, we stopped to consider how a focus on supporting ELL students might be able to simultaneously support all of the needs of the project: (a) to improve teaching of scientific modeling, (b) to support scientific model-building and explanation, and (c) to support the language development of English learners.

As a result of this meeting, the university partners were tasked with synthesizing the direction of the ELL initiative by drawing up an agenda for a 90-minute professional development session to introduce the teachers to the talk initiative. We drew from the multiple professional development initiatives we had engaged in as both teachers and researchers as well as the research base in science education and ELL students. In particular, my role was to ensure that talk activities had a clear, established structure, while the former science teacher collaborating with me worked to make sure that each activity had a scientific *purpose* rooted in the NGSS. Even in our own team, our histories were consequential; the role to engage in the development of professional learning resources (i.e., tools) was one where our histories-in-person confronted each other in local practice.

What we created for the professional development week was an initial outline of a resource to support teachers' planning of student-to-student talk activities. Essentially, we designed a table that matched talk activities to the scientific objective (see Figure 3) in ways that supported the mission of the NGSS, especially the scientific practice of modeling.

*Figure 2. Original Student Talk Activities Diagram for Teachers Mapped to Science Practices*

Student Talk Formats - partly adapted from Kagan & Kagan (2007). Revised 1/28/16

Refine Ideas			Explain	Elicit
D. ARGUMENT			E. EXPLANATION	
<b>Critique</b>	<b>Revise</b>	<b>Reach Consensus</b>		
<u>One-stray</u> : One person “strays” from each group and acts as a critic of another group’s models while the 3 remaining write their criticism. Could use table tents for accepting criticism/praise.	<u>Write &amp; Pass</u> : Students write their ideas and pass them around their tablemates, who add comments to their ideas. Then students write a revised statement. Note: <u>Ss</u> need help learning the art of commenting.	<u>Agree-disagree line</u> : Ss stand at the part of the line their <i>data or experience</i> best support.	<u>Share-Trade</u> : Look at a concept cartoon, write your idea, share with a partner, then trade and share again.	
		<u>All-class Science Talk</u> : Teacher poses a question for students to answer <i>with data and reasoning</i> using ONLY the TERC <a href="#">Talk Moves</a>	<u>Claim-pass</u> : Write a claim at the top of a piece of paper and pass the pencil, with each student adding a piece of evidence or experience and passing the pencil to the next person.	
<u>All-day post-its</u> : Models are left out all day for other periods to comment on - and maybe other teachers, too.	<u>Chips</u> : Print 4 statements on a paper and have students at each table “vote” by placing a BINGO chip on the statement they agree with and why	<u>Discussion Diamond</u> : Students write their ideas in each corner of the same paper, share merits of their ideas, and their consensus in the middle	<u>Idea Coaching</u> : In a pair, one student “coaches” while the other explains. Then switch.	

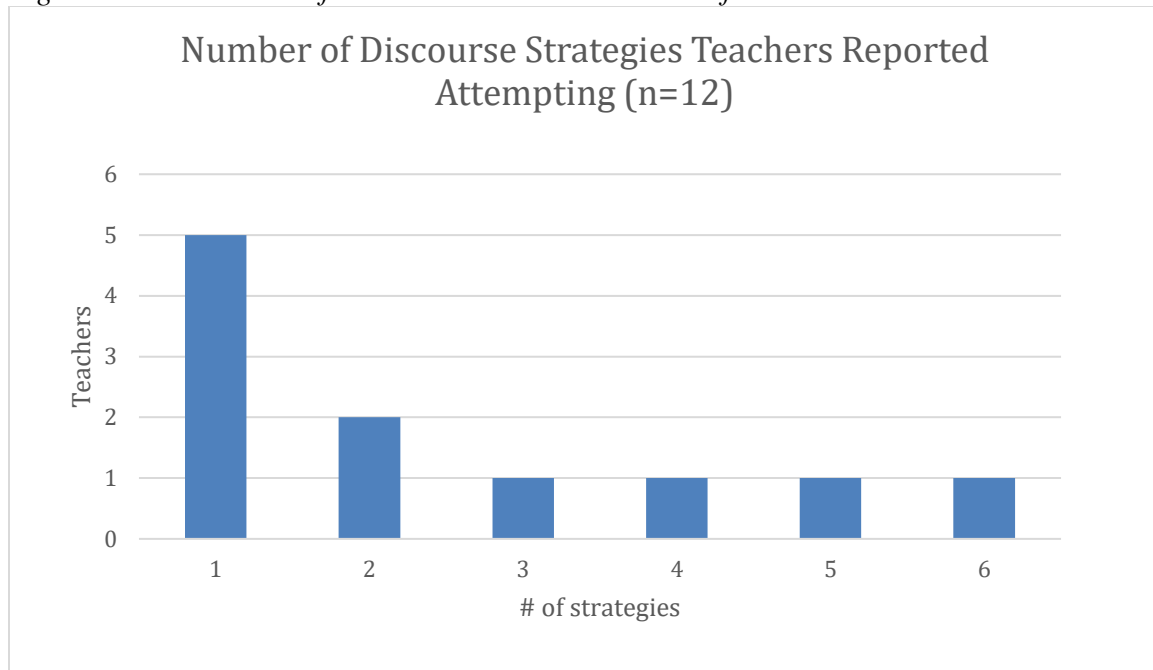
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This table, presented to teachers in a Powerpoint slide in the summer institute, was our attempt at modeling a solution and provisioning the activity system with a usable tool for lesson planning engaging, discourse-based science lessons for English learner students. We wanted teachers to use the table as a way to build in opportunities for students to practice their language together in a way that was rooted in argumentation, explanation, and the weighing of evidence. These activities would give language learner students a shared, low-pressure space to practice scientific language authentically, with the goal of making meaning through talk. This holds with our research-based theory of action described above, in which we conceptualized dialogic learning as the foundation of equitable instructional practice.

On the fourth day of the five-day summer institute, we briefly shared this diagram (Figure 3) with teachers and walked them through an example talk move they could use in their classes, called "claim-pass." In this way, the diagram acted as a tool to support teachers in the process of curricular design and adaptation as well as a reminder of the claim-pass protocol. In this activity, we were *implementing* the new model: broadly sharing its purpose – helping them incorporate more talk activities into their curriculum – and its motivation: supporting language learner students.

Six months later, with this diagram and very little other support, teachers (n = 12) were asked via UW survey how many strategies from this table they had used with their students (Stromholt, Lakhani, & Bell, 2016). In short, a majority of teachers reported using just one or two talk activity strategies in their teaching. We do not have baseline data, so this may represent an increase—other data would suggest that. But this result helped the partners understand that there was a need to provide more instructional support for learning different kinds of talk activities to support English learners' dialogue in science—which has subsequently happened on multiple occasions.

*Figure 3. Teacher Use of Talk Activities Four Months after Introduction*



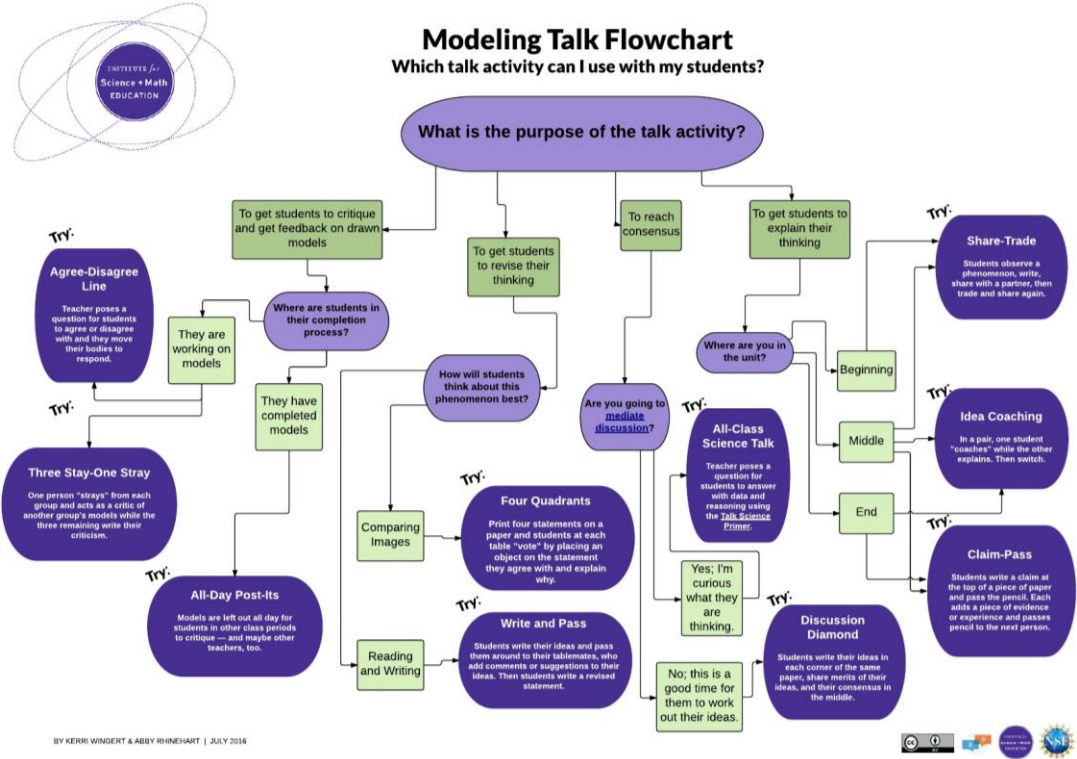
The model for professional learning of talk strategies stabilized throughout the year through continual reflection and design within the partnership, beginning with the realization that teachers didn't seem to have a number of talk activities they felt comfortable using. First, teachers reflected during the months after the initial PD that the table as it was designed and presented was not useful because it was difficult to read and understand, and that the short, six-word protocols were insufficient to support them to actually implement a talk activity in their classroom.

Second, I was compelled to make changes to the talk activities table because of the time I had spent with teachers in classrooms on emerging problems of practice and around the contextual constraints and problems of practice that teachers faced as I worked with them. Of particular significance were three "deep dive" classrooms where teachers invited me to work with them and their students to incorporate these talk strategies in real-time lessons (see subsequent papers for studies of the learning design

and student outcomes). These two features of our research-practice partnership (responding to problems of practice and local “deep-dive” engagement of researchers with practitioners) are longstanding elements of design-based research (A. L. Brown, 1992) and in our partnership they allowed a reflective space wherein continual reflection and improvement was made possible.

Within these classrooms, we noticed that teachers were excited to rethink the logistics of communication and the division of labor among youth in their classrooms. They were eager to use flexible partnering among youth and actively encouraging high levels of student engagement in talk. For many teachers, this represented a pedagogical shift that allowed learners more low-stakes, flexible sense-making opportunities. The collection of data on teachers’ use of the talk strategies allowed for the reorganization of the table about six months after the first one was shared. We aspired to incorporate teacher concerns about logistics, timing, and science materials into the new iteration. The second version of this talk activities flowchart is in Figure 5.

Figure 4. Iteration Two of Talk Activities



This second iteration of the talk activities tool manifested as a flowchart. It included problems of practice and contextual constraints within the diagram itself, including the mode of language (reading and writing, comparing images, speaking with a partner, speaking with the whole class) that youth might use. It also was responsive to the conceptual development of youth and it included different activities for different points in a unit: the beginning, when ideas are fresh, the middle, or the end, when more complete and final ideas are developed. We also engaged other professionals, such as a web designer and a communication specialist, to build and edit a new version of the talk activities diagram. The resulting "talk activities flowchart" was more popular with teachers, and teachers rated it favorably during May professional learning days.

This iteration of the tool—from a table to a flowchart—represented a revision of the object of activity. We had originally sought to help teachers design lessons that included student dialogue, but inadequately provisioned the activity space with tools to support design work at that level. This contradiction allowed us to reflect on the tools we had created, return to them, and revise them to support teacher agency to design at the interactional level of instruction. On its surface this is a cycle of expansive learning, and the teaching tools are new representations of the solution.

When the flowchart was redesigned, the histories of the knotworkers were again made salient. Because supporting student dialogue was not a longstanding practice for the district, teachers wanted access to protocols or scripts to support their teaching of these activities. District leaders indicated, drawing on their histories supporting teachers, that step-by-step guides would likely be useful to teachers as well. Alongside this shift in tool and object, we had also begun to see a change in the division of labor among adults facilitated by technology, namely, the increased use of Twitter and online platforms for sharing materials. In response to these situational developments, we decided to build out a "clickable" version of the flowchart where each bubble linked out to a PDF of a longer-form protocol. This became our third iteration of the talk activities flowchart, again a result of teachers' histories with talk, administrators' histories with teachers, and our own histories with technology and its possibilities.

From this expansive learning cycle emerged an expansive outcome: a new, "clickable" talk flowchart. It went live on STEMteachingtools.org, a project website of professional learning resources, on August 1, 2016. This flowchart was organized vertically so that it could be arranged in a packet with six pages of supporting protocols,

depending on the need of the reader. It was published online to coincide with our summer institute in 2016. It saw very wide use and became quite popular both online and in paper copy, getting 379 direct visitors and another 2,197 to its corresponding STEM Teaching Tool document in its first three months online. Cases of experienced teachers using it in daily practice also arose (JJW, fieldnote 161104), as did at least one case of teachers sharing it with their entire middle school staff, including bilingual aides, administrators, and other content-areas outside of science (MEE, fieldnote 161105). Within all of the fieldnotes, interviews, and shared accounts of the ELL initiative, the most commonly-referenced tool for the equity initiative were these talk strategies and the flowchart. This widespread use illustrates the *stabilization* and consolidation of the model for talk activities that can support English learners.

What elements of our design may have contributed to the success of this tool? The evidence suggests that our responsive stance toward the artifact and our commitment to revision and improvement allowed the knotworking cycle to produce an artifact that was useful to practice thus more widely taken up. This artifact had the following features that facilitated uptake in our context: an online presence and “clickability,” an interactive design whereby users selected talk activities based on their constraints, and a driving mechanism rooted in the promotion of scientific dialogue.

In all, this is an example of a cycle of expansive learning with *focusing a professional development strategy for equity* as its object of activity. It took place over 16 months across several groups of stakeholders and invested parties, and our histories-in-person—as educators and researchers—were continually made salient in the local practice as we refined our object of activity.

**A concern.** However, somehow, the "talk activities" focus seemed to lose its initial character as "an equity initiative" at this stage in implementation. In many of its third-stage iterations, the talk activities flowchart ceased to coincide with mentions of equity for language learners. Instead, when talk strategies were addressed alongside the flowchart, it tended to be somewhat "language-blind" or "culture-blind." Of the 93 documents analyzed for this study, 25 design moments centered around talk activities and the discourse strategy. Of these, only seven mentioned that talk activities strategy as one that promotes equity. As an example, in February when an hour was dedicated to supporting talk activities in PD, my own presentation didn't mention equity at all. Yet it was directly in service of our commitment to equity as the district-level partners and the researchers had agreed on early in the initiative; *"discourse" became a proxy for "the equity initiative."*

Yet this proxy for equity was not made readily apparent to teachers. Data from midway through the first year suggest that teachers did not perceive the connection between discourse and equity. Two teachers specifically called out the absence of equity as an object of the PD, saying, "There's a very loud absence of that (equity)" (fieldnote, 160202 PD, DBE) and highlighting that they wanted the PD to centrally address educational equity (interview DAS). This was also highlighted in August 2016, when approximately 20 teachers convened a lunchtime meeting to talk about issues related to equity in their curricular designs because they felt that the PD needed to do more for English learners.

In short, during the first year of the equity initiative, *it was unclear to teachers that equity for ELLs was the designed object of activity* for the talk activity flowchart, and

teachers found it necessary to seek other supports for making their pedagogy more equitable. In this way, the stabilization of the learning cycle meant that one of the initial objects of activity in cycle one—inequity for English learners—was not made central to all participants. Although dialogic learning was a foundational theory that drove the talk strategies, and it was the object of *the designers' activity in design, teachers could implement all of the talk strategies without ever thinking critically* about the inequities for language learners in their school or classroom. In the first eighteen months where talk activities were a PD focus, equity became silent as a motivator for activity from the teacher perspective.

I argue that something happened here in the knotworking of our shared endeavor that Engeström (2008) has described, by which the initial intention of the partnership was "muffled" (p.74), or where the *talk activities "displaced" (p.72) English-learner students' experiences* as the object of activity from the perspective of the teachers. Initially conceptualized critically, as a way to disrupt traditional "transmission" models of learning where teachers transmit their knowledge to students in favor of dialogic ones where students create understanding together, talk activities became incorporated as a teaching strategy, but not necessarily a concerted effort toward equity. As a PD design team, we were very clear about the need to focus specifically on the supports available for language learner students through authentic shared practice.

However, when we chose to focus on talk activities as a way to simultaneously attend to English learners *and* scientific practices, the relationship of talk strategies to equitable pedagogy was not always made explicit in PD presentations, materials, or even tweets about the talk strategies. This process by which initial intentions can be obscured

through the sheer complexity of an initiative is called "muffling" (Engeström, 2008, p. 76). Although supporting ELLs was a central part of this strategy and theory of action, we didn't *mention* them or other minoritized populations even as we worked to support them, at least during the first 18 months of the initiative. Engeström has called this "contraction by silencing", in which a "pseudo-object" (the equity initiative) did not receive a focus within the activity system such that the teachers perceived it. Engeström (2008) also calls this contraction by silencing (p. 74-5) and displacement (p.72), and he explains that it distorts the object of activity within the knot. It is reasonable to expect that these kinds of conflicting and shifting endeavors might become muffled or displaced as a complicated, long-term initiative with over 80 professionals begins its work.

Is this muffling and displacement, conflict and silencing a good thing? To briefly return to my research question about the affordances and constraints of research-practice partnerships, I argue that it is *necessary* to have these types of conflict to urge collective learning. Our research-practice partnership allowed an environment where we could continually negotiate these tensions in a trusting, long-term arrangement.

### **Cycle 3: Critical reflection & revision of division of labor**

Once again, like concentric spirals, when we moved forward within one expansive learning cycle, we enabled and constrained future expansive learning cycles around the PD initiative. In particular, this cycle of expansive learning involved the division of labor within our research-practice partnership. As a team, we organized around the duties of providing professional development. In this relationship, the district personnel took on the central task of managing the grant: hiring a project manager,

managing the budget, and setting the scope and focus of the professional learning. The research team acted as partners in that endeavor, adding capacity to collect data, support the professional learning program, and otherwise advise and learn from each other. Our focus on student talk afforded future cycles of learning, including one that heavily implicated our division of labor and called into question deeply held values such as mutuality and trust. I will give a brief account of how the questioning phase of the cycle of expansive learning occurred, and discuss it in terms of histories-in-person.

As a result of our commitment to supporting student talk as an equity strategy, we encountered a significant rupture in our collaboration. In our long-standing model of professional development, we hosted teachers for ten 7-hour days of learning each year. Each day featured three parts: presentations, looking at student work, and revisiting the curriculum that teachers had designed to make improvements. The division of labor for these release days typically developed with university partners collaborating to develop teacher learning objectives, the district staff designing an agenda, and the university staff developing materials to further the agenda. Our professional development agenda for December 2015 was slated to include a presentation on a biology sequence of curriculum, a workshop on talk activities to support ELL students, and time for teachers to work together on their curriculum units. As was typical in our partnership, the release day cycle was broken up into three separate teacher release days each focused on a different curricular area; for our cohort of 66 teachers, approximately twenty attended each of the release days that we hosted. The first of the three days focused on a biology unit.

However, as the morning of this professional learning day unfolded, the current and former district science program managers responded to a number of teacher questions

about the professional development initiative, including questions about an online platform for communication that was new to the district. These questions were logistical in nature and concerned the scope and sequence of the professional learning as well as project management strategies. Two hours of the morning time was meant to be spent, but it took forty minutes longer (fieldnote, 161201). This took us off of the allotted timeframe designated by the agreed-upon agenda. See Table 2 for a comparison of the planned and enacted agenda for the day.

*Table 2. PD Agenda as a Site of Rupture*

Planned Agenda	Enacted Agenda
8-9:30 Introductions, icebreaker, revisiting the vision of the PD	8:15 Introductions, Icebreaker, revisiting the vision of the PD
9:30 Web Platform introduction	10:00 Web Platform Introduction
10:00 Curriculum introduction	10:30 Curriculum introduction
11:00 Looking at Student Work	
12:00 Lunch	12:00 Lunch
12:45 Looking at Student Work	1:00 Looking at Student Work & Revising Instructional Plans
1:00 PD on Talk & Equity	
1:45 Revising Instructional Plans	
2:45 Closing, evaluation	2:45 Closing

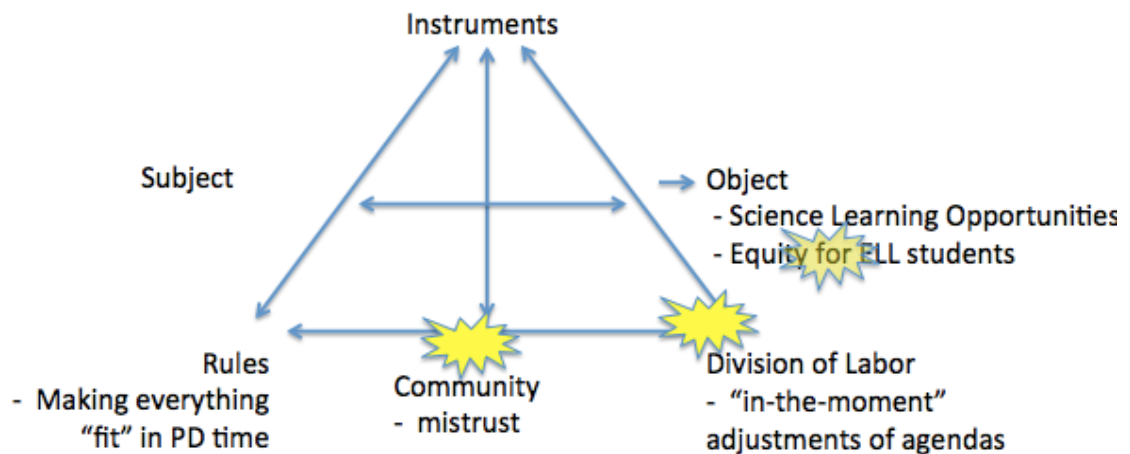
The second portion of the day was focused on analyzing a sample biology curriculum, and the district director facilitated this learning activity. Although others on the design team (including the grant writer/previous science program manager) had voiced concerns about spending too much time introducing a curriculum that teachers would not be using, the program manager proceeded to share the curriculum in a way she later called “frontloaded” (fieldnote 151222). This sharing took until lunch time, it meant that the teachers would only have about 20 minutes to work together at the end of the day if we preserved the ELLs and classroom talk session. Interestingly, the former program manager, the researchers, and the project manager all had separate conversations that we

documented about the session running long and our concerns that the afternoon equity session might need to be cut, but no one voiced this concern as the science program manager was introducing the curricular resources. It is also a prerogative of a district lead to manage an agenda to meet the needs of their teachers, as school districts in an RPP answer to the public, not the researchers. However, given the constraints on timing for the afternoon, we collectively decided to drop a scheduled session on talk activities and equity in order to give teachers more time to collaborate. Together, we agreed that the priority was to maximize the remaining time for lesson design, which necessitated dropping *something*, which was the equity-focused session for the day. After lunch, as teachers worked, we discussed whether we could put the talk activities session into the final portion of the day, but ultimately decided that we would let teachers continue working.

Because our professional learning opportunities were split into three separate days of teacher learning for which we maintained the same agenda, the talk activities session was dropped from the next two iterations of this 7-hour day as well. During one of these sessions, the former science manager mentioned that perhaps the talk activities could be placed in an online learning module using the district's shared learning management system, proposing yet another way forward for the equity initiative for ELLs, although that plan was not enacted. The three professional development days thus ended without any direct mention of English learner students or strategies to specifically support language development. This departure from the planned agenda is an example of what Engeström calls a *rupture*.

What does this rupture tell us? I have described this micro-moment at length in order to describe the ways in which equity-focused RPPs can be a site for contradictions. I now pause to illustrate this rupture within the activity system in Figure 6, placing markers to show where the activity system was experiencing contradiction. I will next illustrate how the contradiction resulted in knotworking.

*Figure 5. Rupture in Cycle Three*

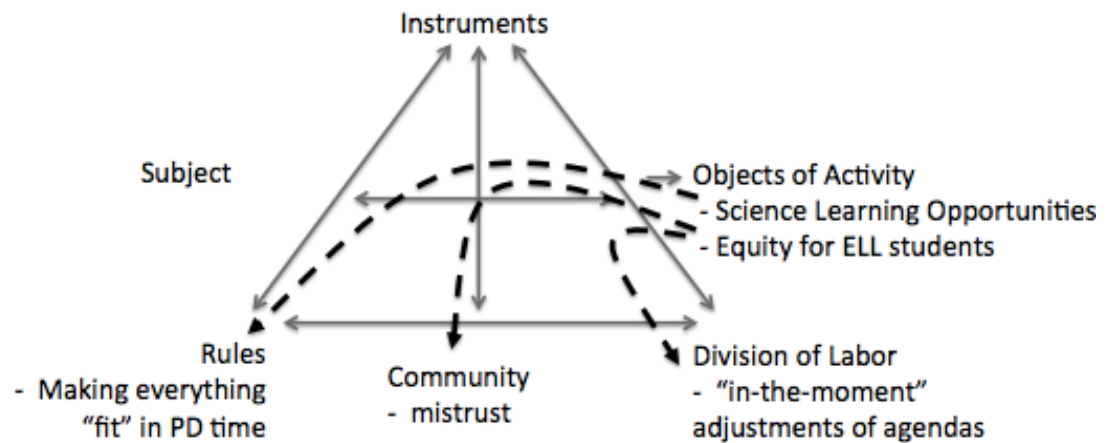


The ensuing activity around the "center" object of activity, the professional learning days, exemplified that "the center does not hold" in complex knotworking efforts. For example, in one of the debriefs that followed this rupture, the university team spent an hour capturing the details of what happened in the PD day and thinking critically about the role and place that our ELL strategy had come to assume in our professional development effort (fieldnote, 151207). As a university team engaged in collective sense-making about this rupture, the individuals involved made sense of the moment in line with their histories. The university PI, for example, had written extensively on equity-focused implementations of the new vision for science, and he organized a debrief meeting to discuss the rupture with the district partners in order to reconstruct the equity

initiative. Another member of our research group who was focused on teacher leadership emphasized the need to involve teachers more in the conversation about equity. Our response to this rupture—informed by *our histories* as advocates for nondominant students and their teachers—was to emphasize that the ELL effort should remain one of our shared goals. Moreover, we collectively voiced mistrust in our joint ability to keep the ELL effort central given the in-the-moment adjustments to the agenda that led to dropping the ELL session. This reflection started with ELLs as the object of activity and reflected back on our construction of community and the rules that allowed for the rupture.

