Equity Conscious Instruction in Problem-based Multilingual Science Classrooms

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Abstract

Equity Conscious Instruction in Problem-based Multilingual Science Classrooms

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This dissertation examines the instructional and relational moves implemented by an equity-conscious teacher in service of supporting discursive participation among her English Learners specifically in a problem-based science classroom. The research included also examines the evolution of discursive participation among English Learners as well as the nature of collaboration among English Learners and their English Fluent peers.

Initial findings suggest that there were productive, unproductive, and problematic responses to the teacher's caring approach. Students saw the teacher as approachable and accessible which resulted in students seeking the teacher out, which in turn meant that the teacher was able to scaffold instruction for her students. Students recognized and appreciated teacher strategies, but

did not generally take up or adopt her instructional supports when working with their peers. English Fluent students shielded English Learners from more rigorous participation in an effort to prevent them from feeling uncomfortable. Furthermore, English Learners and their English Fluent peers defined “help” in the context of group work differently.

The implications for this work include further addressing the ways in which teachers support and scaffold science instruction, thinking more critically about the ways in which teachers are explicit in modeling instructional strategies, and working with students to better understand the implications of differences in the ways that they define help and collaborate.

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ACKNOWLEDGEMENTS

When I was eight, my father was accepted to USC as a doctoral student, contingent upon his successful completion of his Master's at Boston University. That summer he wrote and wrote and wrote and wrote. And when he was done, he rented a van, loaded all that we had into it, shipped me off to my grandparents, and embarked upon a cross-country journey with him at the wheel and my step-mother proofreading the final draft of his 125 page thesis on Ingmar Bergman. In Chicago