As direct response to this rupture, the leadership team held a debrief meeting three weeks after the PD day in which they collectively agreed that in-the-moment decisions made by facilitators should not override key portions of the long-term strategies. This decision emphasized the need to adjust our division of labor. These debriefing conversations, held among heterogeneous groups of researchers and district leaders within the partnership, represented an effort to reflect and reorient (Figure 7) to the object of activity: the talk activities and supporting ELL students. In these meetings, leadership team members discussed ways to reorient to our object of activity, including less time "frontloading" (fieldnote 151222, 160727), or telling teachers information before they get to work, and more time spent directly on the equity initiative. In this way, reflection around the rupture supported us to reorient, adjust our strategy and move forward in the direction of our object of activity.

Figure 6. Revision via Reflection in the Activity System



This reflection, held immediately after the rupturing event, immediately facilitated design changes for the next professional learning days, scheduled for February. The first change was that university partners drafted the initial agenda for the next round of professional learning days. This allowed us (a) to keep the multiple objects of activity balanced and (b) to support our district partners by easing their workload.

This cycle was shaped by the ways in which the subjects were co-developed within the context of rupture and uncertainty; each of us elaborated on different concerns related to dropping the ELL-focused PD module. For example, Mark, the PI and former science program manager, posited that we could put the dropped session online so as to maintain the timeline of the PD, which he had written the grant to reflect (fieldnote 151202). His subject position as a district figure permitted him to reimagine the mode of PD delivery and bring that to bear on the local practice. In contrast, I was concerned that we were failing to attend adequately to ELL students' needs (fieldnote 151205); my subject position contained recent, local experiences where ELL students were experiencing classroom injustice. I even saw one Chinese-speaking student cry as a result

of exclusionary instruction. This engendered in me a renewed commitment to talk activities as a strategy to support teacher learning. A third perspective on the dropped session came from university researchers, who both interpreted the dropped session in terms of academic theory and specific moment-to-moment activity:

Me: Yeah like it's like how this (dropping the equity session) happened is on everybody [00:17:39.13]

Professor: From an actor network point of view no. (laugh) Like particular things get put in the thing (agenda) on some basis and particular people have control over some things, we have a collective responsibility to try to pull it off, but in the details there's always (...)

Postdoc: You (Kerri) didn't write the agenda and you didn't

Me: But I was sitting in a group

Postdoc: But you didn't actually get to type out what was on it and print that out and hand it to people

Me: Yeah (Recording transcript, 160712)

The researchers' histories allowed them a theory-based view of the rupture, allowing an interpretation of activity as a performance by individuals, and they brought this interpretation of actor-network theory and individual performance to the local practice of building an equity initiative. I posit that, combined, these *separate histories-in-person became woven together in the knot* as we jointly revised the object of activity.

Moving forward, the university contingent intentionally assumed the responsibility of drafting the agendas, making sure to allocate enough time for the equity initiative, although it was often still challenging to fit all of our goals into the allotted time given the ambitious goals of the project. This represented our modeling of the new object of activity via a shift in the division of labor.

After many clarifying conversations (spurred by the December rupture) about the central role of the ELL strategy, the program manager and I, with input from the rest of our collaborators, held several meetings and set a fifteen-month strategy for the equity

initiative in the district. To do this, we expanded our division of labor to include an ELL coach, the ELL district leader, and our two close collaborators in the district science program. This marked a shift in the ELL effort because it was the first time we had plotted a long-term plan, and with it, we acknowledged that we were no longer relying on "in-the-moment" decisions to produce coherent PD. We redistributed our work processes to build in redundancy with special attention to the equity initiative. This kind of revision of the divisions of labor was a result of our changing commitments and collective learning, and, I also argue, the enactment of local (contentious) practice as a result of our histories in person. Together, we collaborated over six weeks to synthesize a longer-term strategy for supporting ELLs beyond the talk activities and to include attention to the English Language Proficiency standards and a conversation analysis strategy that was part of the ELL/Migrant office's long-term strategy. Our shared vision for the ELL initiative, with perspectives is still, to the time of this writing, being enacted almost as envisioned. Thus, the disruption of dropping the ELL initiative due to in-the-moment decision-making, across six months' work of reflection and attention to the experiences of young people, became consolidated into a formal and accepted strategy that included varied expertise from several partners. Again, I argue that the specific configuration of a research-practice partnership afforded our continual reflection as well as the rebuilding of trust that was necessitated by this rupture.

Since the termination of formal data collection for this study, the partnership has continued the ELL equity initiative into a subsequent year. The district's own ELL staff have been involved presenting during PD and reinforcing the importance of student-to-student talk. Teachers have been asked to document moments of discursive engagement

in science practices with focal ELL case study students, and there are clearer indications that teachers see the scaffolding of talk activities as being more central to the equity initiative for ELL students. This increased clarity in our intentions from year one to year two may point to the kinds of timescales and commitments that are necessary to generate meaningful, equity focused change in large districts.

Looking at these three, spiraling cases of learning in the knots of partnership, it is evident that the contradictions became opportunities for expansive learning. This is quite fitting with the premises of cultural historical activity theory.

Table 3. *Expansive Learning Cycles*

	Cycle 1	Cycle 2	Cycle 3
<b>Questioning</b> (Need state)	We talk about postponing the ELL effort an entire year in an effort to focus on high-quality science teaching.	The ELL team critiques "Talk Science Primer" to "Academic Conversations"; say they prefer student-student talk over teacher-student talk.	PD presentations go long, leaving no time for equity-focused work with teachers during the second release day of the year.
Analysis (Double bind)	We leverage a focus on classroom discourse as a way to support ELLs and English-speaking students simultaneously.	We consolidate the ELL effort to include supports for student-student talk and remove the <i>Talk Science Primer</i> .	Reflections occur; researchers with researchers, district practitioners with each other.
Modeling the new solution	We agree to "integrate the possibilities" of ELL+talk moves in year one.	We build a matrix of ELL strategies corresponding to the science standards for teachers to use.	We revisit objects of activity to talk about the relative importance of an ELL strategy and balance of timing for agenda items. Together we agree that ELL will be on agenda for February.
Examining the model	The district leader acknowledges the "reframe" of the ELL effort.	We rework PD on talk moves in response to the needs of teachers.	We adapt our division of labor to allow university partners to write the initial PD agendas.
Implementing the new model (resistance)	Teachers are given professional learning time to learn about the ways ELLs should be supported.	We implement talk moves; it is received positively by teachers.	We continue to share agenda-writing responsibilities and negotiate time for ELL in all subsequent PD days.
Reflecting on the process (stabilization)	We support and observe signs of uptake of discourse into classroom practice.	We build the talk strategies flowchart and make it clickable in response to requests and need.	We write a long-term plan for the ELL effort for the next 18+ months, including topics and strategic threads for equity.
Consolidating and generalizing	We continue to allot time to the ELL+talk moves effort.	The Talk Moves Flowchart is still shared broadly.	The long-term plan continues to be implemented; university partners continue to write agendas

## Discussion and Implications

### Subject positions via histories

As I have illustrated with the above ethnographic cases, the subject positions taken up in each moment of contradiction and expansion were relatively complicated. At each moment of contradiction, the collaborators in this study did not expand the learning space from neutral, ahistorical places; instead we operated from our subject positions within the constraints of a large team effort with ambitious goals. Engeström acknowledges that *activity* must be understood in terms of its own historicity (Engeström, 2008, 2011), and that knotworking goes beyond "an additive sum of the separate perspectives of individuals or institutions contributing to it" (2008, p. 194). While I took the "knot" itself as a unit of analysis, this case of a research-practice partnership doing equity-focused work shows increased explanatory power of sociocultural/ethnographic analyses by accounting for the histories of persons within practice and activity. That is, this account would have felt incomplete without interpreting the knot as a construction in which the histories-in-person *mattered*.

This was especially true given the particularly political nature of the object. We explicitly focused our work "in the knot" around English learner students, who are frequently the object of systematic political oppression in US schools. Because US school policy often mandates that students are taught in only English, students' native languages and cultural resources are systematically marginalized in an effort to teach them English. English-only policies of mainstream instruction, which were in place in the Creston schools studied here, can threaten English learners' access to sense-making, complex

scientific ideas, and epistemic practices within the mainstream classrooms we studied (Valdés, 1998). Although we expressed a general concern for English learners and focus on English learners as a population to support in our work, I have found that our perspectives, responses to contradictions, and proposals for moving forward all seemed to be shaped by our relationships to the politic of English learner education. This is also related more generally to the struggle for more just systems of education, which seek to redistribute resources more equitably. As a collaboration of mostly monolingual, US-born adults, our histories related to issues facing English learner students were varied, but in each of the cases above, our varied histories and our relationships to the politic of English-only instruction helped, most conservatively, to account for social causality in this paper. For example, subjects who had histories of working with language-minoritized populations were able to deeply contribute to knotworking toward an ELL initiative, helping align the object (expansive cycle 1), develop tools (cycle 2), and reflect critically on our progress and division of labor (cycle 3).

Most radically, these histories in person constituted the very nature of our knotworking effort. Future studies in research-practice partnership should not minimize the histories of individual subjects in knotworking, and, to the degree possible, try to interpret the ways that their complex histories contribute to the sum total. Or, as Engeström says, to interpret how the knot is more than "an additive sum of the separate perspectives of individuals" (2008, p. 194). These efforts will support both theory development as well as the practical work in partnerships, so that collaborators can think about the ways that partners assume agency as a result of their histories. In this case, it was impossible to fully understand the activity of our equity initiative without both

interpreting the *activity system* as well as the *subjects* in shared practice. This approach to understanding the trajectories of individuals in partnerships may also benefit organizational theory, CHAT, and actor-network theory by offering a hybridized approach to analysis that better seeks to understand a knot as relationships of *individuals as historical persons*.

### **Ideologies and Axiologies in the Knot**

Second, the upward movement of our initiative traced the *values* and *beliefs* we held, and these became hybridized over time. As I have described, the gradual expansion of each object of activity "spiraled" away from the goals of any one individual. Just as a spiral tends to a center, our ELL intervention gradually tended to hybridize the values and beliefs of the multiple parties involved. Our research-practice partnership generated a knotworking environment in which continuing lines of work moved the subjects closer to a object, or "upward" towards axiological innovation (Bang et al., 2015).

If we think of a spiraled coil in three-dimensional space, the movement in the spiral is simultaneously upward but also tends toward the center, meaning that elements of all perspectives can be incorporated as the new object of activity appears. This movement upward was apparent in our design of the professional development as we incorporated the perspectives and histories of the subjects in our collaboration. These perspectives catalyzed movement toward transformative learning, which resulted in our equity initiative coming to be as it is: fairly successful, provisioned with tools and widespread support, and increasing in our attentiveness to the learning of historically nondominant youth. This is not an apolitical endeavor, and I argue that it is linked to a

shift in axiologies. The adults' relationships to power and language teaching are implicated in all three cases described in this study. In the first cycle I described, my ideologies of language teaching led me to advocate for dialogue-focused instruction. In the second cycle, the teachers' ideologies of equity for nondominant youth made it clear they didn't interpret discourse-focused activities as a language pedagogy. In the third cycle, intense reflection helped clarify our shared vision for language pedagogy. Despite seeming to be on very different ideological terrain, we did not pause to discuss what we *meant* by "equity" or how we felt that should be enacted with teachers or youth.

Yet, even though we didn't pause to discuss our understanding of equity until after this third cycle, the prevalent axiologies in the partnership seemed to shift over time. Multiple perspectives on language pedagogy were considered as we worked toward a unified strategy for English language teaching. The approaches to ELL instruction initially advocated by district-level collaborators included: accountable talk (Michaels, O'Connor, & Resnick, 2008), the Common Core State Standards for English Language Development (Officers, 2012), selecting vocabulary for direct teaching, and differentiating between Cummins' interpersonal language and academic language (Cummins, 2008) (Fieldnotes 160613, 160606). These approaches, while based in research, are very conservative in the ways they conceptualize youths' relationships to the dominant languages of English and science. Largely, they hold that there is a dominant language that youth *do not have* but one which they "need" to acquire. These approaches mirrored beliefs and values (e.g., axiologies) held by district practitioners and others in the partnership when we initially began our partnership endeavor; it was not initially

commonplace to discuss power-laden relationships among language and identity, but rather to emphasize science as a conduit for improved English.

Compared to these deficit-based approaches to language pedagogy, critical language awareness focuses on building youths' capacity with English (Pennycook, 2001; Siegel, 2006) but also to promote science identity development in relation to structures of power such as race and class (Barton, 1998; Barton et al., 2012). As I have described, the kinds of ways forward that were proposed during the first year were shaped by the histories of subjects in relation to the teaching of English learners. Over time, the ELL initiative developed out of a shared concern for equity held by researchers and practitioners. With this value at the center of our work, we began to build out a strategy to implement it. Our associated political and ideological orientations shifted over time in response to the object of activity: supporting teacher professional development. Although we began the ELL work from the conception that learners need to acquire “academic English,” we gradually grew to affirm that all learners have “intellectual treasures” (fieldnote, 160212) (Rosebery & Warren, 2008; e.g., Rosebery, Warren, & Tucker-Raymond, 2015). This is a fairly remarkable shift in axiology that each partner, with their histories and values, played a role in shifting. This transformation took years to accomplish among our partners, and it may take years more to see stronger uptake in teacher practice. No doubt it will require sustained commitments from central and local leadership and continual negotiation in the knots of activity. Further research should continue to study how these and more radical changes in K-12 science education might be possible with the purpose of supporting language-minoritized youth.

As a final point, I will state that research-practice partnerships may be aptly suited for the long-term, multi-faceted, justice-focused work that entails shifts in values and ideologies over time. In particular, it was the diversity of voices and perspectives that gave us needed opportunities for expansive cycles of learning. Future work should seek to further explore the ways that linguistically diverse youth can be better supported to engage with scientific language in ways that are critical, additive, and fully expressive of their broad repertoires of practice. Given tensions between prevailing "English-only" practice and a research body that advocates bilingual, "multi-voiced" learning spaces, research-practice partnerships may provide very fruitful bases for constructing new possibilities—rooted in justice-oriented axiologies—for English learners in US schools.

### Chapter 3

## **"What Great Ideas": Negotiated Positioning among Language-Minoritized Youth in Science Class**

### Abstract

This design-based research study explores how language-minoritized youth and their peers use discourse in science class to position themselves and each other relative to scientific sense-making. I examine three students' engagement across three designed discourse-based activities. Ultimately, I found that students encountered and renegotiated problematic positioning from their native-speaking peers, and that students were able to assert positions as scientists when provided the participation structures for doing so. This is a hopeful finding for science education because it illustrates the possibilities for empowering language-minoritized students to take up positions—and over the long term, identities—as science sense-makers in the third space of the classroom. I conclude with design principles that supported the three focal youth to successfully negotiate their participation.

### Research Problem

Although there are decades of empirically-based learning theory and mounting federal pressure for US classroom spaces to contain rich talk and sense-making around complex ideas (NGACBP & CCSSO, 2010; NGSS Lead States, 2013b), classrooms are not always spaces that allow students to develop rich ideas through talk. Frequently, schoolroom conversations rely on teachers' questions and the polite responses of students, with little or no acknowledgement of their peers' ideas (Forman & Ansell, 2002; Mehan, 1979). That is to say, even decades after the first research on dialogic classrooms, research has found that students and teachers retreat to the common classroom "script" of "I-ask, you-answer" instead of pursuing sense-making around pressing questions with each other in interaction (Gutiérrez, Rymes, & Larson, 1995). Of even more pressing concern in the current US context is that rich, rigorous, dialogue-focused teaching is even less common in schools with high numbers of historically nondominant groups (Ladson-Billings, 1995), where students are most likely to come from communities that do not speak mainstream English. I take as my unit of concern the experiences of these students, and for the remainder of this study refer to them as language-minoritized students<sup>3</sup> (Flores & Rosa, 2015) as I focus this study around their experiences in the science

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<sup>3</sup> Terms other than "language-minoritized" do not adequately capture the power-laden relationships of mainstream English to the diverse language repertoires of urban students.

classroom. Indeed, these youth can receive instruction that is repetitive, lacking in challenge, and from teachers who are apathetic or even hostile to immigrant youth (Suárez-Orozco & Suárez-Orozco, 2002).

One strategy that might support language-minoritized youth to engage with science ideas is through dialogue-focused pedagogies that prioritize sense-making. Dialogue-focused instruction is a well-documented and rich approach to support subject matter learning, including second language learning. Engaging language-minoritized students with dialogue provides learning opportunities through the mechanisms of linguistic input, linguistic output by the learners themselves (Swain, 2000), and authentic interactions that cause the learners to negotiate meaning with other speakers (D. Edwards & Mercer, 1987; Long, 1996). These hypotheses intersect with theories in science education around the linguistic and social practices of argumentation and explanation, and, especially salient here, the idea that learners become better at science by engaging in the social, linguistic, and materials *practices* used in science (Bell, 1997; Bell & Linn, 2000; Bell, Tzou, Bricker, & Baines, 2012). In short, the fields of second language acquisition and the learning sciences agree: language is learned when it is used in authentic practice. This study addresses how language-minoritized students engaged in these scientific practices, especially sense-making explanations. Further, I explore how a teacher-researcher collaboration supported language-minoritized students to engage in talk-based pedagogy.

Much of the existing research on classroom interaction, especially in STEM-related disciplines, has focused on the *nature* of youths' talk in relation to academic disciplines (Chi, Bassok, Lewis, Reiman, & Glaser, 1989; Chinn & Anderson, 1998;

Chinn, Buckland, & Samarapungavan, 2011; Elizabeth, Ross Anderson, Snow, & Selman, 2012), and the *instructional moves* that foster certain kinds of youth talk (Forman & Ansell, 2002; Lampert, Rittenhouse, & Crumbaugh, 1996; Michaels et al., 2008; Moschkovich, 2005). It is further understood that student-to-student collaborations *result* in dialogic learning that is complex and skillful (Handsfield & Crumpler, 2013), yet there continues to be a dearth of opportunities for students to learn with their peers in schools (Cazden, 2001; Nassaji & Wells, 2000). Power dynamics and peer positioning discourse are prevalent in and relevant to student-to-student sense-making interactions (Cornelius & Herrenkohl, 2004; White & Pea, 2011), yet no studies have examined the ways that language-minoritized youth are positioned by their peers in English-only science classrooms or what effect this discourse has on sense-making opportunities in science class. This study asks:

- How are language-minoritized youth positioned by peers in dialogic sense-making interactions in science class? How do they respond to this positioning?
- What designed features of science classrooms supported language-minoritized youth to take up positions as scientific sense-makers?

## Conceptual Framework

### Sense-Making Discourse in Science Class

Past work highlights the importance of providing opportunities for young people to engage in scientific *sense-making* (Bell & Linn, 2000; Berland & Reiser, 2009) as part of their science coursework, and particularly through peer-to-peer talk. Sense-making talk differs from traditional teacher-centered classroom discourse (Cazden, 2001; Mehan, 1979) in that it offers youth a low-stakes opportunity for youth to work through their ideas with their peers in ways that are scientifically authentic; that is, they are true to the practices of working scientists (e.g., Lemke, 1990). This practice may manifest as the design of logical arguments (Bell, 1997; e.g., Chin & Osborne, 2010), explanation of a phenomenon (e.g., Braaten & Windschitl, 2011), or “accountable” discourse that builds on science knowledge within the class community and adheres to disciplinary norms (Engle & Conant, 2002; Michaels et al., 2008). Furthermore, studies in educational linguistics have clarified the differences between open-ended and closed-ended questions (Mehan, 1979); closed-ended questions tend to curtail student responses, and open-ended ones can dramatically open up sense-making possibilities (Verplaetse, 1982).

Studies of youth sense-making in K-12 settings are also pragmatically necessary if youth are to succeed in meeting current standards; recent K-12 standards in the US call for students to actively use discourse to make sense of scientific phenomena (NGSS Lead States, 2013b). Lee, Quinn, and Valdés predicted that language minoritized students will need extensive practice with discourse and emphasized two needed pedagogical shifts:

“a shift away from both content-based language instruction and the sheltered model to a focus on language-in-use environments and (b) a shift away from

‘teaching’ discrete language skills to a focus on supporting language development by providing appropriate contexts and experiences. (...) In such classrooms, ELLs are not left to sink or swim. They are supported in using multiple resources and strategies for learning science and developing English.” (O. Lee et al., 2013, p. 222)

Despite this large-scale shift to more dialogic instruction, we know little about *how* these sense-making interactions occur among language-minoritized youth and how (or if) they support all youth to engage in science. Some studies have illuminated the problems that can arise in monolingual sense-making groups. For example, Barron (2000) found that group problem-solving was better supported in a group that made use of joint attention, mutuality, and shared goals than a group where proposals were rejected or attention was not shared. Other studies have found that scientific dialogue can be derailed by issues of competition (Barron, 2003) and power, ownership of ideas, and partisanship (Cornelius & Herrenkohl, 2004). Immigrant students can find peer-centered or “democratic” classrooms a cultural shock after experiencing teacher-centered, memorization-focused classrooms in their home countries (Suárez-Orozco & Suárez-Orozco, 2002), and my study addresses the experiences of these youth in particular. Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes (2001) found that their bilingual science students displayed rich sense-making repertoires when working as a whole class to dialogically construct knowledge. We do not know, however, *how* smaller sense-making groups do their work when participants do not speak the same native languages or when they operate in English-only science classrooms.

### **Positions and Participation**

In order to study how small groups of bilingual students do their work in a classroom that emphasizes dialogic sense-making, I leverage the sociocultural theories of positioning and participation structures as analytical tools and theoretical drivers of this study. I elaborate these concepts here.

**Participation and school life.** To understand social life in school groups, I leverage participation structures (Erickson, 1982) to interpret the ways youth make sense of science as well as their social existence. Specifically, Erickson proposes that there are two elements to understanding students' participation in the academic task and also in the social structures. Erickson explains "participation structures" as the "successful participation in classroom events requires that students accurately perceive" the academic task structure - the way the content is sequenced in the lesson or the task and its sequential steps *and* the social participation structure - the allocation of interactional rights and obligations of participants that shape the discourse. Erickson also says that there are limits to how one can constrain the features of a participation structure, especially in the way of the topic (broad/narrow) and in the way of participation (constrained or free-flowing). These concepts helped me understand the interactional possibilities for students as they work together to "do school."

**Positioning.** As the youth work together, they also collaboratively create *themselves* in relation to each other, to science, and to the larger society via discursive positioning (Davies & Harré, 1990). As Davies & Harré (1990) explain, "*who one is* is always an open question with a shifting answer depending upon the positions made available within one's own and others discursive practices" (emphasis mine, p.46). This

is a complex process which involves perceptions of self, incorporating (or rejecting) the discursive categorization provided by others, aligning with (or against) social categories, and acknowledging the discourse that ties these categories into the social world. When attempting to understand the work of language-minoritized students in science class, positioning then allows us to examine how youth learn to accept and reject positions like: “good student,” “bad student,” “English speaker,” “fun,” or “good at science.”

Second, positioning theory can extend our understanding of conflict (Moghaddam, Harré, & Lee, 2008), such as that which might occur in episodes of everyday classroom life. In examining these moments of conflict, it is important to consider multiple elements of participants’ experience. These include storylines, the illocutionary force of language, patterns of positions, and the use of physical space and gesture. First, storylines are the lived experiences of each participant as they bring them from the moments preceding the interaction. Second, the illocutionary force—or the social meaning—of the language used has social significance that should be interpreted based on local context; in classroom life, a raised hand can have illocutionary force of “I have an answer” when directed at a teacher, but a similar gesture to a peer might have meant “talk to the hand” when shown to a peer. Third, existing patterns of positions in the space should be taken into consideration, necessitating a longer-term understanding of how interactants tend to behave. Fourth, Moghaddam et al. describe the importance of accounting for the physical space that the participants work in, including materials and gestures (Moghaddam et al., 2008). When studying groups of students who do not share a native language, gesture and positioning of one’s body within the space become even more salient for understanding the interaction’s perlocutionary force, the resulting

positions or conflict, and the human learning that results. All of these features of an environment are elements for analysis in the present study.

It is worth noting that studies of epistemics and philosophy have also considered ways to interpret how people interact in ways that are more or less unjust, most notably Fricker's (2009) concept of epistemic injustice in which a conversant is "wronged" either by a) a removal of their credibility in the conversation or b) an assumption that a conversant doesn't know something that's being discussed. While this may be a useful frame for interpreting *that* injustices exist in a conversation, I am more interested in the joint *construction* of sense-making conversations and *how* youth work to continually produce themselves; thus I find positioning and participation theories more helpful.

## **Data and Methods**

### **Context: Design-Based Implementation Research in an Urban School District**

I selected my data from a corpus developed during a large-scale, science education improvement project that occurred during the 2015-16 school year in an urban district in the Pacific Northwest. It was from the fourth year of the research-practice partnership which has continued into a fifth. As a researcher in collaboration with science teachers, I was directly involved in the design, interpretation, and curriculum of classroom life, and my role kept me actively involved in the happenings of the classroom and only secondarily attentive to the work behind the camera. This study examines students' interactions and learning within a large-scale design-based implementation research effort (Barry J. Fishman et al., 2013) that has spent the past three years trying to accomplish an instructional shift focusing on implementing disciplinary practices like

argumentation, explanation, and modeling in science classes across a large urban district. The project is large and complex, as our research team engages in collaborative professional development design as well as classroom-level "deep dives" across two districts. The classroom engagement strategy was linked to the purposes of the broader district-level professional development initiative—where I also engaged in the design, delivery, and reflection on professional learning experiences for about 75 middle school teachers. Across multiple years of the project, about 225 hours of student interaction during class time was captured in all.

The data for this study come from one middle school classroom where I studied three language-minoritized students across their participation in three activities that the teacher and I designed together. The teacher and I shared a priority of supporting collaborative sense-making practices within diverse groups of students. We were both interested in how students' talk was proceeding and how it served to support more equitable access to learning scientific practices, such as explanation. This study thus arose at the nexus of the teachers' desires, the gaps in literature, and my positionality as a former language teacher, an advocate for English learner students, and as a developing researcher.

The style of this study arose as a research effort to understand the on-the-ground teacher experiences as they sought to implement what they were learning in the large-scale professional development. This "deep dive" provided the professional learning coordinators with important information about both student learning and teacher learning. This allowed us to understand the "particular" features of our context and more nimbly respond to the problems of practice that arose through cycles of iteration.

### Analysis

To better understand how language-minoritized youth interacted with their peers in the context of large-scale urban instructional reform, I leveraged interaction analysis (Jordan & Henderson, 1995) to carefully view and re-view the context of the youths' interactions and the artifacts of interaction that support, mediate, and constrain the available identities for the student. In this way, I treated as salient the "regularities in the ways in which participants utilize the resources of the complex social and material world" (p.41). I chose three case study students with different backgrounds in order to understand differences among language-minoritized students' participation *within* the same classroom. I also chose separate moments of interaction to analyze wherein the teacher and I had either *intentionally structured* or *not intentionally structured* the discourse event so that comparative analysis might illuminate differences in students' participation.

For the present study, I first content logged and transcribed several interactional sequences according to Ochs' conventions (2006), especially the insistence on transcribing nonverbal behavior since my focal students often used gestures to index their meanings. After transcription, I generated data visualizations of student interaction focusing on their spatial orientation to the tools in the space, allowing me to see what kinds of verbal cues prompted students to engage in shifts in interaction using their bodies, and vice versa (Kendon, 1990; Leander, 2002; Leander & Rowe, 2006). This also allowed me to theoretically adhere to tenets of positioning within social interaction which emphasize understanding learners in relation to space and materials (Moghaddam et al., 2008). I also brought my data to four sections of an interaction analysis lab (February,

May, June, and July 2016) to engage in collaborative analysis of the video data (Jordan & Henderson, 1995). This process confirmed lines of analysis and generated new directions for my thinking. Following these sessions, I adjusted my transcriptions to better understand shifts in student participation. I also expanded my analyses to include qualitative coding of transcripts for positioning discourse and participant frameworks per my conceptual framework to better understand the types of epistemic "sensibilities" students enact in classroom conversation. From this process, I generated narrative/analytical memos and hierarchical claim-building to develop my findings (Erickson, 1986).

### **Cases of Learner Interaction**

All of the following case study students were observed over the course of the 2015-16 school year. They were all in the same section of sixth-grade science, and their particular section, as the teacher observed, was "my most difficult to teach" because of the range of student backgrounds in the class. I collaborated with the teacher throughout the school year to understand and design for student-to-student talk. Once this classroom was selected, all of the above listed peer discourse events were content logged more closely and analyzed for 1) talk and gesture related to positioning and discursive sense-making, 2) how youth constructed the interaction order physically, including F-formation and O-space, and 3) a general characterization of the activity. I selected interactional sequences by the following criteria:

- Featured students from linguistically-minoritized backgrounds (e.g., non-native speakers of English) in sense-making activity with their peers.

- Contained varied participation structures: broad/narrow topics and loose/tight constraints on participation (Erickson, 1982).
- Contained a participant structure that the researcher and teacher intentionally codesigned for peer-to-peer sense-making (though with varying degrees of structure to the participation).
- Allowed for rigorous analysis of the artifacts in the interactional sequence (e.g., photographs or video had been collected for all of the objects or referents students used).

Given these criteria, I selected six sequences of student-to-student talk resulting from the collaboratively designed by the researcher and the classroom teacher with the specific purpose of supporting more equitable interactions. Because I wanted to get a broader look at the ways that language-minoritized students managed their interactions with their peers and science, I examined three focal students' participation: Raqi, Ziling, and Pilar. I turn to their cases now.

*Table 4. Summary of Analyzed Episodes*

<b>Activities</b>	<b>Explain Sand Formation</b>	<b>Build a Density Column</b>	<b>Sharing Models</b>	<b>Earthquakes Report</b>
<b>Date</b>	Nov 4	Jan 21	Mar 2	Mar 30
<b>Unit of Instruction</b>	Geology	Ocean Currents	Ocean Currents	Earthquakes
<b>Participation Structure</b>	Idea Coaching	None	Gallery Walk	Joint writing at the computer
<b>Students</b>				
<b>Raqi*</b>	x**		x**	x**
<b>Pilar*</b>		x**		
<b>Ziling*</b>		x**	x**	
<b>Fiona</b>		x	x	x
<b>Jacob</b>		x	x	
<b>Barry*</b>	x			
* denotes ELL status				
** denotes part of case study in this paper				

### **Findings: Raqi**

Raqi was a newly-arrived sixth grader from Argentina when I met him in Ms. Wirk's class in October. He was lanky and light-skinned, and Ms. Wirk told me rather proudly that, "I'm his person," indicating that he stopped by her classroom several times a day to say hello, and that he felt very comfortable in her class. Raqi was also admitted to the newcomer program in the ELL class, and I observed him three times in his ELL class. Raqi was reliably gregarious and warm throughout the time of the study. Raqi was identified by his ELL and science teachers as a struggling student. At winter break, Raqi was removed from science class to be placed in a math remediation course, and Ms. Wirk had to convince the counseling department to let him stay in science for the remainder of the year. I selected him for closer study because he had the least experience with English, which seemed more likely to limit his participation in peer groups. I also selected him

because of his popularity with his peers; I wondered if his popularity would translate to more positive positions made available by his peers.

**“The waves, they go and they go and they go”**

In early November, the teacher and I noticed that all of her second-period students seemed to fall into a common discourse pattern when asked to share their ideas, in which each “turn and talk” interaction would begin with a student stating an idea, the next student stating an idea unrelated (or un-chained) to the previous idea, and so on until everyone had taken one interactional turn. This interaction type occurred without much opportunity to further students’ sense-making or scientific thinking. This represented a “tossing about” of ideas *rather than* the deeply scientific practices of argumentation and explanation that we were working toward (National Research Council, 2012). To mitigate this emergent, local problem of practice, we asked students to take turns *coaching* each other and the teacher and I demonstrated how to do this at front of the room one day in early November. Further, we provided sentence starters to support the coaches in asking good questions, such as “Could you say more about \_\_\_?” In short, we provided and modeled a participant structure that intended to engage students in more coordinated sense-making talk (Erickson, 1982) that valued emerging ideas about the science phenomenon of weathering. Specifically, student were asked to discuss how they think sand formed at a beach.

In this interaction, Raqi sat next to Barry, another immigrant student who was also designated as an English language learner (although Barry had already spent a few years in English-only programs within the Creston school district). Barry coached Raqi

first, and I conducted interaction analysis on their discussion. Raqi began by explaining that he knew that a vial of sand originated from a beach because he had seen sand at beaches "when I go with my mom and my dad" (Transcript, 161104, line 31). At this moment in the interaction, Barry seems to lose interest, and pausing in his coaching of Raqi, he turns to Raqi and dares him to eat some of the sand they are examining. Raqi obliges, remarking matter-of-factly, "It tastes like salt water," as Barry listens in rapt attention. As Raqi explains his understanding of the sand, Barry also puts sand in his mouth, making a spitting and disgusted noise. However, in this moment, Raqi merely smiles and continued on with his explanation, becoming much more mechanistic in his reasoning, explaining *how sand forms*:

Raqi: That rocks ((claps hands together)) push like uh (.) a bomb ((makes smash movement with hands)) and it // ((Barry takes piece of sand, puts it in his mouth, and makes a disgusted face))

Barry: //Ew.] ((uses sleeve to try to get it out of his mouth))

Raqi: //((Smiles at this but still intently explaining)) they (.) crush] and they make little pieces and the ocean go ((wide sweeping gesture with left arm)) like with the waves and they go and they go and they go (151104, transcript)

Raqi uses his arms in this interaction to make large sweeping motions to demonstrate his understanding of "the waves and they go and they go" during the weathering process. Given that the youth have differing experience with English, these gestures seem to be providing Raqi a way to communicate the scale of the wave movement and its potential force for crushing objects. In this way, *both* Raqi's personal experience with sand at the beach *and* his scientific explanation of the movement of waves are brought to bear in the interaction, merging Raqi's everyday knowledge with the more "scientific" understandings he is gaining from science class. However, even in

this peer-to-peer interaction, Raqi's personal sense-making of the geology of sand at the beach is subsumed beneath Barry's positioning of Raqi in the following dare:

- 1 Raqi: I see these ones in the beach when I go with my mom and my dad so I see them and I think they're from the beach and ((puts down loupe and turns toward Barry, begins dumping the sand onto the lab table))
- 2 Barry: So yeah but how do you think the sand got here
- 3 Raqi: Got where?
- 4 Barry: Got to the beach?
- 5 [00:26:29.07]
- 6 ((Raqi looks at the sand on the table, wafts the smell of it to his nose and breathes deeply.))
- 7 Barry: Lick it. ((Raqi places his tongue on the table.))

As the youth very skillfully make sense of the social and academic planes of the classroom (Erickson, 1982), Raqi is dared by Barry to break classroom rules about eating science materials. This is a moment of social positioning in which Barry positions Raqi *outside* scientific sense-making while inviting him *into* a social arrangement; Barry does not seem to truly listen to or respond to what Raqi has to say about sand. We cannot know if this is because he chooses not to or rather because he is having difficulty keeping up with Raqi's earnest and speedy explanation, but nevertheless Barry uses his turn at "coaching" to engage Raqi as in a rule-breaking dare, not to engage Raqi in sense-making.

Yet, Raqi responds to this daredevil positioning sure-heartedly, missing hardly a beat in his explanation of how sand washes up on the shore. He smiles in acknowledgment as Barry also tastes the sand, but moves on with wide, full gestures, as if to say, "My idea counts and I'm going to tell it to you." In this way, Raqi responds to Barry's positioning moves by taking up physical space through a wide gesture; he occupies the space as a place for him to explain his ideas. Raqi is able to use the

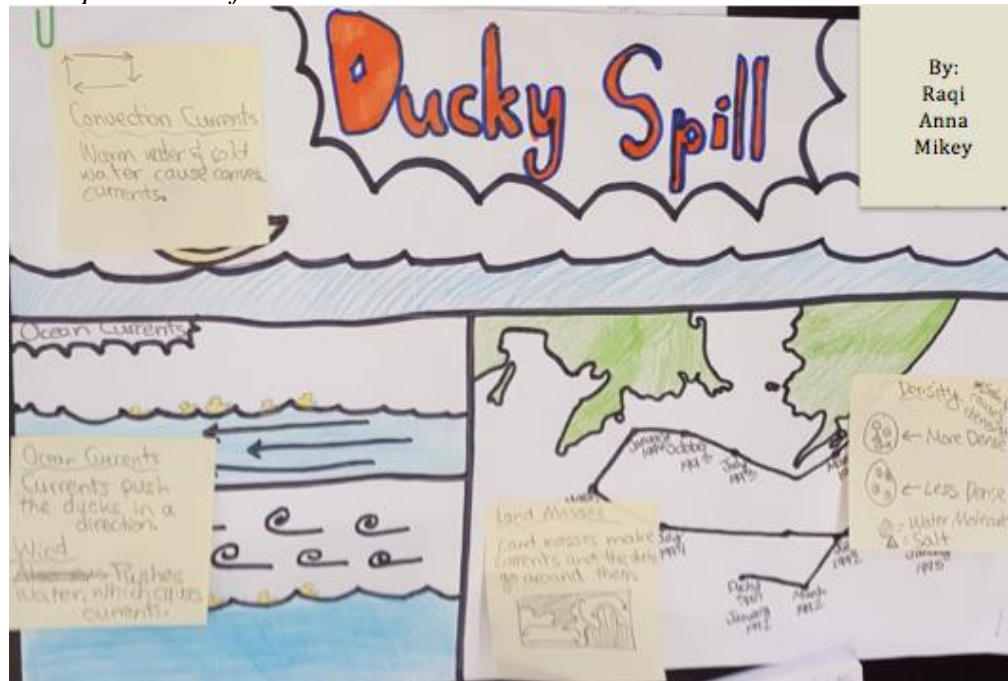
participation structure of idea coaching as a way to counter unjust positioning from his peer. In this way, the classroom environment seems to have provided Raqi a sufficient participation structure to counter unfair positioning, and the structure of idea coaching offers him an opportunity to negotiate his position as a capable sense-maker, even though his peer attempts to engage him in a different social activity.

**"It's gonna be more uh, more uh DENser"**

Raqi similarly advocated for a position as a sense-maker in response to his peers several months later in March, when the teacher and I designed an activity whereby one student would "stay" at each table to explain their groups' conceptual model of ocean currents on a poster. In this activity, Ms. Wirk directly positioned students as *listeners* and *explainers*, saying

“So, what similarities do you see like what things do most people have and what do you wish you had included? What, what GREAT IDEA does somebody else have that you think you wanna steal. Okay those are your thinking questions. Got it?” [Transcription 150302, 00:20:07.13]

Figure 7. Raqi's Model of Currents



For this activity, Raqi stayed at his lab table to explain his group's poster. Over the next 25 minutes, he shared his poster with 22 of his classmates who came around three at a time, and he explained his group's "great ideas." The transcript of the students' interaction is in Table 6.

*Table 5. Transcript: Raqi & The Ducky Model*

Ziling: ((arrives at table with Raqi)) What did you add?  
 Raqi: Those four thingies ((points at four post-it notes on the poster, the "changes" to their model.))  
 Ziling: An: did you remove anything?  
 Raqi: Your fa:ce! ((Raqi offers Ziling a huge smile. Jacob joins table. Raqi gestures toward Ziling in amends-making.)) Just kidding. Uh, we...  
 Jacob: You removed the DUckies  
 Raqi: Yeah yeah the ducky  
 Jacob: an:d are those decorations?  
 Ziling: Why did you add those things?  
 Raqi: So here is Antarctica so (gestures at landmass) it's gonna be more uh, more uh DENser, so, um, and landmasses cause the one the like to get IN (?) the duckies so actually the landmasses PUSH the duckies aWAY from THEM. Uh. (Fiona is making strong eye contact at this point.)  
 Fiona: ((Reaches across table to share sticker with Raqi. The 3 visitors are all writing in their notebooks.) Uh you can have this I don't want it.  
 Raqi: Oh yay a sticker  
 Jacob: I wannit I wannit I wannit.  
 Raqi: Ok NO you can't have it. I told you if you could give me your Rubik's cube [00:35:08.13] for a while. And you said NO OHHH (puts head in hands and pretends to cry) just kidding okay //  
 Jacob: //cuz] you MESSed it UP so // I  
 Fiona: //What didjoo]  
 Raqi: // I just wanted to build with it  
 Fiona:// What did you CHANGE about it?  
 Jacob: //How could you BUILD with it?]  
 Fiona: What did you CHANGE about it? (Ziling response to her questino by pointing to 1, 2, 3, four stickies with his finger.)  
 Raqi: ((touches face/rubs forehead)) What?  
 ((Jacob is playing with a Rubik's cube.))  
 Raqi: For the first sticky notes.  
 Fiona: (inaudible) ((writes))  
 Raqi: Like density we changed to um, ((reaches to sticky note)) land masses and we changed convection currents.  
 Fiona: What did you remove?  
 Raqi: Uh ((flips postit note on top of ducky he removed;)) the ducky.  
 Fiona: (h) (h)  
 ((Raqi smiles))  
 Raqi: ((turns head to Jacob)) "You want this?"  
 Ziling: ((speaking to back of Raqi's head)) Why why you remove the ducky? ((waits for response))  
 Jacob: ((Looking down at Rubik's cube))

Ziling & Fiona: ((Working in notebooks))  
 Ziling: (hh) Okay.

Raqi: Here - I'll put it in better face. ((puts sticker on duck's "face")) ((hh)) Better.

Ziling: You adding those because ((points to both)) is helpful for why ducky move?  
 Raqi: Yeah ((. . .))  
 ((Raqi turns his head to look at Jacob's Rubik's cube.))  
 Jacob: ((offers Rubik's cube)) Here. ((It's almost solved.))  
 Raqi: ((takes it)) Yeah  
 Jacob: Can I have the sticker?  
 Raqi: ((Shows the sticker on the poster; he had put it on the ducky's face in their model.))  
 Jacob: I don't want it now. No you keep it. ((Places hand on post-it to keep sticker on the poster.))  
 Raqi: Why?  
 Jacob: It's too late.  
 Ziling: You remove the ducky because is ugly?  
 Raqi: Yaay I got a free sticker ((gestures toward poster.))

((Teacher stops by briefly.))

Ziling: ((whispers as he records)) Is ugly. ((Ziling points his pencil eraser at a couple of parts of the poster. When he flips a postit note up, Raqi uses his hands to swat at and "shoo" the pencil away.))  
 Raqi: You wanna stEAL something? You needa pay money.  
 Fiona: You coulda added this. ((Unsure to what she's referring))  
 Ziling: Why you don't change the how it// look]

Raqi: //because it] convection currents like have HERE  
 Ziling: I think the ocean current just not go like this but  
 Raqi: No no they go some one di = way in the so ((points at poster)) HERE it went like in one direction so  
 Jacob: Don't say One Direction  
 Raqi: Yeah one direction  
 Ziling: //so the wind go one direction]  
 Raqi: //Yeah!] So the wind it pushes currents pushes the water and make currents ((gesturing with hand)) and it make it sometimes sometimes it makes cold water so it's gonna be denser. and the ducky move and passed. and ((.) keep going straight and they ended up there ((. . . . .))

Raqi: Poor duckies.  
 Ziling: (((Points to postit note, seems to be leaning in to inspect it. ))) What's the difference between a convection current and a // ocean current?  
 Raqi: //Because convection] it's started like uh going like uh ((gestures to poster)) THAT and it started going in like a ((gestures circle on poster)) circle.

((Teacher calls class together, ending the small-group interaction.))

Interaction analysis of one such explanation showed that, although other students invited him to engage with them in ways not related to the science sense-making talk, Raqi continued to advance his "great ideas" about science, even when his peers brought out stickers and a Rubik's cube as possible artifacts to engage with. In fact, he gave his strongest explanation when a peer offered an unexpected critique of their poster. Ziling challenged Raqi's drawing of currents, and Raqi responds to Ziling:

Raqi: So here is Antarctica so ((gestures at land mass on poster)) it's gonna be more uh, more uh DENser, so, um, and landmasses cause the one the like to get IN ( . . ) the duckies so actually the landmasses PUSH the duckies aWAY from THEM. Uh." (Transcript 160302).

In this explanation, Raqi again recruits his body, the drawings in front of him, and his position as a knower to convey his ideas to his peers despite repeatedly being encouraged away from the science sense-making activity; they recruit his interest in stickers and puzzles, and not his scientific thinking. Given that the youth only have a few minutes to ask questions and record notes about Raqi's poster, I would expect the group to stay focused on making sense of the poster, but the visiting students continue to position Raqi in relation to Rubik's cubes and stickers rather than the science of ocean currents.

Yet, Raqi again counters this positioning by forging ahead with his explanation, repeatedly turning his body away from social bids, tolerating a few lines of social interaction before returning his attention—both verbal and gestural—to the task of explaining his model.

**"I kind of TOO!"**

Finally, in a third episode, Raqi is working one-on-one at a computer with a native English speaking peer, and they are researching and writing a joint explanation of the geology of Turkey in order to inform an engineering design project. During this episode, Raqi and Fiona (a white, native English-speaking female) have been assigned to research the geography of Turkey as part of a group project in seismology. The task involves intensive reading and writing at the computer. In this interaction, the two students are continuing to read online and type responses to questions about Turkish landforms. What is notable in this interaction is that the two students must share one desktop computer, and they are supposed to complete the activity during this class period. Raqi's English-speaking partner, Fiona, chastises him several times for his behavior, including incorrect pronunciation, unhelpfulness, and wasting time such as in the transcribed micro-interactions below.

[04:48:08] Raqi: ((reading aloud)) Question. What is the hey-o-graphy ((uses Spanish pronunciation))  
Fiona: ((drops tone, corrects pronunciation)) Gee-OG-raphy  
Raqi: JEEography of the area and how will it affect our building project.

Later Raqi is rereading what the pair has written and reaches to delete something from their written response.

[00:09:47.15]  
((Raqi deletes something from the word processor screen))  
Fiona: What the heck - we needed that!  
Raqi: No we DIDn't ((Fiona searches computer screen))

In a third episode, Raqi wants to edit what they have written on the screen and he is looking for a way to delete something else. Fiona interprets his actions as unhelpful,

and the two have an open disagreement that results in Fiona positioning Raqi as actively wanting to fail the project:

[00:10:09.06]

Raqi: I needa erase it howdya erase it

Fiona: I KIND OF want to get a good grade on this

Raqi: I kind of too!

Fiona: No you don't.

Raqi: Yeah I do but I don't know how to take this out

Fiona: Well if you give me the MOUSE. ((takes mouse)) ((Raqi leans over Laurel's laptop to see what she is doing.))

Raqi responds to these moments of peer criticism in various manners. In the first example, he quickly adopts Fiona's correction of his English pronunciation, moving on to read the question aloud as if to remember where to start their work for the day. In the second interaction highlighted here, he defends his choice to delete something from their paragraph, even when Fiona shows frustration ("What the heck?!"). Raqi doesn't really justify his choice to make the deletion by explaining his thinking, but rather he simply says, forcefully, "NO we DIDn't."

In the third interaction, he is accused of not caring about his grade by Fiona, although triangulating data suggest Raqi did care about his grade in science, and that he even came to class before and after school to work with Ms. Wirk to show he had met content standards on exam questions (fieldnotes, 160620). Yet in this interaction with Fiona, he gives up, breaks the expected participation structure and leaves the table altogether to bat around a beach ball, saying, "You don't NEED me" [23:21.16]. In this example, the communication and interactional space has marginalized him quite definitively, preventing him from sharing any of his thinking or language, and shutting him out of scientific sense-making opportunities altogether. This is problematic because

the goal of the activity is specifically designed to support his sense-making. The participation structure of “work together on a shared computer” thus becomes a site for social negotiation and problematic peer positioning, where Fiona states Raqi’s incompetence.

Across these three episodes, I argue that Raqi was regularly positioned *outside* scientific sense-making in peer to peer interactions. In episodes one and two, Raqi’s peers did not engage his *ideas* but rather his social participation, and in episode three his partner seems to think he is wholly incompetent as a scientist, student, and language user. However, in the first two episodes, certain aspects of the classroom environment afforded Raqi a space to reframe and effectively renegotiate this positioning by recruiting all of his resources in support of his scientific ideas. In the third episode, we see how Fiona and Raqi are limited by the interactants of the space: they are sharing one computer, one assignment, and one joint grade on the project. Moreover, there had been no provision by the teacher for respecting each other’s ideas or contributions, and this in particular seems to constrain Raqi’s participation and eventually, his positioning *out of* the task and the interaction.

### **Discussion: Raqi**

Taken as a whole, these three sequences offer evidence that Raqi is able to make his sense-making a priority within scientific interactions. Moreover, they serve as evidence that certain environmental provisions, such as time, space, and a sense of respecting ideas may be important design principles. Raqi’s case advances our understanding of youth sense-making by giving us a glimpse into the micro-interactional

work that constitutes learning science as a language-minoritized, yet popular, student. In two of the interactions, peers offer Raqi opportunities to take up positions in the social participant structures of the classroom—playing with a Rubik’s cube and eating sand. Cornelius & Herrenkohl (2004) have pointed to the ways that power affects students’ interactions, pointing to the ways that the social influence of certain students can affect other students’ relationship with the course content. Raqi’s case offers more evidence that peer interactions can support and constrain sense-making opportunities for language-minoritized youth through positioning moves. In these three examples, we also see that Raqi responds to this positioning in an agentic manner in these three cases; twice he argues for his own participation as a scientist by asserting his ideas, and a third time he leaves a conversation in which his partner has declared him unmotivated and unfit to work with. In this way, the youth actively constructed a “third space” among themselves in ways that transcended adults’ plan for the lesson (Gutiérrez et al., 1995). The students built meaning and positions for themselves in ways that were valuable to them in relation to the subject matter. However, in the process of doing so, the native English speakers narrowed Raqi’s opportunities to engage in sense-making talk by encouraging him to instead engage in social talk or even to tell him he doesn’t care about his grade. In all, Raqi’s case allows us to better understand the ways that language-minoritized youth a) *bring each other into* or push them *out of* scientific sense-making dialogue and b) to negotiate positions as scientific sense-makers despite being positioned out of it by others. Raqi allows us a glimpse into the everyday interactions that comprise the learning experiences of youth as they negotiate their participation in small groups in school.

### **Findings: Ziling**

I continue my analysis of participant frameworks and student sense-making with a second focal case: Ziling. Ziling arrived in September for a 9-month stay in the U.S., and he was entered into the beginner level of the school's ELL program. However, his teachers soon found out that he had not only had rigorous science coursework in his home in Taiwan, but that he had also studied English previously. Although he did not write like a native speaker, he was able to convey thoughts quickly in writing and speaking, and had a great deal of background knowledge about science content. I selected Ziling because he had a non-Western background, he was also a newcomer student (and his language proficiency was likely to increase over the school year), and he seemed to take on a different attitude about school related to Raqi. Whereas Raqi embraced the social elements of school life, Ziling seemed to orient to the academic work of school. I wondered how these differences would afford similar or differing participation in the science sense-making via the positioning of their peers. Here I will describe how the classroom environment seemed to support his meaningful participation in sense-making discourse.

#### **“WHY YOU REMOVE THE DUCKY?”: Reorienting others to sense-making**

First I examine Ziling's participation in the "three-stray, one-stay" sequence described above, where both Ziling and Raqi participate. Ziling is one of the students who "stray" from his own table to visit Raqi's lab station and review his drawn model of how plastic bath toys traveled on the ocean currents. Ziling's two table partners, Fiona and Jacob, join him in this interaction with Raqi. The three “stray-ers” have been

assigned to "steal" the good ideas (that is, listen carefully and write them down) from Raqi's poster, but as we already know from Raqi's case, both Fiona and Jacob (native English speakers) also bid for Raqi to engage in non-science social banter around stickers and a Rubik's Cube. In addition, the teacher and I incentivized Ziling and the "straying" students to "ask good questions" by offering stickers when we heard students asking questions to push the explainer's thinking. Ziling, in the four-minute interaction with the three other students, takes this challenge to heart. He asks exactly the questions that the teacher has assigned, writing the answers down in his notebook. Yet he doesn't stop there. In total, Ziling makes the following statements over the course of the interaction (Table 6):

*Table 6. Utterances from Ziling*

<b>Line</b>	<b>Utterance ((activity))</b>	<b>Type of utterance</b>
2	What did you add?	Question required by teacher
4	An: did you remove anything?	Question required by teacher
10	Why did you add those things?	Question required by teacher
28	Why why you remove the ducky?	Question required by teacher
29	Why you remove the ducky? WHY YOU REMOVE THE DUCKY? ((Pokes Raqi with pencil eraser))	Question required by teacher
31	Okay.	Affirmation of understanding
33	You adding those because ((points to both)) is helpful for why ducky move?	Probing question
43	You remove the ducky because is ugly? ((Speaks to self as he writes)) Is. Ugly.	Clarifying question
49	Why you don't change the how it// look]	Probing question
51	I think the ocean current just not go like this but	Comment

53	//so the wind go one direction] ((Points to postit note, seems to be leaning in to inspect it.))	Comment
56	Ziling: What's the difference between a convection current and a // ocean current?]	Probing question

In this table, a pattern for Ziling's engagement emerges. He spends his first five turns asking questions that the teacher has required, sometimes forcefully bidding for attention –including prodding Raqi with the eraser end of a pencil and demanding, “WHY YOU REMOVE THE DUCKY?”— in order to accomplish this work. After he gets the "required" teacher questions in his notebook, he asks three probing and clarifying questions. Then, Ziling presents Raqi an interactional curveball by challenging his group's decision by saying, "I think the ocean current just not go like this." In this way, Ziling is applying his own understanding of an ocean current to the group's drawn model. This interactional space has afforded him an opportunity to offer critique, which is a well-known practice of professional scientists (e.g., Kelly & Bazerman, 2003). In turn, Raqi responds to this critique with a more fully-articulated idea than he had previously expressed. In this way, the participant structure permitted Ziling to practice scientific ways of working, an interactional move that expands the sense-making possibilities of the space for both students. The interactional structure allowed Ziling to participate in a way that opens up scientific talk among these peers, even though they do not speak the same native language.

However, Ziling also faced obstacles in his pursuit of this scientific interaction. In the table above, there is a gap from line 10 to line 28 where Ziling says nothing and the

students' interaction is focused on negotiating the ownership of a sticker and a Rubik's cube. During this time, none of the other three students look at Ziling or invite his participation in this interaction (see Figure 9). Although he is not being left out of the scientific work of the day, he is still not invited in to the social participation structure. The configurations of the youths' bodies, their transfer of the materials, and the linguistic organization of the space all position him *outside* the shared activity. This, too, is a form of positioning, by which Ziling is construed by his peers as being unfit in some way to participate in the social participation structure of class life.

Figure 8. Ziling is left out.



34:41 (Jacob's bid)  
 "I wannit I wannit I wannit"  
 "You said NO!"

And yet, although Ziling was not given full credence as a social participant in his group for interactions regarding the toys, he *was* able to engage in the scientific life of the classroom through sense-making. In this way, Ziling responded to this "positioning-out" by emphasizing the academic work of the task—hearing the group's rationale for removing components of the model. He brings to this interaction a deep understanding of

the scientific concept of ocean currents, and by asking probing questions, he seems to be inviting Raqi (if not the other two students) into the scientific practice of critique.

Ziling's participation in this episode illustrates a different relationship to scientific sense-making in response to positioning by other students, and interestingly, here Ziling relies on the established academic structure of "stealing great ideas" in order change the group's interaction with Raqi. This micro-moment offers a glimpse into how the provided academic structures set in place by teachers can support students to take up positions as capable sense-makers.

### **Density Column: Bids for Support go Unheard**

In the second episode, I selected in order to understand Ziling's engagement, Ziling and three other students—Pilar, Jacob, and Fiona—are working together at a shared design task. They have been given a tall graduated cylinder, a small beaker, a dropper, and four colors of food coloring. They are to use what they know about density to try to get the colors of water to layer on top of each other in graduated cylinder in an activity called a "density rainbow column". Throughout the interaction, they use salt, different temperatures of water, and different methods, but they never quite get the desired effect. In contrast to the "ducky models" sequence, the teacher and I did not offer the students any suggested structures or participation frameworks to use during this activity; we hoped that students would use sense-making talk on their own and be able to successfully negotiate their positions within the design task. Students were allowed to work in their groups however they wanted, as long as they had "come to consensus" before making big decisions (Transcript, 160120).

As the four students work to figure out the best design for the density column, Ziling shows his commitment to the task by maintaining a firm gaze on the density column, and he attempts to participate by stirring the red food coloring into the water to prepare for layering the liquids and then he takes on the task of filling a small beaker with cold water:

- 1 ((Ziling starts to swirl the liquid and Jacob takes it from him.))
- 2 [00:12:09.13]
- 3 Ziling Why don't we just mix in here?
- 4 Fiona: Why don't you use THIS to mix it Jacob? ((Hands Jacob a dropper that's long and thin to reach the liquid in bottom of the grad cylinder))
- 5 ((Jacob tries to mix with thin dropper))
- 6 Jacob: I can't fit it all the way down
- 7 (h) (h)
- 8 Fiona: ((reaches for cylinder)) Lemme do it.
- 9 ((Ziling reaches into interactional space and grabs beaker that is now empty.))
- 10 Ziling: (to group) So this is the tap water? or the cold water without salt.
- 11 ((Group does not turn to acknowledge Ziling))
- 12 Fiona: //Yeah I'm mixing it.]
- 13 Ziling: ((repeats)) Jacob, is this the hot water? Or ((gestures to faucet)) cold water
- 14 Jacob: That's the cold water
- 15 Jacob: //I think that's good enough]
- 16 Ziling: //So this is the tap water right?] ((touches Jacob's shoulder when Jacob doesn't acknowledge his question))
- 17 Jacob: Now let's get the tap water.
- 18 Ziling: Okay ((goes to fill beaker with water as instructed, Jacob follows along with Ziling to get the water that's needed.))

In this interaction, Ziling attempts to engage in the discourse and engineering space that the other group members are engaged in. He proposes that the food coloring be mixed with the water *before* dumping it in the beaker (line 3), but this suggestion is not acknowledged, must less considered as viable. (Twenty-two lines later this same suggestion is taken up by Jacob after Pilar and Fiona argue for this method.) Then, Ziling asks his group members which kind of water is in the beaker (line 11), but this direct question is also unacknowledged.

Yet Ziling is not deterred by these failed attempts to join the social interaction. He names his addressee directly and tries again (line 13) "Jacob, is this the hot water? Or cold water?" This is direct enough to get a response from Jacob, who then turns his attention back to the cylinder. But Ziling has a question about "tap water" and requires clarification, so he taps Jacob's shoulder to get Jacob's attention again. Jacob does not respond to Ziling's question with an answer, but rather Jacob goes to the sink with Ziling and supervises how he gets the water from the tap, and what temperature it is.

In this interaction, there are several interesting moments of positioning. The first is that Ziling's direct questions are not acknowledged by his peers on three separate instances. This could be because Fiona and Jacob are engaged in stirring the cylinder at the moment Ziling asks the question. And yet, these youth do not typically ignore each other's ideas; there is only one other instance of a student's utterance going unacknowledged for the rest of the 6-minute interaction (Pilar makes a comment that is not acknowledged in line 38). Therefore, I interpret this lack of attention to Ziling as a participant in the interaction as a form of adverse positioning; others in the group do not acknowledge his request for information and his bid for interactional participation.

However, Ziling uses interactional strategies to get the answers he needs *despite* this temporary interactional marginalization: he *counters* this adverse positioning. He repeats his question, states his addressee's name directly, and even prods the shoulder of his listener to get his attention. Ziling uses these interactional resources as a way to get the information he needs to participate - in this case to understand the relationships between three "types" of water: "warm," "cold," and "tap." As in the previous example where Ziling advanced a critique of Raqi's drawn model, here we see Ziling using the

interactional space to do the science work of clarifying shared procedures with a team.

In these two interactions, Ziling offers an example of a student who has a strong academic background being positioned outside peer interactions in science class. His case is also compelling evidence that *teachers can support youth to renegotiate problematic positioning* by offering concrete strategies for engaging in scientific discourse.

### **Discussion: Ziling**

Ziling offers another example of how a young person with language-minoritized status negotiates science learning environments. Here we see contrasting cases in which the classroom interactions were more and less structured. In the first case, he uses the academic talk structures that the teacher and I had provided to negotiate a position within the interaction. In the second example, the teacher and I only recommended that students try to come to agreement about how to build the density column, but we did not specify how they should go about using the materials or what kinds of things they should figure out. In both of these interactions, Ziling used these recommendations as a default when he was not being attended to in his interactions. For Ziling, the overt structures that were provided in these examples served to support him to advocate for his own equitable engagement in sense-making.

### **Findings: Pilar**

I took as my third focal case Pilar, also in Ann Wirk's 6<sup>th</sup> grade science class and a classmate to Ziling and Raqi. She is a Latina of Mexican heritage and her family experienced hardship related to the deportation of a relative during the 2015-16 year. As a result, Pilar missed dozens of days of school. I selected Pilar for analysis because she

offers a case of someone with several intersectional statuses that are historically marginalized in STEM: she is of Latinx heritage (racial status), female (gender status), she has previously participated in ELL programs (school status), and she speaks English non-natively (linguistic status). Her case illuminates possible ways these identities might interact in small group settings in science.

Because Pilar engaged in the same episode of rainbow column-building as Ziling, I turn back to this episode to highlight how she participated, and I then interpret her participation in terms positioning and the ways that the classroom may have supported her behavior.

As Pilar sat at the table with the other students during the density column episode, her participation comprised several features. First, she kept the objects of the engineering task (the salt, food coloring, graduated cylinder, etc.) consistently within the space in front of her within her transactional segment. By this manipulation of her body and the materials, she was “engaged in the line of activity” (Kendon, 1990, p. 211). Compared to Ziling, she used language as a tool for participation more frequently, making 25 of the 111 utterances (23%) within the group, compared to Ziling's 11 (10%) utterances and Jacob's 36 (33%). She also used language to do a broader range of things: whereas Ziling primarily used language to ask and answer questions, Pilar used language to regularly make bids for participation (3 times), to acquiesce to others' thinking (twice), to predict & explain (3 times), narrate her progress (twice), and even to disagree with or contradict others (4 times). In this way, Pilar seemed to be well-positioned member of the group: although she spoke less overall than co-participants Fiona and Jacob, she participated

with similar patterns to the two white native speakers. In other words, she seems not to be marginalized in terms of her linguistic participation.

However, she is not given the same participation rights in terms of materials. As I mentioned above, Pilar keeps various materials in front of her during this activity, but she doesn't get to use them to participate in the sense-making activity of engineering. She regularly has the food coloring, stirring sticks, and taken from her so that others can use them in this twelve-minute interaction; of the 15 instances she uses materials, six times the materials are taken by someone else for use, and nine times her use of the materials was rushed, managed, or overtaken by Jacob. These behaviors include, reaching and taking objects from her hands without a bid for them, and even a moment when Jacob actually tips the bottom of a beaker up to hasten her pouring it into the graduated cylinder, saying "GEEZ!" in disapproval. In these subtle and not-so-subtle ways, Pilar has her credibility as an epistemic participant doubted—she is positioned outside the social activity by having the materials taken out of her hands *almost every time* she touches them. In contrast, Jacob only takes things from Ziling on 25% of instances.

Yet Pilar shows strong capacity in science and engineering, and she often has well-developed ideas that the others could likely benefit from if they listened to her. For example, she shows that she knows that pouring the colored water more slowly might help the layers stay intact in the density column. Yet when she reminds her peers to pour "SLO:WLY", they do not heed her advice and dump the water too quickly; it mixes and their design has failed.

Thus, Pilar *said less* and *got less access* to the materials, *despite* having a strong understanding of their task and how she might get their desired outcomes. In this way,

her group did not position her as a credible participant. I argue that this is a form of interactional injustice; her opportunity to participate in scientific sense-making was foreclosed on by others in her group. Considered together, Pilar and Ziling are positioned outside of scientific sense-making, and in more categorical ways (such as being ignored or having their materials taken away) more often than the white, native English speakers, or even than their peer Raqi, a male student with lighter skin.

That this kind of positioning occurs in peer interactions is worrisome, but what is most problematic about Pilar's case is that, of the three students, she seems to do the least to specifically counter this interactional injustice. She remains fairly quiet, although she shows her understanding through the use of the materials—such as reaching for a dropper when Ms. Wirk asks, “What can we use to pour the water more slowly?” and regularly reaching for the food coloring that will come next in the rainbow layering sequence. She often agrees with Fiona, and she practices calling “dibs” to claim certain actions, such as mixing the salt or pouring the food coloring which gets her permission to do these actions in subsequent test runs, but the space remains largely governed by the instruction/narration of Jacob, the white male student in the group.

Further, Pilar seems to accept this arrangement and position; she said in interviews that she *likes* working with Jacob, even though “he messes around sometimes” (Interview 160617). We also know that the previous year she was “bullyed” [Student writing, sic] which may also have contributed to less forceful participation or acquiescence on her part.

Pilar offers a case of a student choosing not to respond to adverse positioning from peers. Instead of asserting her ideas as Raqi does, or tapping on shoulders as Ziling

does, she keeps her thoughts small, and despite her good ideas, her classmates do not listen. She also doesn't seem to see the problem with this arrangement – she seems to have interpreted that her ideas really are secondary to her classmates'.

### **Discussion: Pilar**

Given the limitations of this study, it is impossible to ascertain precisely how Pilar construes herself within this complex social activity in response to the positioning of her peers. However, other studies have found that racial and gender identities do matter in relation to, for example, practicing math (Nasir & Hand, 2008; Spencer, Steele, & Quinn, 1999). Although Pilar is an extremely capable student, she appeared resigned to letting her ideas go unheard, even when she had a strong understanding of how the task might be best accomplished (e.g., pouring “SLOW:LY” to prevent the types of water from mixing in the cylinder). Of the language-minoritized students in this study, Pilar has the most experience in US schools. Is it possible that, if Ziling and Raqi are positioned outside of science enough times in their US science contexts that they will similarly grow quiet? Or is it the intersection of Pilar's language status, racial status, gender status, and previous status as a victim of bullying that have functioned to keep her ideas silent? Kendon (2002) showed how moments of negative positioning for one language-minoritized youth became laminated over time. Eventually, Latanya, the subject of his study, dropped out of the AP English course sequence. Has the same thing—a sequence of positioning moments that problematically position her relative to science content and school—also occurring with Pilar? It seems plausible, but further research should investigate *why* students like Pilar stay quiet and what classroom participation structures might help them

raise their voices. If possible, this research should privilege and highlight the voices and unique experiences and responses to these kinds of everyday—and troubling—micro-moments.

### **Designing with Resilience**

All three students—Ziling, Pilar, and Raqi—faced problematic positioning in the context of social interactions with their peers in science class. I will treat them together now and interpret their individual findings in light of broader conclusions and implications for practice and theory.

In these cases of youth learning, all three students experienced moments where their peers positioned them in problematic ways that reduced their opportunities for scientific sense-making. Raqi's scientific ideas were given secondary interest compared to his social interactions, Ziling's bids were ignored, and Pilar had materials taken from her. In order for science to be “for all students,” youth like Raqi, Ziling, and Pilar require regular access to opportunities for sense-making through engagement in scientific practices. As teachers, districts, and states emphasize that students should have regular access to scientific sense-making, we must bear in mind that even the smallest-scale interactions among students can work against goals of equity and equal participation.

Yet these young people showed remarkable resistance to adverse positioning, and in many cases, elements of the classroom design seemed to support them to engage as knowledgeable and capable. I summarize these design features here with the hope that educators can supplement the resilience of youth with activities that allow them an interactional way to access science sense-making practices.

**Emphasizing *ideas* over *outcomes***

Raqi and Ziling were both able to assert their scientific ideas during the gallery walk (“three stray, one stay”) even when others in the group were engaged in social talk. Raqi was able to respond to Barry’s dare to eat sand while moving forward a complex explanation. These activities both had collaborative sense-making at the core of the design, and it seemed to support the youth to take up positions as sense-makers in joint work with their peers, even despite negative positioning from others.

In contrast, in social arrangements that emphasized the *outcomes* of a task, such as the joint work on the computer between Raqi and Fiona, evoked urgency and even stress. This stress causes Fiona to chastise Raqi: "I sort of wanna get a good grade on this" and drive her emphasis on getting the task finished in a timely way. When juxtaposed with the episodes where Raqi is positioned as having "great ideas" in both Idea Coaching and the Three-Stray, One-Stray protocol, it is particularly striking how little access he gets to the scientific tools of reading, writing, and sense-making when the emphasis was on getting something turned in. This emphasis on ideas also took the form of open-ended questioning (versus right/wrong, yes/no questioning) (Verplaetse, 1982) among peers, but it was first supported and modeled by the teacher.

These examples illustrate the importance of making student ideas central to the daily conduct of classroom life. As a design principle, emphasizing ideas over outcomes is a well documented strategy for supporting student sense-making and engagement in scientific practices (B. A. Brown & Spang, 2008; Duschl et al., 2007). This study adds evidence that a continual focus on developing student ideas can support multi-lingual

peer groups, and, most importantly, that an emphasis on ideas can support youth to renegotiate the positions that are available to them.

### **Time**

The development of scientific practices and concepts requires significant time allocated to sense-making (Duschl et al., 2007; National Research Council, 2012). All three focal students showed negative responses when they felt pressure to rush their thinking, either as a result of peer or teacher-initiated hurrying. Further, they showed more positive responses (e.g., more insightful thoughts and more fair and positive interactions) when time was not central—that is, when they were given time to explain and interpret ideas. It took almost four full minutes for Raqi to explain his thinking about waves to Barry, and the most substantive parts of his explanation came toward the end. The time allotted to Raqi supported him to take up and defend a position as a sense-maker; he was instructed to *continue* to explain until the teacher called for student to switch roles, and he maintained his position as sense-maker even while Barry ate sand. This sort of structuring of explanation time may be useful way to balance the participation of all youth as they explain their thinking.

### **Materials Matter**

Students engaged more deeply in scientific activity when they were provided scientific materials such as models, drawings, and vials of sand. For example, Ziling used the post-it notes on the poster as the basis for his critique of Raqi's group, and Raqi used a vial of sand to motivate his explanation about weathering. The crucial role of materials is not a new finding; researchers in science education have long reported that

provisioning the classroom with the tools and materials of science promotes productive disciplinary engagement (Engle & Conant, 2002). However, in this study, I found that it was a *combination* of provisioning the “materials” of science with structures for participating in science practice such as critique and argumentation that permitted language-minoritized students such as Raqi and Pilar to engage and re-position themselves as active participants in science and engineering.

**This finding also speaks to work in studies of curriculum in second-language classrooms; students who are learning English benefit from being able to express their thinking in multiple modalities (e.g., Lightbrown & Spada, 2003) such as through talk, writing, drawing, and gesture, and in ways that allow for the communication of their experiences. However, my findings also suggest that it is not just the ‘multiple modes’ that supported the students, but the combination of *scientific materials* and a *participation structure* to support students’ in the pursuit of scientific explanation. Finally, researchers and educators must remember that the critical element of this arrangement is not an instructional recipe that generates spaces for learning; the mechanism that allows for these learning arrangements lies in the remarkable resilience of young people. Provisioning the space with authentic materials, in combination with participation structures that support youth to engage in explanation, can offer youth multiple ways to position themselves as active sense-makers. Listening**

Finally, during structured sense-making activities, the students and the teacher showed deep respect for others’ ideas. For example, Ms. Wirk instructed students,

"Listen for what great idea do I wanna steal" before sending them into the gallery walk, and she regularly asked students to write down what they learned from others. This "generous listening" seemed to allow Raqi to share his thinking freely, even when faced with adverse positioning and unexpected critique. Barry also showed Raqi this generosity during the sand explanation, asking questions and pressing Raqi for further details about his thinking.

Careful listening from a peer can support language-minoritized students to engage deeply in difficult linguistic practices in science. Similar findings have been documented with language-minoritized populations; good listening supports "accountable" learning environments (Michaels et al., 2008; Resnick, Michaels, & O'Connor, 2010) through the achievement of intersubjectivity, mutuality, or joint work (e.g., Barron, 2000). However the present study adds a dimension of *justice* to this work by illustrating how listening *positions* youth as capable sense-makers and supports them to take up these positions, even when other classroom factors may marginalize their participation.

Further, unjust positioning of the focal students occurred in situations where students were *not* listening to each other. Thus, careful listening may well be a way to mitigate the kinds of injustice that are documented in this study. Therefore I argue that more attention be paid to the role of careful, authentic listening in student-to-student interactions in the classroom, and I further argue that research and design alike should focus on ways to support adults and students to better understand each others' meanings.

### Implications

This study is a response to a problem in K-12 science education: the continued worry that “ELL” students are “struggling” in our science classes, and that the professionals teaching them continue to feel unprepared to support them (Rodriguez & Kitchen, 2005).

While it has long been understood that dialogue is a rich source of learning (Bakhtin, 1982; Vygotsky, 1978), this study investigated the talk of immigrant “ELL” students in order to see how structured classroom talk activities supported their sense-making in peer groups. In particular, I interpret what occurred for these students in these structured talk opportunities as an instance of “third space” (Gutiérrez, 2008; Gutiérrez et al., 1995), a “new sociocultural terrain” that is outside the normative teacher dialogue and also outside the students’ typical roles as passive receivers of information. Although Gutiérrez, Rymes, and Larson (1995) found that third spaces arise but are not often taken up as transformative spaces in classrooms, this study offers further evidence that language-minoritized students thrive in the third space with their peers and *without direct or ongoing teacher intervention*, using their linguistic tools, their bodies, and all of their varied experiences to engage in lively critique, design, and explanation. This was even true for newcomer students who have recently arrived in the US. Further, structured classroom discourse activities where students were given distinct participation structures and disciplinary tools seemed to make the third space an explicit goal which students could work toward in the manner of their own choosing: linguistic and physical, using everyday and scientific practices (Ann S. Rosebery et al., 2010).

Although a number of studies have investigated third space constructions involving the teacher in direct interaction, my study is unique in that I examined how students themselves contribute to the creation of third spaces, how peer positioning discourse can silence or overwhelm language-minoritized students, and finally, how youth renegotiated positions that didn't serve them. They did this within the social participation structure of the classroom, all while laying forth complex ideas in their second or third language of English. Continued work in science education should more generously interpret the creative, social processes that youth use to take up and maintain their positions as sense-makers as well as the classroom arrangements that make it so.

Second, this study adds practical design implications for researchers and practitioners who are designing for more equitable science classrooms. Because this study took place in an urban classroom as the result of a long-term, collaborative relationship between the researcher and practitioner, the research-based findings presented here are of secondary concern to me; most importantly, the teacher and I were able to nimbly adapt instruction around the day-to-day interactional positioning we saw occurring, and provide students opportunities to navigate them. Together, the teacher and I codesigned about six weeks of lessons, each containing opportunities for students to make sense of a phenomenon, and we saw meaningful results both within the classroom and in the teacher's larger professional network. Together, we were able to share the strategies we learned with 70 local teachers. Thus, the research and development that resulted is thus more rigorous (Gutiérrez & Penuel, 2014) because it deeply contributed to the learning of the teacher, the students, and through DBIR mechanisms, the larger district. This is an implication for research-practice partnerships, and specifically how

mechanisms within DBR/DBIR can *support practice to drive theoretical innovation*. The design-based implementation research study that supported this work committed to using “deep dives” of classroom-based research to better understand how scientific practices might be equitably developed. Thus this study sits at the nexus of research and practice and contributes an understanding of how theoretically-driven traditions of research may better inform practice, but also, and I think more importantly, what mechanisms can allow for practice to inform research. Future work should continue, as Gutiérrez has put it, “to imagine new trajectories and futures and forms of agency in learning processes for youth in vulnerable circumstances” (2016, p. 187).

Finally, this study also adds to literature in science education a case of remarkable resilience of youth in moment-to-moment interactions. I have used interaction analysis not just to investigate how language-minoritized students are positioned relative to sense-making practices in science class, but also how language-minoritized youth can *engage in negotiation of those positions*. This study specifically presses against a literature that assumes that “language learners” are going to struggle because they have deficits (Gutiérrez & Orellana, 2006). Here, I have attempted to show the remarkable repertoires that learners leverage in order to resolve conflict and preserve their positions relative to science and sense-making. Thus this study is an argument for *the possible*; we have garnered a sense of the curricular and social supports that seemed to support language-minoritized youth to push back against unwanted positioning in science class.

Finally, this study adds a case of what kinds of micro-moments in science classroom might accrue into long-term identity formation. These micro-moments of positioning, such as those documented here, do not stand alone in longer-term life at

school. Each of these moments of positioning can be thought of as one layer in a larger, “laminated” identity-building enterprise (Leander, 2002). These moments of positioning via peer relationships *can* support stronger relationships to content (Wortham, 2008), but they can also position students outside the content area and even outside the culture of school (Leander, 2002). If we care about supporting language-minoritized students in navigating their ways to strong science or school identities, we must consider their local, everyday everyday experiences in our classrooms. When interactions are understood as part of a longer-term, laminated identity, it is very troubling that Raqi, Ziling, and Pilar all experienced peer interactions in which they were ignored, left out, and assumed incompetent *even when we designed specifically for more equitable interactions*, since these interactions, accrued over time, can result in negative outcomes in relation to disciplinary identity formation.

Yet this study also gives us important insight into how youth *can resist* being positioned as less able, and what instructional designs in science might support this resistance. In particular, these students were able to assert more positive disciplinary positions when classroom activities emphasized careful listening and made idea development central. Although peer interactions can be a site of injustice and problematic positioning, they can also be spaces where youths’ great ideas propel them to take up positions as scientific sense-makers.

## Appendix A: Transcription Conventions

### Transcription Conventions

Adapted from Ochs (2006)

- CAPS loud or emphasized speech
- (h) laughter
- (( )) denote activity
- ? raises voice at end of utterance
- // ] overlapping or simultaneous speech
- (.) denotes a pause in speech
- (. . .) denotes longer pause in speech
- : extended vowel or consonant sound (e.g., re::ally)

## Chapter 4

### **Idea Coaching: A Pedagogy for Transformative Science Talk Among Language-Minoritized Youth**

#### Abstract

This design-based implementation research study sought to work directly with middle school teachers to design a pedagogy for supporting science explanation and learning among language-minoritized students, such as English learners and emerging bilingual students in mainstream science class. We call this pedagogy—a scaffolded participation structure for small groups—“Idea Coaching.” Invoking a sociocultural conceptual framework of transformation through dialogic learning and pedagogies of science practices, I used conversation analysis to qualitatively code adjacency pairs of resulting student talk. I found that the responsiveness of student dialogue engendered stronger peer explanations among language-minoritized students. Additionally, I explore the relationship among positioning, knower status, and sense-making dialogue with language-minoritized youth. These findings support a conclusion that the Vygotskian processes of cumulative talk, supported by renegotiated positions, can support individual students’ development of concepts, and that this pedagogy may fill a wide gap in research and teaching about the possibilities for conceptual development through dialogue in modern K-12 classrooms.

### **Research Problem**

Too often, young learners are minoritized in school by the languages they speak despite the rich language practices of their homes (Dyson, 2009; Flores & Rosa, 2015; Gutiérrez et al., 2009), and scholars report a need for pedagogies to support these language-minoritized students in science disciplines in particular (O. Lee & Luykx, 2007; Ann S. Rosebery et al., 2010; Wells, 2007). This lack of attentiveness to linguistic resources of bilingual students has been linked to problematic consequences, including such worrisome statistics that 31% of students nationally classified as "ELL" dropping out of high school, compared to 10% of their peers (Short & Fitzsimmons, 2007).

Researchers have suggested different methods for better supporting instruction for language-minoritized youth, from school policies on curriculum and language (Hakuta, 2011; Hakuta & McLaughlin, 1996; Hopkins, Thompson, Linqanti, Hakuta, & August, 2013), school-based models such as sheltered instruction for "English language learners" (e.g., Echevarria, Vogt, & Short, 2000), supporting culturally responsive learning communities (García & Lee, 2008), and theoretically-driven pedagogies that support language-minoritized youth, such as critical language awareness (Pennycook, 1999, 2001; Siegel, 2006). The present study focuses on the development and study of a pedagogy to support language-minoritized students as they learn in "mainstreamed" (e.g., not "ELL" or sheltered) science classes. This pedagogy begins from the following evidence-based assumptions:

- 1) That language-minoritized students bring rich knowledge and practices to their classrooms, and these can be supported through peer-to-peer talk

2) that pedagogies that support cumulative talk can foster sense-making for all students including language-minoritized students, and

3) the positions made available to youth through pedagogies of talk may support and constrain their engagement in scientific practices.

I take each of these design assumptions in turn here.

### **Conceptual Framework**

#### **Talking to learn science**

This design holds that science is a set of practices and complex social goals that communities engage in together, and that youth are already adept at many of these sense-making practices. In school, youth should have access to these practices as part of their participation in science class. In other words, the discipline of “science” does not comprise coherent, unified principles, but rather a set of social constructed scientific *practices* (Rouse, 1999). Therefore the science that we teach in schools should help youth connect their experiences doing science in their lives to forms of the practices that scientists engage in, such as explaining complicated phenomena, building arguments based on evidence, and revising models (National Research Council, 2012; NGSS Lead States, 2013a). These professional practices are partially rooted in the linguistic and semiotic activity of scientists, including discourse-based learning through participation:

“In this way, gradually the neophyte (scientist) becomes socialized into the semiotic behavioral-perceptual system of a community with language taking a major and multivalent role in the organization of that system, but with that system also shaped around concrete worldly activities. In terms of contemporary cognitive psychology, she will have developed the scripts, schema, and plans appropriate to participation in the community.” (Bazerman, 1988)

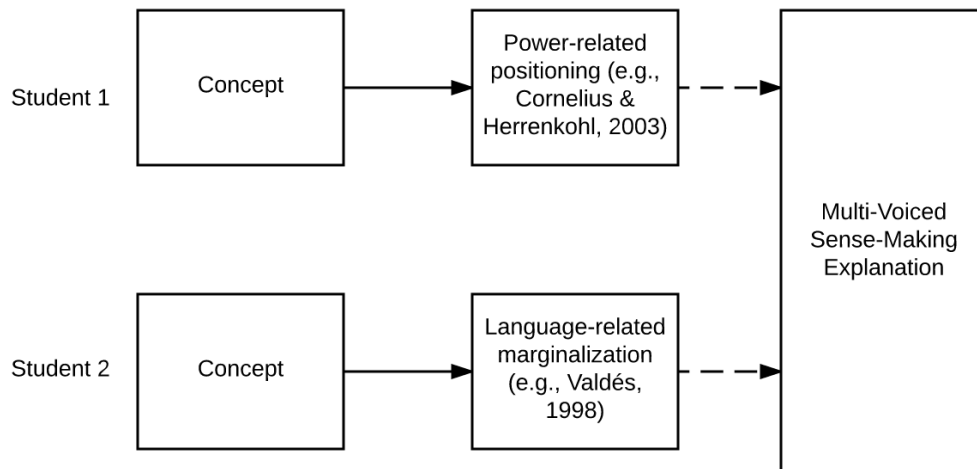
Decades of work in science education—and the learning sciences more generally—has focused on sophisticated discursive practices in which students' concepts are compared and critically analyzed and adjusted in the social practice of argumentation and explanation (Chin & Osborne, 2010; Engle, Langer-Osuna, & McKinney de Royston, 2014; Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Michaels et al., 2008; Resnick et al., 2010). In the classroom, explanation practices can bring to the surface the rich and varied histories and funds of knowledge that students bring to the classroom (Duschl et al., 2007). As Vygotsky and subsequent sociocultural theorists have made clear, the relationship of the social sphere, the word, and the concept are closely intertwined, and explanation can support learners to develop new meaning. In the process of human learning, the learner's relationship with the concept and the learner's understanding of the word merge. Vygotsky describes the interdependent nature of thought with language as, "The concept is not possible without the word. Thinking in concepts is not possible in the absence of verbal thinking" (1978, p. 131). In science classrooms, teaching can support students' conceptual understanding to be made manifest through engagement in discursive practice.

**Cumulative talk.** One genre of talk within the discursive practices of science is called cumulative talk, in which "speakers build positively but uncritically on what the other has said. Partners use talk to construct a "common knowledge" by accumulation. Cumulative talk is characterized by repetitions, confirmations and elaborations" (Mercer, 1996, p. 369) In science education literature, cumulative talk tends to receive less attention than exploratory talk, yet I argue it is critical for the formation of concepts, for it is the relationship of this self-explanation to concepts that prompts us to re-examine and

formulate new ideas (Vygotsky, 1978). Throughout this chapter, I will emphasize the importance of cumulative talk and the ways it can be supported among language-minoritized youth. It is an assumption of the design that all youth should be given opportunities to make sense of their thinking about scientific phenomena through explanation, and in particular, cumulative talk.

**Language-minoritized youth and talk.** Science classroom discourse is difficult to foster largely because it can contribute to imbalances of power among students (Cornelius & Herrenkohl, 2004), between the school authority and student (Valdés, 1998), or because of teacher-student power dynamics (Forman & Ansell, 2002; Gutiérrez et al., 1995). Language is implicated in this process of *minoritization* (Flores & Rosa, 2015), with students who speak English non-natively often left out of classroom dialogue. Thus sense-making talk can be disrupted for students with these marginalized statuses (see Figure 10).

*Figure 9. Model of Disrupted Sense-Making Talk*



I hold that language-minoritized students already engage in sophisticated practices (e.g., Hudicourt-Barnes, 2003) that stem from culturally held funds of

knowledge (Moll et al., 1992), and that teaching must begin with understanding of cultural wealth (Yosso, 2005). This is in specific contrast to scholars who maintain that language-minoritized youth should be given “bridges” to canonical science, thereby allowing “access” to Western modern scientific thought (O. Lee & Fradd, 1996, 1998), a view which problematically emphasizes that the student should come to understand and accept "settled" notions of science. Rather, I argue that science itself and its pedagogy must be more broadly conceived in order to leverage the indigenous ways of knowing (e.g., Bang, Warren, Rosebery, & Medin, 2013) that nondominant students use in their everyday lives. Accomplishing pedagogical shifts in K-12 science classrooms that appropriately celebrate and build on students' funds of knowledge may indeed be a "conundrum," (Rosebery et al., 2010, p. 353) but it is one that teachers and I worked to better understand through this design.

These assumptions of youth competence are represented in national policy for US K-12 science education via *A Framework for K-12 Science Education* (National Research Council, 2012) and the resulting Next Generation Science Standards (NGSS Lead States, 2013b) which argue for approaches to science teaching that value multiple forms of student sense-making. In particular they hold that the linguistic repertoires of youth are valuable resources that can be leveraged as a sense-making tool within the science classroom. This was a key element of our local implementation effort; we sought to directly support teachers to develop strategies for building youths' sense-making practices, starting with their existing linguistic repertoires and funds of knowledge.

Language learners can also be marginalized on the classroom interaction level. For example, in classroom discussions in that they may speak less often than their native

English-speaking peers (Nassaji, 2013), thus getting less access to sense-making talk opportunities in English. Second, nondominant youth who speak English non-natively have been found to engage less in classroom interaction (Johnson, 1995) This can result in fewer overall opportunities to engage in science practices in the classroom. Young people can learn science language through interactions with “more advanced users” of science language (Gee, 2004, p. 22). Small-group or dyadic interactions have been advocated by many scholars in order to support classroom talk (Johnson, 1995; Nassaji & Wells, 2000; Wittwer & Renkl, 2008). Thus supporting youth to engage with each other in cumulative, sense-making talk may provide an important opportunity for language-minoritized youth to practice language while incorporating their experiences in a low-stakes, supportive environment.

Yet this is not a straightforward instructional approach to implement. Teachers need support in implementing this kind of youth-controlled discourse opportunity (Braaten & Windschitl, 2011; Wells, 2007), as it is a departure from traditional classroom participations structures in which the teacher controls the flow of classroom ideas in dialogue (Cazden, 2001; D. Edwards & Mercer, 1987; Wells, 2007). This design sought to engage teachers and researchers in solving this problem through joint engagement (Bell, 2004).

### **Positions in Practice**

Positioning theory (Bricker & Bell, 2008; Davies & Harré, 1990; Harré, Moghaddam Fathali, Cairnie, Rothbart, & Sabat, 2009) is helpful tool for analyzing and understanding the ways that students navigate the discursive terrain of the classroom;

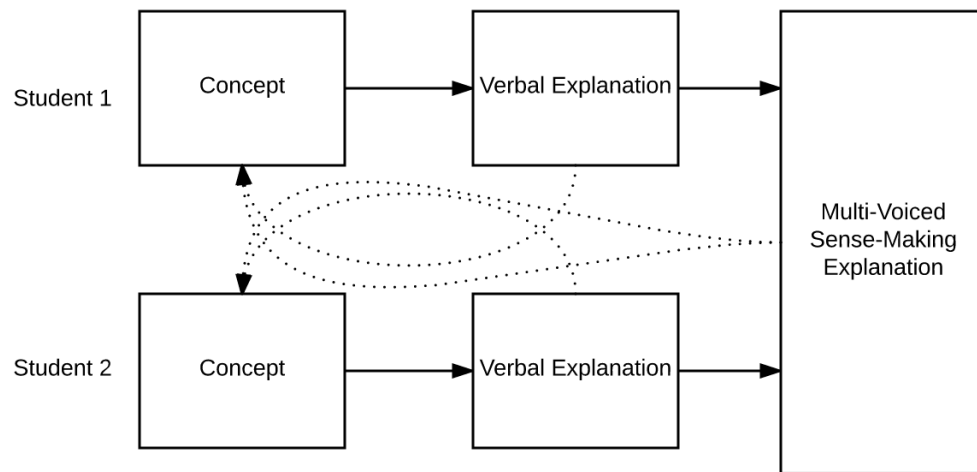
students consistently work within the social positions they are offered by the teacher and other students or which they assert for themselves, and participating in a discursive exchange means taking up different social positions and story lines which may or may not conform to cultural stereotypes. One commonly studied positioning move that is well-regarded in classroom linguistics literature is the conferral of "knower" status (Berry, 1981). "Knower status" is granted in interactions when teachers or other students actively regard another person in the classroom as a competent holder of intellectual ideas. This position as a knower can also be taken up—or rejected—by students and teachers. For example, Nassaji and Wells (2000) describe how teachers relinquished their default position of "primary knower" when they asked open-ended questions that "solicited student opinions and conjectures" (p.392). In other words, when the teacher opened the floor for the intellectual contributions of the students to be *valued* instead of *evaluated*, the teacher conferred the status of "knower" onto the students. Granting students' "knower status" has been found to support meaningful classroom engagement (Tabak & Baumgartner, 2004), while maintaining positions of "teacher-as-knower" can reinscribe problematic power dynamics that can further minoritize youth from nondominant backgrounds (Gutiérrez et al., 1995).

This design experiment posits that, through changed social positions orchestrated within classroom discourse structures, improved access to the epistemic practice of cumulative sense-making talk can occur in science classrooms for language-minoritized students (see Figure 11). For example, if language-minoritized students are granted knower status by their peers in dialogue-based interactions, one could reasonably conjecture that their diverse ways of making meaning in science will become more

salient, respected, and foregrounded. This was precisely the goal of the present study.

The approach involved engaging classrooms of student dyads in a tool-mediated shift in social positioning as students participated in the epistemic practices of science.

*Figure 10. Model of Individual Explanation and Shared Sense-Making*



Although a growing number of design-based studies in science are motivated by various combinations of these assumptions and findings, no recent studies have used design-based research to seek methods to engage language-minoritized students in this kind of discourse through direct engagement with their peers in culturally and linguistically diverse classrooms. Given these theoretical commitments to language-minoritized students, transformative and discursive learning, and scientific practices, I sought to fill this research gap. Thus I posed the following research questions: How can inclusive, sense-making discourse practices support student's verbal explanations and promote sense-making positions for students within the science classroom? How do language-

minoritized students engage in the scientific practice of explanation—and the associated learning processes—as a result of inclusive pedagogies for scientific explanation?

The participating teachers and I designed a pedagogical intervention to promote opportunities for students to build explanations. We called this intervention "Idea Coaching". We implemented and refined the approach in five middle-school science classrooms in an attempt to understand the particular designs that might afford youth to learn through sense-making.

### **Setting and Data**

Within a long-term research-practice partnership (Coburn et al., 2013), I spent three years engaged with teachers in developing pedagogies and curriculum that would support learners to engage with science and engineering practices. Over the final year of my work with teachers (2015-16), one teacher, Ann Wirk (pseudonym), and I developed a discourse strategy we called Idea Coaching. We shared the goal of supporting language-minoritized students to engage deeply in scientific explanation by shifting their positions in the classroom from “non-knower” to “knower” status (Berry, 1981; Tabak & Baumgartner, 2004). This intervention resulted in deeper engagement in explanation practices, especially on the part of language-minoritized youth. Through the research-practice partnership, we were able to share Idea Coaching with 70 other middle school science teachers in the urban area. Five of these teachers, who each had indicated interest in having researchers visit their classroom, were selected for classroom-based collaborative research with university partners. These teachers all served in the same large urban district in the Pacific Northwest, and were involved in the overarching

district-level implementation project. Their student demographics, school communities, mission statements, and curricular opportunities within their schools differed significantly, but each teacher supported at least 2 students who spoke languages other than English at home. I worked with the teachers in several settings including professional development at the district office, school-based professional learning communities, and one-on-one design work over a period of one calendar year. Across these settings, the research team and I focused on documenting and understanding problems of practice (Penuel, Coburn, et al., 2013) that faced teachers as they implemented new instructional models. The importance of our long-term commitment to understanding local pedagogical models undertaken before this study was conceptualized cannot be understated; collaborative, long-term partnership approaches to documenting and resolving problems of practice have been found to support longer-term, more sustainable change efforts in educational systems (Coburn et al., 2013; Penuel, Coburn, et al., 2013).

The primary data corpus for this particular study comprises eleven instances of student dyads or triads engaging in the Idea Coaching pedagogy from five classrooms and three middle schools in the same district. I defined instances of verbal explanation as those which the teacher recognized and named as Idea Coaching, although the teachers had other forms of student-to-student talk instantiated as routine practices—the most prevalent being short “turn and talk” routines of a minute or less. The instantiations of Idea Coaching almost always followed this sequence (full recommendations for using Idea Coaching are in Appendix B):

1. Announce that the talk structure is going to involve one student keeping their ideas “to themselves” while the other student gets an opportunity to explain about a phenomenon.

2. Give each partner time to explain their thinking (this varied from 1-7 minutes).

3. “Switch” roles so that the “coach” becomes the explainer and the explainer becomes the coach.

4. Keep the adults’ participation minimal.

For the episodes of Idea Coaching in the study, students were selected based on two criteria: first, I only gathered video and audio data on students who brought family consent forms signed from their parents. Second, I focused data collection on students who were labeled as “ELL” or who were otherwise minoritized by their language practices. Thus, in the resulting sample, all of the pairs or groups contained a student of a language-minoritized background. In all, this study examines the practices of 19 students as they acted as “idea coaches”. A summary of the participants is in Table 7.

*Table 7. Participants*

<b>School</b>	<b>Teacher</b>		<b>Curricular Unit</b>	<b>Participants</b>	<b>Home Language</b>
STARR Middle School	Ms. Wirk	6 <sup>th</sup> grade	Rocks & Minerals	Raqi Barry	Spanish Chinese
Wiseau Middle School	Mr. Dobbs	7 <sup>th</sup> grade	Catastrophic Events (Weather)	Jordan David Micah Josue Archie	English English English Spanish Thai
Mayer Middle School	Mr. Sechel & Mr. Li (bilingual aide)	8 <sup>th</sup> grade	Properties of Matter	Cristian Ling Hian Min	English Cantonese Cantonese Cantonese
	Ms. Brewer	8 <sup>th</sup> grade	Properties of Matter	Steph Draco Deonte Evie Kuma Lar Maya	English English English English Oromo Thai English
	Ms. Meacham	8 <sup>th</sup> grade	Properties of Matter	John Tyler Jiang Kylie Afsana Charles	English English English English English* English

\* Indicates a student with an Individualized Education Plan (IEP) for language

## Methods

I employed critical design-based research methods (Barab, Thomas, Dodge, Squire, & Newell, 2004) in order to deeply understand how social practices and material elements of a designed intervention can influence learning outcomes. The research team embedded themselves deeply in several classrooms and the district office in order to continually improve the work of the partnership (described in Chapter 2). In particular, I sought to understand how elements of the classroom activity may have supported language-minoritized youths' engagement in scientific explanation. The research team and I used these data to inform design work and redesign the activity (Bell, 2004). Further, this study held a deep commitment to understanding local instructional theory unfolding in classroom contexts (Gravemeijer & Cobb, 2006). I spent approximately 160 hours working directly with the teachers in this study outside of classroom instruction (e.g., in professional development sessions, design meetings, etc.), and I kept fieldnotes of these interactions and the teachers' thinking. Additionally, I audiorecorded and videorecorded 130 hours of instruction, which were content logged and segmented by the kind of activity taking place. Because my research question focused on student participation in the scientific practice of explanation during the design, I reduced my data corpus to the nine episodes in which students engaged in Idea Coaching. I also gathered photos, fieldnotes, and student work from these classroom episodes to include in analysis.

In this study, I employed at least one video camera during each observation, placing a wireless microphone near students to as to capture their speech and further deduce their member meanings. My criteria for quality for including segments of video data were as follows: students' voices must be clearly intelligible, the presence of data

about what students have in front of them (a photograph or fieldnotes) in order to discern the focus of the sense-making, and data on other objects in the interactional space. These criteria allowed a multimodal understanding of youth communication and context. In all, nineteen episodes of Idea Coaching within nine small groups of students were included in this sample. This selection process allowed for comparison of activity across similar classroom routines (Goodwin, 2000) via conjecture mapping (Sandoval, 2014).

**Coding.** Within this design-based research approach, I used conversation analysis (Goodwin & Heritage, 1990) with the data sources described above as a primary framework for conducting analysis. First, I maintained a commitment to the orientations and members' meanings of the interactants within the activity at hand by using a coding scheme that was largely emergent from the interactions of the youth in the study (Stevens, 2010), although supported by literature in classroom discourse and science learning. A complete description of my coding scheme follows in Table 2. Conversation analysis allowed me to understand how students supported or did not support each other in the Idea Coaching practice because of its emphasis on adjacency pairs as a way to understand how interactional sequences of sense-making unfold (Goodwin & Heritage, 1990). Adjacency pairs are a worthwhile unit of study since activity and speech are time-bound and contextual, thus each turn of talk necessarily permits and constrains acceptable *possible next turns*. As Goodwin and Heritage describe:

“By relaxing the highly structured provisions of the adjacency pair concept to incorporate the more generic notion of ‘next positioning’ in which a current action may project, but not strictly require, one among a range of possible next actions, a much broader range of actions can be found to function in similar ways.”  
(Goodwin & Heritage, 1990, p. 288)

In a study of classroom talk, a teacher or peer's utterances function to afford and constrain the scopes of possibility available for the explainer (e.g., whether or not to expand on their thinking, revise their thinking, consider another perspective). My coding scheme thus included separate codes for the idea coach and the explainer in each situation.

When I had selected the relevant episodes from my larger corpus, I began detailed transcription using Ochs' (2006) transcription conventions in Inqscribe™ software. When possible, I labeled students' paralinguistic activity using double parentheses. After I transcribed each episode of Idea Coaching, I entered the student data line by line into Excel and began coding students' linguistic moves—with strong consideration for the paralinguistic features that guide the activity - using a coding scheme I developed out of student meanings but also with an understanding of literature in classroom talk, explanation in science class, and English language development (“L2A”) literature. A summary of the coding scheme is below.

Table 8. Codes for Youth Idea Coaching Discourse

Code	Definition	Derived from	Example
<b>Codes applied to Coach Discourse</b>			
<b>Evaluate</b>	Coach offers their judgment (either positive or negative) of a student's explanation, as teachers often do in "IRE" talk	Verplaetse (1982) Mehan (1979) Cazden (2001)	John: I like that. Jiang: "You gotta put the arrows, bro."
<b>Responds</b>	Idea coach asks a question including or referring to an idea that the explainer has just shared	Gutiérrez (1993)	Barry: "Could you say more about the sand that eats your feet?"
<b>Asks a question</b>	Coach asks the explainer a question about the science content or practice	Barron (2003)	David: Give me an example of X
<b>Hesitation</b>	Coach hesitates in responding to the explainer	Cumulative talk, Mercer (1996)	Charles: "Um" (13 sec pause)
<b>Adds information</b>	Like IRE, the coach acts as knower and shares their knowledge with the explainer OR the coach corrects the explainer		John: while exploding I think Tyler: ((correcting)) IMploding

#### Codes applied to Explainer Discourse

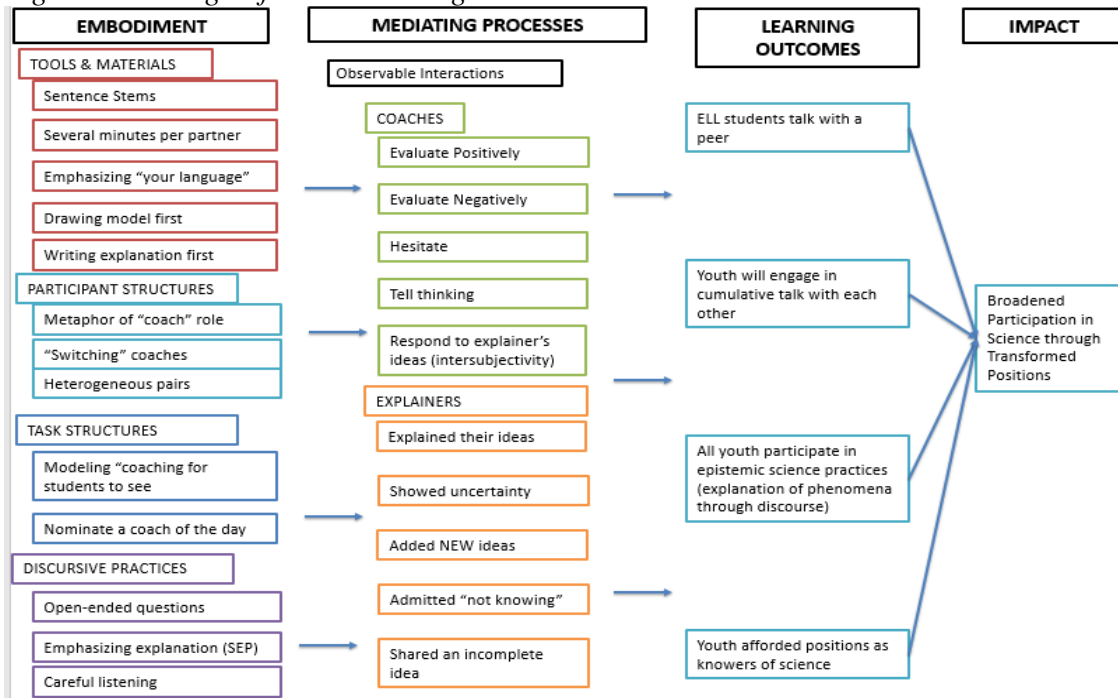
<b>Makes claim</b>	Explainer indicates what they hold to be true in a succinct, evidence-free statement.	Bell (1997), National Research Council, (2012)	Ann: The sand came from the dead animals. Raqi: The sand came from the beach.
<b>Adds idea</b>	Explainer contributes an <i>additional, conceptually related</i> thought of any veracity	(Ann S. Rosebery et al., 2010)	Jiang: When heat energy is added to the air um, the air space expands like right here
<b>Shares developing idea</b>	Explainer contributes an idea that shows conceptual development.	Bang & Medin (2013)	Ritchie: The particles on the inside um, of when something contracts it's cuz the particles...on the inside are colder than the particles on the outside.
<b>Idea on Paper</b>	Explainer restates an idea that they had already written on paper; this code was used to deduce which ideas	Emergent	

In order to study our intervention systematically, I engaged in conjecture mapping (Sandoval, 2014) to document designed elements within the intervention space of the Idea Coaching practice. Below I outline three learning outcomes that the teachers and I hoped Idea Coaching might foster. These are related to the conceptual framework outlined above, and directly represented in the conjecture map in Figure 12.

1. Language-minoritized students talk with a peer,
2. Youth engage in cumulative sense-making discourse,
3. Youth are afforded positions as knowers, and

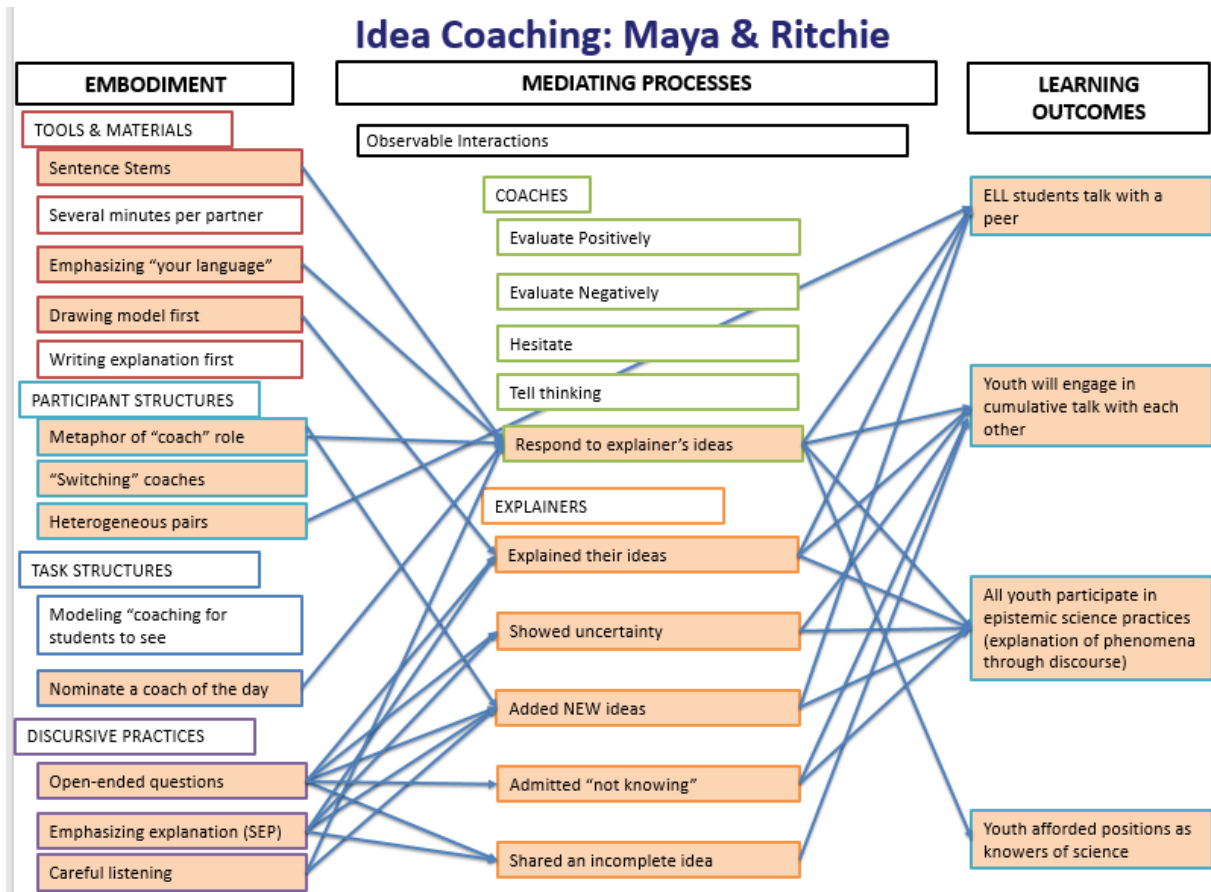
Together, these four outcomes are the larger, theoretical-yet-visible goals that the teachers in the study and I worked for. The first three goals listed are related to science practices. The last two goals are related to transformative science learning. As Sandoval (2014) indicates, columns one and two contain the interactants and the mediating processes that occurred as Idea Coaching was enacted, and these all link together with arrows so as to indicate social causality in each specific context.

Figure 11. Design of Idea Coaching



As part of my analysis, I illustrated an enacted conjecture map for each of the instances of Idea Coaching (9 recorded episodes of dyads or triads in all). For example, when Ritchie and Maya engaged in Idea Coaching, their map highlighted attention to “your language,” because on that particular day, the teacher emphasized that students could use any sentence stems they wanted to clarify and direct students’ talk. As they enacted Idea Coaching, Ritchie explained his thinking, and Maya asked him a question based on his response. In other words, she *responded to* his thinking and asked a related question. This led Ritchie to explain his thinking further, and also to indicate that he didn’t know what else to say, thus expanding the classroom science activity beyond “getting the right answer.” You can see this chain of social causality illustrated in Figure 13.

Figure 12. Case-specific conjecture map



In the sections that follow, I use descriptions of the embodiment of Idea Coaching in each classroom and its mediating processes described in this conjecture map in combination with qualitative cases of student talk to make claims about how Idea Coaching practices supported the outcomes of interest. Although the conjecture map contains elements of the sociomaterial enactment of Idea Coaching in each of the nineteen cases, it cannot represent all of the possible elements that may have contributed to achievement of the design's outcomes.

### Findings

This study investigated how students engaged in a sense-making practice we have named Idea Coaching. In particular, findings center on characteristics of successful

dyads' interactions and how idea coaching shifted student social positions in the science classroom toward meaningful engagement in sense-making discourse.

First, Idea Coaching supported language-minoritized students in engaging in the epistemic practices of science. One element of embodiment and mediation processes stood out. That element was the *intersubjective responsiveness* of the student in the coach role. In the sections that follow, I describe cross-case and within-case data to show how a responsive coach supported the other student in the dyad to verbally explain their thinking. By responsiveness, I mean that the coach intersubjectively responded to something that the explainer had said in the previous turn or turns (Barron, 2003; Gutiérrez, 1993). To be considered responsive, a peer coach must have carefully listened to the explanation and attempted to further support the explanation through some form of revoicing or responsive questioning.

Across cases, students engaged in a wide variety of discursive moves when they were assigned the role of coach. In keeping with the tradition of conversation analysis, it is important to understand what each kind of student coaching move enabled and constrained for the explainer on the very next turn. In the data for this study, I saw coaches make two kinds of responsive turns: responsive statements and responsive questions. These types, along with two examples of nonresponsive turns, are outlined in Table 9.

*Table 9. Forms of Coach Responsiveness*

Responsive Statement	Oh so you think the sand is made up of dead animals. (revoice)
	You said that weathering is important. (revoice)

Responsive Questioning	How do you think the animals became sand? (refers directly to what explainer said)
	Does anything we did in class help you explain that idea? (refers indirectly to what explainer said)
Not Responsive	Oh. That sounds good. (positive evaluation/affirmation)
	That's not what we learned in class. (negative evaluation)
	Okay I think that's it then. (ends exchange)

In this analysis, I focused on the coach's moves and whether they afforded deeper explanations by their partner. In order to identify deeper explanations, I focused on whether or not students added an idea to their explanation *after* the coach's turn of talk. In this way, I used the analysis of adjacency pairs to understand the ways that coach's discursive move opened up or constrained the explanations of their listener. After I coded for responsiveness and questioning tactics by the coach and whether or not the explainer added an idea, I found the following results. (See Table 10.)

*Table 10. Aggregate Responses to Coach Talk Moves*

Coach Talk Move	Subsequent Explainer Talk Move			
	Adds Idea	(%)	Adds New Idea	(%)
Responds to Explainer's Idea n = 62 (25.94%*)	46	74.19%	37	59.68%
Asks a Question n = 89 (37.24%)	55	61.80	40	44.94
Asks a Responsive Question n = 52 (21.76%)	34	65.38	25	48.08
Unresponsive Question n = 39 (16.32%)	20	51.28	14	35.90

**\*Do not add up to 100%; fields overlap; total of n = 239 coaching turns coded.**

The goal of this design-based study was to support students in elaborating their scientific sense-making explanations as a result of dialogue. Thus, I was interested in the relative frequency of explainers' adding of new and previously unstated ideas following four types of coaching tactics by the idea coach: (a) responding to the explainer's ideas as either a statement or a question, (b) asking a question about science content knowledge, (c) asking a question that was cross-coded as responsive (e.g., "Can you say more about the sand that eats your feet?"), and (d) a question that was not responsive. I selected these four categories because typical classroom talk features questions that are *not responsive but rote* (Cazden, 2001; Mehan, 1979; Nassaji & Wells, 2000).

When expressed as a percentage of responses, we can see that the form of coaching that most regularly elicited explainer ideas was the coach's use of a responsive framing. Seventy-four percent of coaches' responsive statements or questions resulted in explainers adding an idea to their explanation. This was higher than other elicitation strategies: asking any question, even a non-responsive one (supported explainer to add an idea 62% of the time), asking a responsive question (65%), and asking a non-responsive question (51%). This is somewhat surprising given the emphasis in literature on the asking of *questions* to support students in elaborating on their arguments (e.g., Chin & Osborne, 2010). Instead, this result seems to emphasize that *the grammatical form of the peer coach's response is less important than the intersubjective acknowledgment that the explainer's ideas have been heard*. I call this characteristic *responsiveness*, and it seems to have been related to the positions made available to the explainer through the coaching story line and cultural stereotype which allowed the speaker to continue to hold the floor and work on his idea. As Harré and Davies discuss,

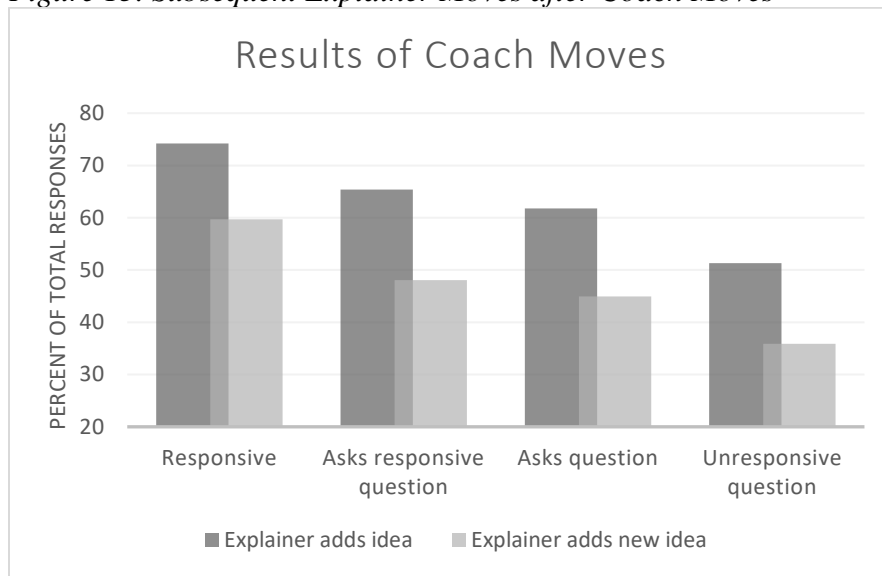
"One speaker can position others by adopting a story line which incorporates a particular interpretation of cultural stereotype to which they are 'invited' to conform, indeed are required to conform if they are to continue to converse with the first speaker in such a way as to contribute to that person's story line." (p.50)

In this youth interaction, coaching seemed to provide the cultural stereotype and story line that allowed youth to continue to explain their ideas in the presence of a supportive, coaching peer who responded to their thinking.

Additionally, I triangulated students' spoken explanations with their written ones in the cases where students had written or drawn explanations to see whether students were truly adding novel ideas as a result of dyadic interaction or whether they had previously stated those ideas in the individual work they had done in previous lessons. In a few cases, students simply proceeded to add the same ideas in conversation which they had already written down; they were simply *repeating* the thinking they had done previously. For example, Evie began her explanation to Kuma by reciting what she had written on her diagram. In these cases, Idea Coaching did not seem to support broader sense-making activity. However, I found that the overall pattern favoring responsive coaching held when I removed from analysis responses that were already written on student papers from individual work earlier in that lesson. Students added new ideas after 60% of *responsive statements and questions*. When the coach was responsive *while* asking a question, students added a new idea 45% of the time. This is compared to when the coach asked any kind of question (responsive or not); in these cases, 48% of responses elicited a new idea. Finally, when the coach asked a question that did not respond to students' previous ideas, only 35% of adjacent turns of talk were used to add ideas by the explainer. These cross-case statistics show that there was an increased

likelihood for youth explainers to add ideas to their explanations when their coaches are intersubjectively responsive to their thinking. In other words, coach responsiveness seemed to be a key mediating process in supporting youth to add to their explanations.

*Figure 13. Subsequent explainer moves after coach moves*



It is clear that the coach's responsiveness—their specific inclusion or revoking of explainer ideas—supported the addition of ideas to students' responses across 19 cases. Yet this cross-case summary does not specifically inform *how* to go about supporting students to engage in scientific explanation in ways that broaden participation for language minoritized youth. I turn now to two case studies of successful student coaches to investigate what kinds of youth activity supported the construction of scientific explanations in ways that leveraged their linguistic backgrounds and funds of knowledge.

**Case 1: Barry.** In the first case, Barry—a bilingual student who speaks Chinese at home and English at school—and Raqi—a newcomer Spanish-speaking student from Argentina—are paired with each other for Idea Coaching. The students are learning about the weathering of rock formations and the associated causal mechanisms such as wind,

water, and pressure. The teacher, Ann, has distributed vials of sand and rocks from a beach and she describes their challenge: to make a claim about the sand and explain it thoroughly, in her words, "Have a complete thought." Ann and I modeled what this explanation process would look like from the front of the classroom. In this demonstration, she explained her thinking about a vial of sand being pieces of dead creatures, and I "coached" her by asking her to make a claim and explain it using observations. In doing so, I asked her questions about her observations, such as, "So you're saying that (sand) is dead things?" In this way, I revoiced her thinking with questions and statements as she clarified and added to her initial explanation. Ann distributed a set of sentence starters to support the youth in their explanations (see Appendix A), and said, "Now you're going to do the same thing. All I want you to do is talk about ONE idea you have for your observation or inferences about the sand." Barry was the first coach in his pair, and through Barry's coaching, Raqi eventually comes to generate a powerful explanation in response to Barry's intersubjective participation. This interaction with codes and notes is included in Table 11.

*Table 11. Barry Coaches Raqi*

	<b>Speech</b>	<b>Coach Move</b>	<b>Explainer Move</b>
1	Raqi: ((full attention is forward on loupe and rocks.)) Because when I go to the beach I see these rocks too they are right in my feet. They want to eat me. So.		Uses background to state inference
2	Barry: Oh okay okay oh (looks at yellow table tent)	Affirms	
3	[00:25:09.19] Barry: Can you explain a bit more about the sand that eats your FEET?	Responds to puzzling idea the explainer has just offered	

4	[00:25:16.05] Raqi: Yeah... it's yeah it's sometimes it's warm (Barry has grabbed a loupe), sometimes it's cold, it's really has little rocks you can't even see they're too tiny they' look like they're like almost smooshy. so yeah. (Coach is staring forward, is messing with a table tent.)		Offers observation from his experience
5	Barry: So (..) what do you mean when (.) you're (.) what? (.) I'm not sure I understood what you said would you tell me more? [00:25:51.04]	Asks a question but is not responsive	
6	Raqi: About what?		Asks for clarification
7	[00:25:56.00] Barry: about what you said? ((Barry places his loupe to his eye))	Repeats question	
8	[00:26:00.27] Raqi: I said. (.) I said that these rocks are too tiny so: sometimes they are cold and sometimes they are hot and I see these ones in the beach when I go with my mom and my dad so I see them and I think they're from the beach and (puts down loupe and turns toward Barry, begins dumping the sand onto the lab table)		Offers observation & Inference based on experience
9	Barry: So yeah but how do you think the sand got here	Presses for causal explanation	
10	Raqi: Got where?		Asks for clarification
11	Barry: Got to the beach?	Clarifies	
12	[00:26:29.07] (Raqi looks at the sand on the table, wafts the smell of it to his nose.)		Observes
13	Barry: Lick it. ((Raqi places his tongue on the table.))	Dares	
14	Barry: You better lick it	Dares	
15	((Raqi moves the sand/saliva around on the table with one finger, pinches particles and places them in his mouth.))		Responds to dare; perhaps another mode of observation
16	Raqi: Oh?		
17	Barry: ((Barry looks back at his coaching tent and decides on another question.)) Okay-okay. So how do you think the sand got to the beach?	Repeats his question; requests causal explanation	
18	Raqi: ((explains very clearly)) It tastes like salt water?		Offers observation
19	[00:26:55.12] Barry: No no no no no. I'm asking ... what do you think the sand ... ((Raqi puts lid back	Determines evidence is insufficient	

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	on vial)) at what ... HOW do you think the sand got to the beach. ((Loupe falls to floor))	
20	[00:27:03.26] Raqi: I think with the ((Raqi turns in his chair toward Barry, IMAGE 3.)) is that the ocean is sometimes too hard that rocks ((claps hands together)) ((Barry puts sand in his mouth at this point, smiles, makes a terrible face)) push like uh a bomb ((makes smash movement with hands)) and it...	Begins causal explanation
21	Barry: ((students smile at Barry's trying the sand)) Ew.	Tastes sand
22	Raqi: ((continues without pausing)) They they they they . CRUSH and they make little pieces and the ocean go ((wide sweeping gesture with left arm)) like with the waves (and they go and they go and they go until they got to a place to weather? they stop and they stay and they weather? and they stay there and that's it = I think like the rocks come and come the rocks are like pushing and, not pushing, like they push they push and they crash and they make little pieces with the water and they make little pieces and they make like this so they're [00:27:50.07] tiny shells they crash they're tiny rocks (Barry is staring off into space toward Raqi and touching the table tent)) tiny stuff. (Looking at objects). ((Raqi pretends to drop the vial)) OOO OOO! ((Barry returns his attention to Raqi)) [00:28:01.26] Ahhhhhh.	Causal explanation based on inference, classroom demos.

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In this explanation, Barry's continual questioning eventually supports Raqi to build a strong inferential explanation using what they learned in class as well as observations of the sand in front of them. Yet Barry is not simply asking questions; he is responding to Raqi in intersubjective engagement (Schegloff, 1992). One example is in line three, when Barry asks, "Could you say more about the sand that eats your feet?" In this question, Barry is responsive while acknowledging that he's not sure what Raqi is talking about, and that he thinks Raqi could say more on the subject to either make himself clear or abandon the narrative he has produced so far. Raqi changes discursive course and steers toward producing a causal explanation.

Throughout the next several lines of student talk, Barry repeats the same question four times (lines 9, 11, 17, and 19)—“But how do you think it got to the beach?”—while supporting Raqi to answer. He rephrases, pauses, and offers feedback. On line 19 he prompts, “No no no no no. I’m asking ... what do you think the sand ... at what ... HOW do you think the sand got to the beach?” This responsiveness, along with his willingness to repeat the same question multiple times, indicate that he was not only listening to Raqi, but that he was considering Raqi’s ideas and determining whether or not Raqi had had adequate opportunity to explain his thinking. In other words, Barry’s persistence in asking the same question multiple times over four minutes leads Raqi to eventually flesh out his thinking at length, despite spending several turns deciding whether or not to eat the sand. As a coach, Barry is responsive and committed to intersubjective meaning-making.

It is also worth noting that there are several moments in this interaction when Barry is not using a sentence stem from the table tent that was passed out, but Barry is responsive nonetheless. One example is in lines 7 & 8 when Barry not only goes off-script but also against firm class rules to dare Raqi to eat sand. I argue that it is this uniquely child-like presence and attentiveness to Raqi’s activity that drives Barry to ask questions that are responsive to Raqi’s thinking, and Raqi engages fully in the scopes of possibility for science practices that results (including some taste-based observation).

Finally, Barry’s coaching seems to offer an example of how privileged epistemologies in science can work to marginalize nondominant epistemologies. Although the students were told to allow for both observation and inference, Barry here privileges and presses for more sensory observation and logicodeductive reasoning. For

Barry, Raqi's explanation of "I see sand when I go to the beach with my mom and my dad" simply isn't good enough—Barry responds, "Yeah, but how do you think the sand GOT there" signaling that the answer made sense but wasn't an explanation he thought fit the circumstances.

It is also worth noting that Barry seems to be seeking the kind of explanation dominant paradigms of school science language. Barry, although in just his first weeks of middle school, is subtly demonstrating a preference for the same ways of knowing that western science has long preferred, whether it is simply because it matches his own way of thinking or because he has learned the ways in which school science can disregard students' experiences with the natural world (Bang et al., 2013). In contrast, it was the hope and intention of the design-based study to *broaden* the participation in practices of science, and here a young middle school student seems to be narrowing the scope of possibility for his language-minoritized peer. Although this did not happen in all cases, it is a clear example of how youth can easily take up practices that marginalize students' indigenous ways of knowing.

A second example of students using responsive coaching comes from 8th graders Evie (a native English speaker) and Kuma (a student classified as ELL who speaks Oromo at home). These two youth were paired to coach each other in explaining diagrams they had just drawn on kinetic molecular theory. Unlike Raqi & Barry, these students had already practiced "Idea Coaching" with each other a week earlier, but they were also told that they could use whatever language they felt comfortable with to support their partner. The following transcript tracks what happened when Kuma, who receives support from the school for English language development, coaches Evie.

Figure 14. Evie's Drawing

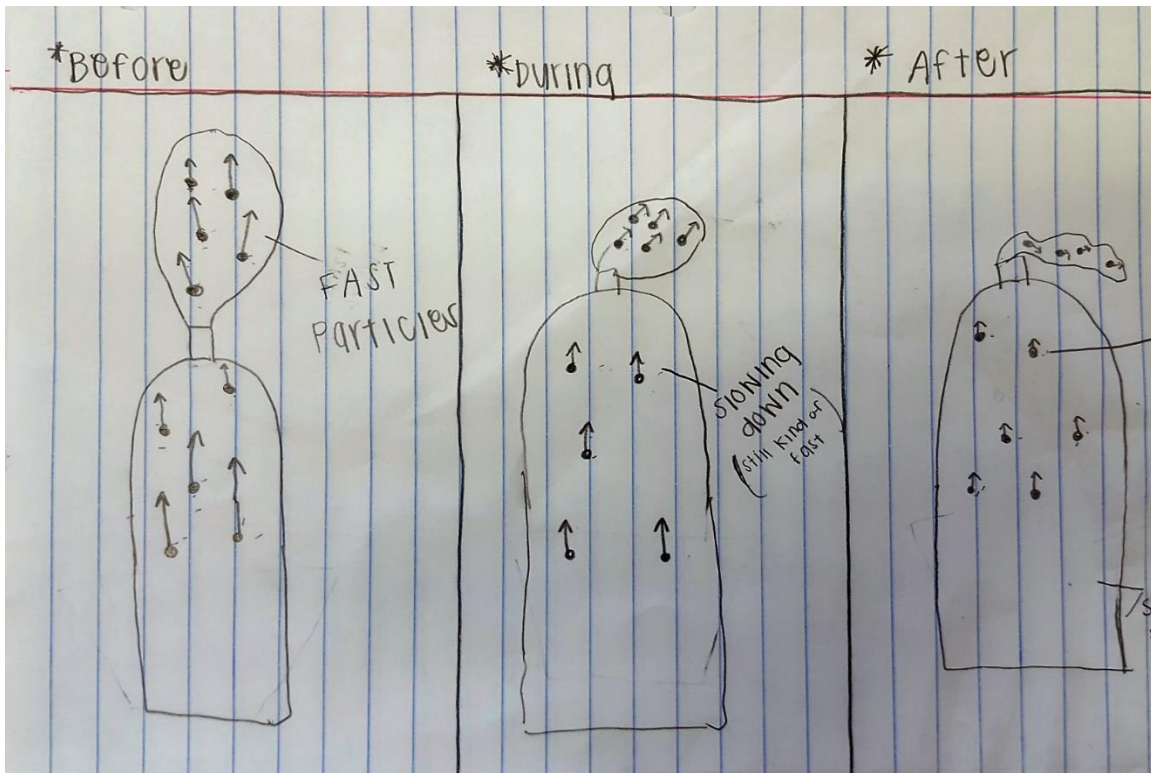


Table 12. Kuma Coaches Evie

Line	Talk	Coach Move	Explainer Move
1	[00:38:07.08] Evie: So for the before I put <b>fast particles going up to the blue because they like collide together</b> and ((inaud)) here during the during the (.) thing (.) I put like medium (uptalk) arrows [00:38:21.07] cuz <b>it's slowing down but it's still fast</b> and then after (uptalk) I put <b>small arrows cuz it's slowing down</b> and I said <b>the temperature is the same for the inside and outside.</b>		Shares four ideas she has written down (in green)
2	[00:38:31.19] Kuma: Why are some of your arrows um, and in this one before why = why some of them are long and some of them are short?	Responds to written diagram	
3	[00:38:44.21] Evie: I went to put = to make them all long but I didn't wanna like go OVer so they're all like long arrows (uptalk)		Explains her modeling practice logistically
4	[00:38:52.08] ((R looks over at her diagram)) So. Okay why this one's distance - like farther than this one?	Presses for more than a logistical explanation	
5	[00:39:06.26] Evie: Because it's like getting cooler but it's still hot so it's like farther away from the arrows and for this one it's close together cuz they're moving fast and they are colliding together more (uptalk) and this one's like still fast but it's not AS fast. Like.		Adds three ideas
6	((13 seconds of quiet time. Kuma holds table and leans over to R's diagram))	Inspects, hesitates	
7	[00:39:23.10] ((Evie looks off to the side))		Waits
8	[00:39:37.07] Kuma: What do you think is happening in the -- and the bottle system like when the the air particles is cooling down?	Asks question about science principles	
9	[00:39:49.05] Evie: Umm i think the balloon is deflating or = contracting because <b>it's getting pulled down</b> so the particles aren't hitting each other and they won't cause any = like make it expand (uptalk) so they'll deflate instead.		Explains and adds three ideas not in the drawing
10	[00:39:35.20] Kuma: you think the temperature outside and inside are the same?	Asks another principle-based question	

11	[00:40:07.10] Evie: Yeah.		Adds idea
12	[00:40:08.10] Kuma: When the air particles are cooling down?	Asks another principle-based question	
13	T ((arrives at table)): I'm wondering what are the particles out here doing? ((seems to be pointing at the outside of the model.))		
14	[00:40:08.10] [00:40:14.02] Kuma: Yeah what about this one?	Responds to thinking on paper	
15	Evie: It's -- they're different temperatures. This one's warmer and the inside and this one's like room temperature		Adds to explanation
16	[00:40:22.29] Kuma: What about during?	Responds to thinking on paper	
17	Evie: Umm, It's still gonna be warmer than THAT one but it's gonna be like closer to this temperature than that one and this one would be cooler.		Adds to explanation

Over the course of this interaction, Kuma asks Evie six questions that elicit eleven total ideas, seven of which are not represented on Evie's drawn diagram. In my estimation (as well as the teacher's, per email 161003) this constituted a very successful episode of Idea Coaching because Kuma elicited continually richer and richer explanation through responsive questioning. I now turn to the linguistic strategies in which Kuma engaged Evie to better understand how participation in this scientific practice of explanation was broadened in the interaction.

First, Kuma was responsive to Evie by relying on Evie's drawing to coach her. In lines 2, 4, and 14 Kuma's referents are indicated when he points at and uses pronouns to refer to different elements of Evie's drawing (Figure 15). These deictic referents are underlined below to indicate how he refers to objects drawn in Evie's notebook.

- (line 2) Why are some of your arrows um, and in this one before why = why some of them are long and some of them are short?

- (line 4) So. Okay why this one's distance - like farther than this one?
- (line 14) Yeah what about this one?

This questioning strategy seems to allow Kuma two dialogical advantages. First, he doesn't have to apply scientific terminology in order to use precision while engaging in deep sense-making. Rather, he can simply ask his explainer to give her thinking and in doing so supply the verbiage. This is an advantage for students who are still learning the dominant classroom dialect; they are still able to participate in scientific practices and classroom life. In this way, referring to pictures as part of idea coaching disrupts processes of marginalization that might have overwhelmed Kuma's efforts to coach Evie.

Second, Kuma takes up the position of a coach in his responsiveness; he demonstrated that he thought deeply about Evie's written ideas, and he has rather challenging questions for her. It is worth noting that the teacher uses the same strategy—relying on the drawn diagram to begin coaching Evie—when she joins the interaction in line 13, asking “What are the particles out here doing?” and pointing at the drawing. In the case of coach Kuma, the diagram seems to support his responsiveness and this prompts an increasingly complex explanation from Evie. Ultimately, Kuma coaches his partner into the scientific practice of explanation in a way that is multi-voiced, allows for broad participation in the practice of scientific explanations.

Both of these cases as well as the cross-case analysis offer an interesting counterpoint to worries about “language learners” struggling or being unable to meet the rigorous requirements set forth in the new vision for K-12 science standards. As you can see, Kuma, Raqi, and Barry—students whose native language is minoritized in the school science setting—all seem to thrive in the context of scientific sense-making explanation

within the participation structure of Idea Coaching. Kuma is able to use Evie's diagram to support his communication—and hence language learning—process. Barry is able to attend to Raqi's talk and respond to it, and even Raqi, with only four weeks' experience in U.S. schools, is able to produce long strings of talk, causal explanations, observations, and inferences that make sense. Each of these youth coaches offers a powerful counterexample to predominant narratives that language-minoritized youth will invariably struggle with rigorous science standards in comparison to their peers (O. Lee et al., 2013; Quinn et al., 2012). These youth also demonstrate the powerful meaning-making that can arise from shared diagramming (e.g., Larkin & Simon, 1987), and the possibilities that result from allowing youth to connect their science meaning-making practices with their everyday language (e.g., Duschl et al., 2007; National Research Council, 2012). I argue that this engagement was achieved by way of the altered positions of coaches and explainers afforded by Idea Coaching. Yet one can only wonder about the kinds of success they may have had if they had been able to use their native languages to explain their obviously-rich ideas; future studies should seek to understand the ways in which youth recruit their native languages or engage in translanguaging practices within the context of sense-making dialogue.

### **A Model for Positioning of Youth as Knowers**

I found that Idea Coaching the renegotiation of positions among the learners, the researcher, and the teacher. These were visible within the sociomaterial practices and mediating processes that I described in the conjecture maps above, and especially when I compared the outcomes of Idea Coaching to the outcomes of other discourse-based

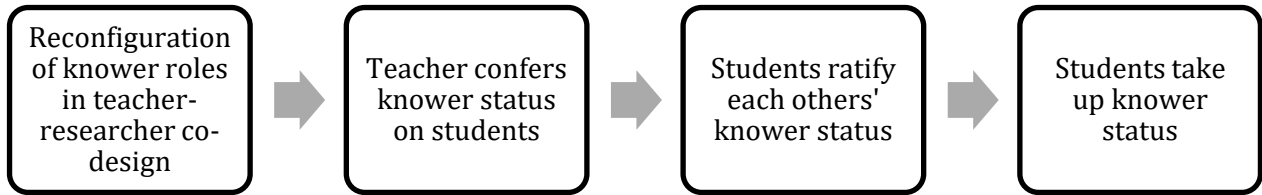
science lessons. In this section I describe how new positions were made available and taken up by language-minoritized youth: through the reorganization of knower status in these classrooms. Transforming knower status in science learning is ultimately a shift in the position of the teacher and learner relative to scientific practices (Bell, Tzou, Bricker, & Baines, 2012). In traditional K-12 classrooms, knower status is held by the teacher; the teacher has the “correct” answer or way of doing science, and the learners’ role is to repeat or guess what the teacher is thinking (D. Edwards & Mercer, 1987). This often manifests as initiation-response-evaluate, or “triadic” discourse (Cazden, 2001; Mehan, 1979; Philips, 1985), reinscribing the teacher’s role as the ultimate source of truth<sup>4</sup>. This discursive practice is so widespread, I was not surprised to observe this questioning behavior in almost all of the classrooms I studied.

However, when Idea Coaching was implemented successfully in these classrooms, students were conferred knower status by the teacher *and* their peers. Further, they took this position up in ways that expanded their participation in science sense-making practice. As knowers, students engaged in the distinctively scientific practices of substantiating and clarifying claims while remaining accountable to their peers and classroom understanding. This process can be visualized as in Figure 7, and I shall now illustrate each step in this process with case studies.

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<sup>4</sup> Studies have provided exceptions to this pattern, which were instrumental in the design of this study; see Nassaji & Wells (2003) for an explanation of how triadic dialogue can alter power structures in relation to knowledge and practices.

Figure 15. Transforming Knower Status in Sense-Making Dialogue



First, in the transformation of students' positions, knower status was conferred by all of the teachers in the study to the students as in the following cases of Ms. Wirk and Mr. Dobbs.

**The case of Ann offering knower status.** Idea Coaching as a named strategy for peer-supported explanations began in Ann Wirk's 6<sup>th</sup> grade classroom as a way to solve an emerging problem of practice. Specifically, the problem was that students did not engage with each others' ideas, but merely gave their "best answers" in sequence without being asked to critique or add to their thinking. To introduce Idea Coaching, the classroom teacher and I explained that students would elaborate and expand on student thinking; in Ann's words, coaching should support their peers to share "fully cooked ideas" with each other. After we briefly introduced the task, Ann and I modeled what it looks like to coach someone. In this way, I modeled what responsive, open-ended questioning looked like and made sure to highlight that I was keeping my own ideas to myself. Then Ann turned back to the students:

Ms. Wirk (from front of classroom): All I want you to do is talk about one idea you have from your observations or inferences about the sand. Okay? ANY iDEa about your observations or inferences about the sand. Um the pillar partner, the partner closest to the pillar, is going to TALK first. Okay? And the window partner is = their job is not just to listen but to do like Kerri was doing and *coach*

the other person until they have a complete thought. Okay? So you're not disagreeing (.) you're not arguing you are just *helping* the other person to have a complete thought. Okay? You guys ready to start. (151104, JJW, [21:28])

In Ms. Wirk's instructions to students, she emphasized their status as knowers by building a participation structure (Idea Coaching) that permitted and supported all students to deeply explain "any idea" they have related to observations and inferences about the sand. She also structured the time so that each student (pillar partner and window partner) would have an opportunity to explain their thinking. This is a dramatically different arrangement than had typically occurred in Ann's classroom to this point; typically students were concerned only with "correctness" in their responses. By shifting toward a participation structure in which students were free to share *any* idea they have about the sand, and to have that idea unconditionally supported and workshopped in dialogue with their peers, students were offered *knower* status. This knower status was reinforced by Ann's instructional emphasis on *helping* each others' thinking develop, notably in her setting the goal of "having a complete thought." Finally, because we allowed each student to have "their own turn" at both explaining and at coaching, we further indicated that all students have valuable ideas through this equal assignment of talk time. This example demonstrates several ways that the teacher (and in this case, the researcher as well) offers knower status to students.

In a second example of the adults offering knower status to youth, the teacher and I introduced the activity very differently. Mr. Dobbs, a 7<sup>th</sup> grade teacher teaching a unit on weather, typically introduced activities in terms of the logistical constraints, such as the following (151120):

“You should be able to do it again really fast. You should be able to get the important points. You're only going to get five minutes again, so there are points involved. It's gonna be important that everybody's working together and you try and get as much down as you can so there are points for each factor you put into the poster.” (Dobbs, 151120, 3:30.00)

This is an example of how students were positioned in his classroom before Idea Coaching was introduced, and it is not surprising that students spent the majority of their five minutes of work time coordinating the logistics of who would contribute *rather than* sharing their sense-making practice or negotiating their understanding with each other.

However, when Mr. Dobbs and I shifted the participant structure for Idea Coaching, we told students that they would be responsible for “pushing” each other, asking “hard questions,” and challenging each others’ thinking. This also positioned students as capable practitioners who were responsible for *advancing* their peers’ scientific practices. In this way, the adults in the room conferred knower status onto students. However, it differed than the positioning of youth that had occurred in Ms. Wirk’s room in that it emphasized “improvement” over “completion;” in all it was framed in a competition-driven way.

After this challenge-focused framing, I observed and recorded the coaching that occurred in the classroom. The two coaches I followed, David and Jordan, were competitive and harsh on their peers during their Idea Coaching, resulting in few advances in student ideas compared to the more help-focused introduction given by Ms. Wirk and her students. Take this example from David's experience coaching Micah and Archie:

*Table 13. David Coaches Micah and Archie*

David: ((Arrives at table and begins to read group's poster slowly)) heat from the warm water  
 Archie: ((to David, combative after last coach)) What you gotta say about that huh?  
 David: Can you give me an example of the warm wa  
 Archie: ((interrupts)) Hot tub.  
 David: ater ((places both hands on table, as if frustrated by being cut off, looks directly at Micah))  
 David: ((repeats)) Can you give me an example of the warm water heating the air  
 Micah: ((leaning back in his chair)) hot tub.  
 [00:42:29.12] David: Hot tub?  
 Micah: That's warm water right?  
 David: That's not an example  
 Archie: STEAM  
 Micah: YEAH it is.  
 David: What - that's that's not  
 Micah: Okay fine  
 Archie: Hot water's hot water.  
 David: ((shouting)) NO! Can you give me an exAMple of hot water - of warm water fueling a hurricane.  
 Archie: No.

In all, only one or two conceptually-linked ideas (hot tubs and steam) arise as part of David's coaching session, and the three youth ended the session very frustrated and unhappy (fieldnotes 151211). Although the social configuration of Idea Coaching did not result in ideal coaching tactics, Mr. Dobbs' case offers a useful contrast in how students

were positioned by the adults in the classroom before and after Idea Coaching. This contrast suggests that, although both instantiations of Idea Coaching gave students access to transformed positions, framing Idea Coaching as a way to “help expand their ideas” results in much more responsive coaching and more sustained engagement in the explanation practice.

Across the classrooms, nearly all of the teachers shifted their positioning of students when they introduced Idea Coaching in ways that contrasted their typical classroom instruction. The exception is Ms. Maple, who regularly positioned students as capable scientists and holders of valuable information. Because students were regularly positioned in this way, Idea Coaching merely represented a change in the participation structure; it did not require a re-positioning of students relative to scientific practice for Miss Maple.

**Ratifying peer knower status.** As a second step in the transformative practice of Idea Coaching occurred after teachers had instructed students in how to coach each other. I call this process of affirming peers’ ability to participate as a competent young scientist *ratification*. In literature in science discourse, this is the moment in discussion that appears to be most problematic and in most dyads, this ratification occurred verbally, with youth asking each other earnest questions and listening carefully to the answers. After the teachers and I offered knower status to students and assumed roles as participants (Tabak & Baumgartner, 2004) within the classroom sense-making process, the student-coaches had the opportunity to ratify or deny knower status to their peer explainers. Although we did not plan for the young people to engage in this positioning move, students enacted this decision-making in situ and its enactment was visible in the

video and audio data that were collected in each group. Specifically, this findings section asks, “What patterns existed in the process of student ratification of knower status through Idea Coaching?” This positioning of their peers as knowers occurred in most cases of Idea Coaching (although not all of them). I give a summary of how youth positioned their peers relative to knower status in Table 14.

*Table 14. Peers' Positioning of Explainers*

<b>Positioned as Knowers</b>		<b>Foreclosed Knower Positioning</b>	
<u>Coach</u>	<u>Summary</u>	<u>Coach</u>	<u>Summary</u>
Evie	Consistently responsive	Tyler (two instances of coaching)	Corrects his explainer, refuses to offer support
Kuma	Steady and responsive	Jiang (two instances of coaching)	Corrects his explainer
Barry	Responsive but distractable	Jordan	Complains about legibility
Raqi	Responsive although hesitates	David	Repeats same question over and over
Charles (two instances of coaching)	Responsive although stumbles		
Min & Lucy	Stumbles frequently but responsive		
Jiang (two instances of coaching)	Responsive but also evaluative		
Lucy	Asks few questions, but responsive		
Mr. Sechel's group	Scaffolds student's response to questions		
Maya	Asks responsive question		
Ritchie	Responsive but cuts coaching short		
John	Affirms, revoices		

In all, ten of the thirteen students ratified their partners' contributions, and they did so in different ways, through responsiveness despite various difficulties getting started within the participation framework of Idea Coaching. Interestingly, the three students who most infrequently (if at all) accepted and encouraged their partners' contributions were all native English-speaking male students in the highest-achieving class I studied. Although I do not have evidence to explain why these students in particular were less likely to position their peers as knowers, it may have to do with their past success with the traditional classroom script in which only the teacher is considered to have the "answers" (Cazden, 2001; D. Edwards & Mercer, 1987; Gutiérrez et al., 1995), and in which their envisioned storyline is to have the same ideas as the teacher. Future iterations of Idea Coaching or other strategies for supporting youth to engage in cumulative sense-making talk should directly support youth in responding to their partner's ideas or questions.

All of the language-minoritized students in the study consistently ratified their partners in a number of ways: affirming and revoicing their peers' ideas, asking responsive questions, and by asking open-ended questions. Together these three behaviors comprised a general cultural assumption that their peer can contribute meaningfully to the sense-making conversation; this stance of youth-as-knowers was introduced and promoted by the teacher within the participation structure of Idea Coaching. A successful and unsuccessful case of language-minoritized students' ratification of knower status are each discussed here.

**Evie, positions Kuma as a Knower.** I return to the case of Evie and Kuma in order to see the ways in which Evie ratifies Kuma's status as a knower and capable

practitioner of scientific explanation. She did much of this work verbally, especially by responding directly to ideas Kuma states. Here is a transcript of Evie's coaching over a short exchange (160225):

*Table 15. Evie Coaches Kuma*

- [00:35:14.10] Evie: Uhm. Tell me more about what happened DURING the process when the heat was getting least.  
 Evie: Mmhm.  
 [00:35:30.26] Kuma: It's like in the middle it, like, it's not that slow and it's not that fast.  
 [00:35:39.02] Evie: So during THIS it got slower?  
 [00:35:40.20] Kuma: Yeah it got slower  
 [00:35:40.20] Evie: Why do you think it got slower?  
 [00:35:45.09] Kuma: Cause (.) because after = after its' cooled and it, it goes from slow.  
 [00:35:58.25] Evie: But did the particles change at all?  
 [00:36:00.21] Kuma: No because  
 [00:36:02.07] Evie: How do you know?  
 [00:36:06.03] Kuma: No because the scientific principles say the air particles' number stay the same

In this short exchange, Evie asks five questions (none of which were provided by the teacher), which is remarkable on its own right. However, what she does within the questioning discourse works to affirm and ratify Kuma as a knower and capable practitioner of science. First, each of her questions contains some reference to something Kuma has just said, and this responsiveness or “revoicing” is known to have the effect of validating and supporting his ideas (Forman & Ansell, 2002). Second, her questions are open-ended, rather than yes/no or either/or questions. This has the effect of asking Kuma to think hard and to use his own words to explain his thinking. Although the students have been directed to support each other through questioning, open-ended questions contain the assumption that there is no one correct answer, but rather that the explainer can share his understanding. This is at the heart of Bakhtin's theory of *heteroglossia* and

how language is shared and learned through exchange and authentic use. As he writes in the *Dialogic Imagination*, “Expropriating (a word), forcing it to submit to one's own intentions and accents, is a difficult and complicated process” (1982, p. 294). However, in Evie and Kuma’s exchange, we can see Evie adeptly creating a space for Kuma to make this scientific explanation his own by way of Evie’s carefully responsive and open-ended questioning.

Although many students engaged in deeply responsive, dialogic questioning that allowed for transformative and heteroglossic opportunities to explain their thinking, other students chose different ways to engage their explainers, and I describe one case here.

**Tyler forecloses Knower Positions.** In an interesting second instantiation of Idea Coaching by Ms. Meacham, Tyler and John were paired up to discuss models of molecular theory that they had drawn. In their exchange, John says that he’s not sure what happens to molecular air particles that are on the outside of the drawn form of a balloon, but Tyler is more interested in copying over some work he missed from the day before (the “green paper”):

*Table 16. Tyler Forecloses John's Explanation Opportunity*

---

John: What IS happening with the outside particles?

Tyler: I can't TELL yooou ((singsong tone))

John: Arright I d'no yet.

Tyler: Okay I can't really coach you anymore, so...

John: Oh wait

Tyler: I need to copy off your green paper.

[00:25:18.11] John: And then for the after the air is cold so the air contracts so that makes it really small and tiny so the air moves so all the particles are really small I mean really slow. So that's ... I dunno what happens on the outside

[00:25:37.06] Tyler: Lemme see your green paper

---

The exchange ends here; Tyler spends the rest of the interaction focused almost solely on the green paper and John sits with no partner to interact with. Tyler chose to foreclose John's opportunity to explain his drawing in response to John's uncertainty about what's happening. In doing so, Tyler does not position John as a knower, but rather devalues John's sense-making practice in favor of a rote, individual activity that benefits his own standing in the class, but does not offer John an opportunity to engage in sense-making. Within the corpus, three students regularly foreclosed their explainers' status as knowing. They jumped in with explanations of their own (Jiang 160216), and evaluated their explainer in unhelpful ways (DBS 151120). For example, David shouted the same question over and over at the group he was working with when they didn't give him a satisfactory explanation, as described above. In another case, Jordan told his group that their drawing was inadequate or unreadable, and Jiang couldn't help but give his explainer instructions, "You GOTta put the arrows, bro." As might be expected, almost none of these coaches elicited added additional information from their explainers. These students' talk moves effectively sidelined the explanations of their peers, and, in so doing, foreclosed their opportunities to engage in scientific discourse. I argue that interactions such as these could become routinized in peer-to-peer interaction, and that this could be problematic, especially for language-minoritized youth, who are less likely to engage in sense-making dialogue in science class.

In these two examples, I have traced the transformation of positions in the classroom from the teacher to the student. From these examples, we see that the conferral of knower status among peers is not always a smooth process; in student-to-student interactions, students' coaching discourse could specifically foreclose opportunities for

their peers to engage in authentic science practice. As a final step in the conferring of knower status in student-to-student dialogue, I examine how explainers responded, or took up, their status as knowers.

**Taking up knowing.** In some way, almost all students whose coaches ratified their knower status took it up in some way. I will give two examples of how language-minoritized students responded to being positioned as knowers by their peers, one of a whole-hearted explanation, and one of a student's choice to say, "I don't know," which, I argue, makes up a new category of transformative space.

One such example was described above, after Barry has repeated his question several times to support Raqi in producing an explanation (line 22) of how sand is formed. I repeat his explanation here:

"(The rocks) they, they, they, they (.) CRUSH and they make little pieces and the ocean go ((wide sweeping gesture with left arm)) like with the waves and they go and they go and they go until they got to a place to weather ((uptalk)) they stop and they stay and they weather ((uptalk)) and they stay there and that's it -- I think like the rocks come and come the rocks are like pushing and, not pushing, like they push they push and they crash and they make little pieces with the water and they make little pieces and they make like this so they're tiny shells they crash they're tiny rocks." [JJW, 151104, 00:28:01.26]

As one watches Raqi's rushing, labored explanation, you can sense his eagerness of his voice and the earnestness of his sweeping arms. Moreover, his recruitment of taught vocabulary like "weather" support him to engage in this scientific practice.

Moreover, this explanation is not only whole-hearted, but it is exactly what the teacher and I were designing for; he focused on the science topic, engaged in practices, and used conceptual ideas to explain his understanding of how sand comes to rest on the beach.

This is an ideal combination of everyday language, epistemic practices, science topics,

and concepts (National Research Council, 2012) to foster broader participation in science for language-minoritized students.

Many students explained their thinking at length to their coaches, but I want to turn also to another way in which students took up status as knowers. It is an important feature of a sense-making community for students to feel comfortable saying “I don’t know” (A. L. Brown, 1992).

**Freedom to not-know.** In most disciplines in K-12 schooling, students spend most of their time seeking the “correct” answers, and math and science are particularly known for instructional routines that emphasize “right-answer” kinds of dialogue and written responses (Cornelius & Herrenkohl, 2004; Lemke, 1990). Subverting these norms can be a difficult process. In this section, I present findings that suggest that the Idea Coaching practice opened up spaces for students to come up against the limits of their knowing in a safe way.

Of all the students in the study, the ones most isolated and marginalized by their native language were Min and Ling, both 8<sup>th</sup> grade students from China who used a bilingual liaison full-time in their science class with Mr. Sechel. Science was one of few mainstream classes they were scheduled to attend; both spent the majority of their day in English as a Second Language courses. Idea Coaching gave both of these students a participation structure that allowed them to attempt scientific explanations in English or Cantonese. It also allowed them to indicate the limits of their knowing and areas for future learning. In this example, Lucy had been coaching Min for several minutes, and she was struggling to produce an explanation. So far, Min had been silent. When I visited her table, I prompted the more experienced English-speaker, Lucy, to ask Min a question:

KW: Lucy you should ask - ask a question.

[00:46:59.24] Lucy: Okay. Why did you draw why do you draw, uh, ((Min moves mic)) Uh, why does it does it less particles in the beginning and then more at the end?

Min: Uhhhh (4 sec pause, studies paper) I don't know

While this may seem unremarkable, it provides a strong contrast between what happens when Mr. Sechel asks her a question that she doesn't know the answer to from the front of the room during an IRE sequence; in that example, Min is unable to answer and becomes extremely frustrated, almost to the point of tears. By contrast, Min and Lucy's exchange allows Min the social freedom to not-know, which is a fundamental transformation in the positioning available to her as a recently-arrived student. However, one of the limits of Idea Coaching in Lucy and Min's exchange—as well as a few others (see coaching attempts from Tyler, Jiang, Min, and Maya)—is that the structure did not guide students to give each other linguistic or content-related cues to help them respond to a question even when the explainers were requesting support. Future designs should attend to this problem of practice, while making sure that coaches do not respond with full explanations.

Interestingly, in other examples from the corpus where an adult was present at the table, students hesitated more and indicated "I don't know" much less relative to the number of questions asked. I take this as evidence that teacher-student questioning, even when given the participation structure of Idea Coaching, bears too much of a historical resemblance to IRE patterns of evaluative speech, and students feel it is inappropriate to indicate "I don't know", even though it is a meaningful cognitive and scientific realization. This indicates that although the Idea Coaching practice is shifting small group

discourse, other efforts are needed to shift the overall classroom into a community of learners culture.

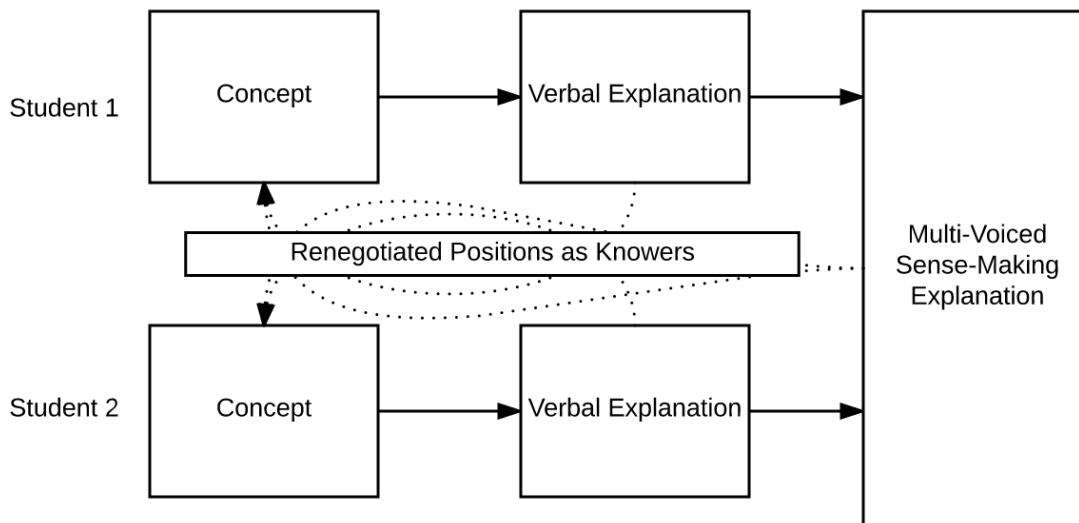
**Uptake across contexts.** Looking across the cases, and including native English-speaking students, I found that although students' hesitation and expression of uncertainty did not seem to correlate to their production of ideas, it was a common occurrence more generally. Of the nineteen instances of Idea Coaching examined, twelve contained some linguistic evidence of explainer confusion or hesitation—which can largely be taken to be a productive sign of reflection and learning. Of the seven language-minoritized students (Lucy, Hian, Min, Ling, Raqi, Barry, Josue) in the study, all but one of them took the opportunity to share that they didn't know something or that they were confused during instantiations of Idea Coaching. This freedom to hesitate, to break the historical expectation of “correct-ness”, to reflect on what one really knows, momentarily transformed the classroom into a place where all students' ideas were accepted, and where all students could participate in the practice scientifically explaining natural phenomena. This is in itself a broadening of participation.

### **Discussion and Implications**

Ultimately, this is a study of a pedagogical approach and how it altered the classroom participation structures (Erickson, 1982; Johnson, 1995) to allow for transformed student positions that permitted broader participation of language-minoritized students in science investigations and learning. The discursive role of the idea coach supported the social positioning of language-minoritized youth as knowers, which led for increased opportunities to engage in meaning-making explanations. I

illustrate this renegotiation in Figure 17. I have drawn some of these conclusions within the findings sections above, and here I will connect these findings together to expand theory and propose directions for research and practice.

*Figure 16. Sense-making Talk through Renegotiated Positions*



Truly heteroglossic spaces, such as those wherein the local funds of knowledge held by all students is truly leveraged (Moll et al., 1992), where multiple ways of knowing are valued (Bang et al., 2013), and in which all participants develop deep meaning, are difficult yet necessary to accomplish in K-12 settings (Rosebery et al., 2010). Further, in most formal education settings, emphases are placed on individual students' knowledge at isolated moments in time through practices such as grading. This is partly due to a culture of individual achievement that is strongly rooted in Western values, yet this static, individualist emphasis is not held by all communities served by public schools. Pedagogies such as Idea Coaching, which takes as presumption the

heterogeneity of student thinking, can help disrupt the marginalization of non-Western values by incorporating students' indigenous ways of knowing and supporting their development over time and among a classroom community (Bang et al., 2013). In building systems of pedagogy that align to the values of nondominant communities, it is important that we incorporate such heteroglossic pedagogies that emphasize shared knowledge rather than individually held “correct answers.”

However, transforming these positions in historically rigid environments like K-12 classrooms through heteroglossic pedagogies is not a straightforward process, as illustrated above. Once adults confer new positions and participation structures on the students, it is not guaranteed that the students will ratify those positions in peer dialogue or take up these positions. In fact, we saw students re-instantiate problematic power dynamics, such as Barry's privileging causal claims and refusing to accept experience-based narratives. What *is* necessary is the continued effort by adults to provide opportunities with pedagogies like Idea Coaching that *allow* for expanded opportunities for youth, for it takes time and persistence for these new classroom activities to take hold as routines. As my study has shown, heteroglossic pedagogies can allow for dramatic shifts in participation for language-minoritized youth. Additionally, I argue that the learning space of Idea Coaching was transformative because it also changed the role of the teacher and researcher within the Idea Coaching configuration. I take the case of Mr. Dobbs as an example. Although we struggled with our first implementation of Idea Coaching in his classroom, as a configuration it still changed our participation. During a typical lesson, Mr. Dobbs lectured from the front of the room while I took fieldnotes and spoke with students one-on-one about their science learning. However, during Idea

Coaching, the arrangement of the adults in the room shifted. First, our bodies no longer hovered from the front and back of the room; we were both crouched around tables to listen to students share their ideas. Second, we decentered our own thoughts and ideas; we did not tell students how to go about scientific practices or what to get their peers to say. This shifting of researcher and teachers' roles permitted us to deemphasize our own possession of "correct" ideas about science, and instead focused on understanding our students' thinking. Finally, Idea Coaching supported me, as a researcher, to come out from behind my camera and to engage in instruction, modeling, close listening, and formative understanding of students' scientific thinking in ways that are typical of design-based research (Bell, 2004). This shift happened in some way in all five participating classrooms.

In this DBIR study, the findings demonstrate what is possible in terms of shifting classroom practice across classrooms in an educational system when teachers engage in a district-centered educational improvement project. In the following section I lay out design principles substantiated by my study that may support educators and other designers of learning environments to build toward heteroglossic spaces for youth scientists in contemporary classrooms.

### **Design Principles**

By comparing the conjecture maps of each other nine instantiations of Idea Coaching, I was able to deduce a set of design principles which could most readily support Idea Coaching and heteroglossic spaces that encourage verbal explanation as a form of conceptual development. They are as follows:

**Scaffold specific epistemic moves for sense-making.** We made the practice of coaching very explicit for students, including modeling what coaching looks like. By providing sentence stems for coaches, sharing an example, or emphasizing micro-practices like careful listening, educators can support youth to engage meaningfully with others' ideas. Sentence stems are a strategy that is familiar to most ELL educators via SIOP (Echevarria et al., 2000) and GLAD professional resources (Pasco School District, 2014), and to the learning sciences (Scardamalia & Bereiter, 1991). In my study, Ann also recommended reinforcing the practice of coaching by asking students to reflect on their coaches at the end of the activity with questions like, "Who had a really great coach? What did your coach do that made it really great?" This metacognitive reflection can support students in improving their learning (B. Y. White & Frederiksen, 1998).

**Focus student's science explanations on completeness—not correctness.** In the classrooms where the teacher and I deemphasized "correct" answers and emphasized attempts at complete explanations, we not only saw deeper explanations, but more "correct" and complete answers. As in Barron (2003), the success of the dialogic relationship in supporting a logical answer depended on students' ability to keep the conversation moving forward, even when someone shared an incomplete thought. Theories from language learning also suggest a student's comfort in working with a peer may allow them to take risks and share their thinking in a lower-stress environment (i.e., Krashen, 1985), and peer coaching provides such an environment.

**Emphasize "their own words".** The pedagogical choice to have students practice scientific explanations "in their own words" is rooted in robust learning theories in three disciplines: those of science, and second language acquisition, and foundational readings

in human learning. In science, researchers largely agree that young people should have opportunities to practice “doing” science, including using scientific language to make claims, design experiments, add evidence, etc. In language learning, the transactional theory of language learning is supported by strong evidence that linguistic repertoires are broadened when students use language to accomplish a desired outcome (Gass & Selinker, 2008; Long, 1996). Bakhtin’s theory of *heteroglossia* notes that building one’s language about a concept is a difficult process (1986), but nevertheless sense-making can be facilitated within dialogic, scientific conversations in the classroom (Gutierrez, 2007; Rosebery et al., 2010). Finally, encouraging students’ use of their own dialects, languages, and vocabularies is essential for transforming the power structures within learning environments. Encouraging students to use their own languages for scientific sense-making subverts structures of oppression that too often marginalize non-native English speakers. This is emphasized by national policy documents as a major need for pedagogical innovation to foster equity via everyday language (National Research Council, 2012). In my study, Ms. Maple emphasized that students could use their own words to encourage their explainers; for example, she had students volunteer sentence stems that they might use to further prompt their explainers. This practice seemed to make it easier for the coach to respond to their explainer; some of the richest explanations and most responsive coaching emerged from Ms. Maple’s students immediately following her instruction to “use your own words.”

**Assume youth competence.** This study found that both the uptake of knower status and the conferral of knower status onto a peer stemmed from the teacher initially telling the class to share what they know. This positioned youth to take up a knower role

with each other. The transformation of the classroom into a more equitable space for meaning-making began when the teacher assumed both the scientific and linguistic competence of the youth. This implication has been studied across science-learning settings with nondominant youth, and it has powerful implications both in and out of school (Bell et al., 2012). Idea Coaching and sense-making conversation may be a very important first step in supporting youth to engage in verbal explanations of their thinking, even if teachers haven't shared all of the course materials with them. As shown in this study, cumulative talk allowed students to make sense of their learning little by little.

In all, this study offers a promising pedagogy for how sense-making talk can be fostered in the classroom. By encouraging youth to work in dyads, structuring their talk so that partners get equal opportunities to expand their ideas, offering familiar positions and storylines such as that of “coach,” and by de-emphasizing correctness, language-minoritized youth engaged in sense-making explanation in ways that encouraged them to use their linguistic repertoires and funds of knowledge. Future iterations of this pedagogical design should expand this pedagogy into different disciplines and encourage youth to use their native languages as they explain their ideas. Research should continue to seek designs that support equity and work for more just classroom interactions for youth from nondominant backgrounds, including ways to highlight translanguaging practices. In particular, research and pedagogy should attend to the ideologies of classroom life that caused students like Tyler to refuse to support their nondominant peers. Why is it that some students struggled to attend to their partners' ideas? What practices can disrupt this hesitation and help youth see value in helping each other? And how can more dialogic sense-making opportunities be built into cycles of classroom life?

**Appendix A: Sentence Stems Used to Support Raqi and Barry in Idea Coaching**

These sentence stems were written by teachers in the Highline School District in Washington and saw broad use in the Creston and Brentwood School Districts.

I heard you say \_\_\_\_\_. What makes you think that?

I heard you say \_\_\_\_\_. What if \_\_\_\_\_?

Can you repeat the part about \_\_\_\_\_?

Would you explain a bit more about \_\_\_\_\_?

What do you mean when you say \_\_\_\_\_?

I'm not sure I understood \_\_\_\_\_. Would you tell me more?

## Appendix B: Protocol for Idea Coaching

Pre-teaching (For the first time you do Idea Coaching)

1. Brainstorm, as a class, the characteristics of a good coach. “Patient, responds to what you need, during the game stays on the sideline, supports you to do your best, loyal, supportive, etc.”
2. Tell students, “Now you are going to coach each other with science ideas. When you are the coach, *your* ideas have to stay on the sideline. Your job will be to listen carefully to your partner to help them move their ideas forward, to be the best scientist they can be.”
3. If possible, model this, using a student as an explainer and the teacher as a coach. Ask something easy, like, “Could you explain how you got to school today?” The Teacher/Coach should press for detail, especially around unclear terms or parts that aren’t fleshed.
4. If possible, the teacher should add some commentary about how they are making decisions about what to ask. For example, call a quick time-out and explain, “Wow. It’s really hard not to tell the explainer how I got to school today, but I’m trying really hard to get these ideas out of my explainer.” Also, “I’m not telling the explainer why their ideas are bad.”
5. You can test this out as a whole class with an easy question to practice:
  - a. *Example: “What would your dream job be like?”*
6. You can also have students edit the conversation prompts so they sound more authentically teen-like.

For regular, every-day idea coaching:

7. Pass out the conversation table tents to the coaches.
8. Coaches can self-select who goes first, with the most confident student explaining first to seed the other student with ideas OR you can say “person closest to the window goes first” etc.
9. Designate an open-ended, explanatory question that students should talk through. It is helpful if this is about something students have already thought about or examined. A good point to do this is after a lab, demo, or observation.
  - a. *Example question: “What did this lab teach us about pressure/respiration/convection/etc.?”*
10. **Present the question** you want students to talk about as a whole class. Repeat it once so everyone can hear.
11. Give the room **time to think** about it. (A few seconds is fine, but you could expand this to a pre-write if you prefer.)
12. Ask the idea coaches to ask their first questions. The rest of the students are explainers.
13. Move through the room and listen carefully. Try not to interrupt.
14. When the conversations slow, ask the explainers to tell something helpful their coach did.
15. Have the coaches give their explainers a “very coachy high five.” (or something else) :)

16. Switch coaches and repeat.
17. Ask class to nominate a coach of the day/reflect again on their coaching practice.  
Listening to each other is really, really hard. Especially if you have a big idea of your own.
18. Coaches give explainers a “very coachy high five” or “tell your explainer, ‘you’re my MVP!’”

### **Chapter 5: Responsive Listening as a Transformative Dialectic**

The studies in this dissertation separately ask questions about the treatment of language-minoritized youth in three ways: as adults organize and prepare themselves to serve them, as classroom activity is designed to support their participation in science practices, and as youth interact with their peers. These studies have examined different phenomena across these linked phases of educational work and draw separate conclusions, yet there are common threads and implications that extend through this coordination of activity. I will contrast them briefly before I take them together.

Chapter two, “Organizing for Equity: How a Science Research-Practice Partnership Developed an Equity Initiative to Support English Language Learner Students,” found that professionals from different sectors of educational work engaged in a continual redefining of the object of activity, in this case an initiative to promote equity for students designated as “English learners.” Enacting a shared equity goal for these students proved difficult, but eventually the partners in the study came to focus professional learning on supporting students to make sense of science through talk. The emergence of science talk as an equity strategy was complex, and in the first months of implementation the goal of equity became muffled—for a range of pragmatic reasons—as we implemented science talk. However, over the first fifteen months the talk strategy became solidified and we were able to make its connection to equity-centered instruction for language-minoritized students more clear. I argued that the solidifying of this strategy did not come out of one mind, one history, but rather that subjects’ histories mattered in the contested space that involved competing initiatives, shifting staff, and differences in pedagogical models for professional learning. Further, working on a politicized object

such as the support of language-minoritized students brought our values into consideration and eventually helped us negotiate and act on an ideology of praxis that collectively positioned language learners not as deficient, but as competent. I argued that this negotiation of values was part of an axiological innovation that would not have been possible outside the shared problem space of the research-practice partnership arrangement. This process took considerable time, commitment, and coordination from the partners, and the research-practice partnership was a helpful arrangement for accomplishing this shift.

The study featured in Chapter 3, “‘What Great Ideas:’ Negotiated Positioning among Language-Minoritized Youth in Science Class” found that three language-minoritized students in a diverse classroom responded to the positions their peers offered in different ways, and their participation in science practices could be narrowed or invited by these interactions. Raqi and Ziling both had their scopes of possibility constrained by their peers, but they heard and responded to these moments of adverse positioning in remarkable ways. First, Raqi resisted the position of a troublemaker by relying on the participation structures of the activities of a “gallery walk,” in which he was positioned as an expert and tasked with sharing his ideas with visiting students from other groups. Raqi was also problematically positioned by his peers as a student who causes problems and doesn’t want to succeed in school, and the video record documented ways that Raqi worked to resist these positions in science class. Ziling, also resisted adverse positions relative to science practices, especially having his participation ignored by other participants—a common occurrence for many language-minoritized students. In one instance, he actually prodded his classmates with a pencil and raised his voice in order to

gain the floor or to have his questions answered and to be able to participate in science investigation and engineering design practices. In this way, Ziling heard and spoke back to discursive moments of marginalization, even though he was only in his first few months in US schools. In a final example, Pilar seemed to acquiesce to a position on the sidelines of science activity, making good recommendations to her partners that went unheeded. Of the students studied in this section, Pilar seemed to have the strongest conceptual ideas, but her proposals were least likely to be executed in the group.

I argue that these multilingual youth showed remarkable resilience, and that in many cases the centrality of student ideas within the activity structure allowed youth to renegotiate problematic positions. I concluded that educators should think of ways to foreground ideas of youth and design classroom activity around these ideas in ways that allow all youth to participate. These cases offer evidence that youth can use participation structures of classroom activity to counter adverse positioning relative to science practices.

The third study, “Idea Coaching: A Pedagogy for Transformative Science Talk Among Language-Minoritized Youth,” explored how to productively shift youths’ practices for talking with their peers towards sense-making of ideas—and how this talk may have supported or constrained the scientific responses of their peers. Each of the dyads in the study included at least one student designated as a current or former ELL, and the pairs were able to support each other in extended meaning-making discourse which opened up linguistic practices as well as science sense-making. Further, there is evidence that the introduced pedagogical practice of Idea Coaching generally promoted a useful participation structure that positioned youth as knowers and allowed for their

earnest, cumulative talk in ways that expanded their shared sense-making and conceptual learning. In that study, evidence suggested that the *responsiveness* of the listener often mattered more than the kind of question they asked in eliciting an explanatory and scientific response from their partner. This study extends previous research findings about pedagogies for language learners by offering evidence that conversations should not be shallow and rote, and that students' linguistic repertoires can be expanded through pedagogies that value sense-making. In this study, dialogues opened up in more extended sequences of sense-making and more complex ideas when listeners responded to and revoiced the explanations of their peers.

This study also highlights processes for supporting youth to encourage each others' explanations through a chain of positioning moves that extend into the dyadic interaction. I argue that first, the teacher regularly positioned youth as capable sense-makers and explainers of their ideas. After the teacher framed the activity in terms of youths' joint sense-making (and not competition), youth were able to position each other as knowers within the dyadic interaction. Finally, the youth explainers could take up this position and more fully explain their thinking. In some cases, taking up a position as a knower meant admitting when they didn't know something, or that they didn't know how to explain something in English. This renegotiation of positions allowed language-minoritized youth an opportunity to, as one teacher put it, "have a complete thought" by talking it through. This study is further evidence that idea formation and conceptual development can be supported through the scaffolding of cumulative talk. The study also provides a set of case studies of how classroom cultures can be cultivated to be more inclusive spaces of shared sense-making and learning.

### **The Transformative Work of the Dialectic**

All three of these studies feature a commonality: the transformative power of the dialectic, the notion that when two differing ideas are placed in tension, both are fundamentally changed through social interaction. The dialectic has deeply influenced the learning sciences (through the work of, for example, Hegel, Marx, Vygotsky, Wertsch, & Cole), and this dissertation bears out this influence: I have illustrated the complexity and eventual productiveness of tensions in power-laden micro-interactions and through long-term ethnography of a partnership. Although dialectical learning is a fundamental premise for Vygotskian theories of human learning, the present body of work adds contextual richness to the ideas of the dialectic by showing how it functions in social processes of disciplinary learning in these K-12 environments with some of our most vulnerable youth.

The dialectic I am most concerned with, as an issue of ethics, is perhaps one of the most common and basic to the learning of our species: that of truly mutual, responsive listening. Indeed, the act of not-hearing someone can be considered an injustice in its own right (Fricker, 2009); manifested in a classroom, not-hearing can mean silencing, assuming incompetence, privileging a subset of voices, or foreclosing youths' right to make sense of their learning. For language-minoritized youth, this silencing can be particularly pronounced and damaging to their identities as learners; even our policies have rendered them voiceless by disallowing their native languages in many K-12 classrooms (Hakuta & McLaughlin, 1996; Hakuta, Santos, & Fang, 2013; Hopkins et al., 2013). This body of studies—and in truth, my career—represents an effort to highlight their voices, their competence, and their struggles by cultivating systems that

can support a liberatory pedagogy for students—rather than minoritize them. Design-based implementation research, in particular, allows for this close collaboration that can help support more sustainable, long-term shifts in systems.

To the field of the learning sciences and science education, I envision this work as a reminder that human learning is not simply a matter of students matching words with concepts, but that there are social configurations that can support deep conceptual change among learners fostered by verbal interaction. As Vygotsky reminds us, “Thinking in concepts is not possible in the absence of verbal thinking” (1978, p. 131). At its most hopeful, this body of work is a proof that we can learn to prioritize youths’ ideas at district-level scale over those of canonical science, giving a greater number of students space, time, and structure to take science learning truly into “their own mouths” (Bakhtin, 1982, pp. 293–4), and through district-level support and classroom sense-making opportunities, support more equitable learning spaces for language-minoritized youth.

The first example of this poof of possibility is the Idea Coaching practice, a classroom pedagogy that supported youth in leading each other in concept-centered conversations. Although I studied the practice in five specific classrooms, teachers reported enacting Idea Coaching seventeen times in the subsequent school year, and 27 teachers reported wanting to use it in their instruction. In science education, student talk and its relationship to conceptual change has been well-studied, but the notion of designing learning environments for *responsive listening* has received less attention. The second and third studies in this body of work show how language-minoritized youth can respond to being positioned by their peers as capable of science practice. Both of these

studies offer evidence that responsive listening may benefit language-minoritized youth by encouraging them to engage deeply in scientific practices.

The second set of social structures that can emphasize learning through responsive listening is within the research-practice partnership itself. The second chapter makes the case that our partnership generated dialectics or knotworking efforts across research and practice, as a result of including professionals with the wisdom of practice working alongside those with knowledge of research. For professionals who want to develop institutionalized routines to better support English learners across educational systems, research practice partnerships provide a strong way to bring the two knowledge bases together around pressing problems and priorities of educational practice.

### **Limitations**

This study is limited by my positionality as a researcher in these contexts, a limitation which I addressed in chapter 1. My conclusions here are also limited by the methods which I used, namely the qualitative ethnographic and discourse analysis approaches that I took. I sought to understand the particular elements of our partnership work that allowed for larger scale change in pedagogy in this partnership, and therefore my conclusions are not generalizable to other projects, districts, or education endeavors. Indeed, this dissertation simply seeks to be “a test case for the possible” (Bang & Bell, personal communication 1/13/2015), asserting that with *these* circumstances, *these* social structures supported certain outcomes.

### Future Directions

Certainly, the idea that dialogue enriches learning is not a new one. Yet, responsive listening and even cumulative sense-making talk get meager attention compared to other linguistic practices, such as “explanation” or “argumentation,” which both made it into two national-level sets of standards in the early 2010s: the Next Generation Science Standards (NGSS Lead States, 2013b) and the Common Core State Standards (NGACBP & CCSSO, 2010). I am not arguing that responsive peer listening should be a national standard, but I do argue it is a signature of exemplary pedagogical praxis. More generally, I suggest we stop collectively overlooking its critical importance in fostering more just educational environments. The studies in this dissertation suggest that researchers, practitioners, and policymakers might also consider the role of responsive listening in building classrooms that are more equitable while being scientifically rigorous and intellectual. Moreover, they might also try to engage with others who do not see things from their same perspective; the knotworking effort described in chapter two is an example of how the researchers and practitioners *heard each other*, adding complexity to our equity effort, making way for new solutions, leveraging and building internal human capacity and tools, and helping model a way forward. In chapters three and four, youth heard each other in order to counter adverse positions and to think deeply about science concepts. I will now offer a short list of considerations for designing environments that foster this responsiveness.

**Put someone else’s ideas first.** Whether this is in a conference room or a 5<sup>th</sup> grade classroom, sense-making dialogues were often most productive when listeners

prioritized the sense-making of their collaborators. My own fieldnotes are riddled with reflections of things that I wanted to say in meetings that I didn't get to speak out loud: a testament to how I prioritized my own agenda and goals rather than being fully present with my collaborators. When activities were organized around deeply hearing other perspectives, such as in idea coaching, the social script of the classroom shifts from one of getting a correct answer for a teacher who is controlling the flow of information (A. Edwards, 1980) to one where youth truly value and generate deep explanation among themselves. This is simultaneously a shift of script (e.g., Gutiérrez et al., 1995) and a shift of classroom values: responsive listening helped shift the goals within the classrooms here from "I know the answer" to "your thinking is interesting."

**Back up to clarify.** In this study, we taught youth to say, "Wait – are you saying \_\_\_\_" when they didn't understand their partner's thinking or if they needed something clarified. This generously allowed their partner a chance to restate their idea or "back up" and add details. The adult corollary to this "let me back up" talk move was to ask partners to talk through their objectives and goals if we didn't understand each other. We did this in several ways: by holding debrief meetings (fieldnotes, 161222), by revisiting our goals in meetings, and by revising our strategy for supporting ELLs looking forward. Another way to say this might be to bring everyone's ideologies forward so that all motivations are more clearly understood as implementation decisions get made.

**It's not a competition.** Collaboration, or the notion of working *with* a colleague rather than trying to advance your agenda at the cost of theirs, seemed to make a difference in the quality of interactions for both youth and adults. In an educational system that grades and rewards individuals for their success on competitive measures,

such as getting into top colleges or earning valedictory awards, we saw youth struggle to take on the mantle of “helping;” one coach even resorted to angrily shouting their “coaching questions” at the others in their group to try to make them say what he presumed was the right answer. For the adults, we experienced productive, collaborative meetings on the ELL agenda other ELL professionals were able to collaborate with the science team; they helped guide and shape our agenda. Prioritizing the ELL work in the grant and waiting for the appropriate opening for the involvement of district ELL staff opened up a space for generative collaboration (as reported in chapter two).

**Recognize power.** No two people are set out as equals in a conversation. Even when participants have seemingly equal social status in terms of markers such as race, gender, language, or class, they can still be marked and marginalized by the kinds of things they *know* (Fricker, 2009). In the studies here, some participants were tenured faculty, others (like myself) were graduate students. Some were district leaders, others first-year teachers. Some were native speakers and some were in their first months in English-only schools. These circumstances can undergird differential access to social capital and even the opportunity to make sense of learning in school (e.g., Valdés, 1998). Chapter Three of this dissertation offered examples of how language-minoritized youth can be generatively positioned in peer relationships. One way to flip this script is to reimagine classroom life in collaborative, noncompetitive ways (described above) in which students collectively generate and talk through deep conceptual ideas without the conversations being controlled or moderated by the teacher.

In this dissertation, I have offered evidence that the simple act of listening and attending to the ideas of others is a very powerful practice for fostering justice-centered

educational spaces. These design guidelines—put someone else’s ideas first, back up when you don’t jointly understand, attend to power in the interaction, and prioritize collaboration over competition—may be useful in supporting responsive listening in many contexts as well. In an increasingly polarized public citizenry, responsive listening could serve to bridge divides and promote more just development of our ideas.

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## Chapter 2

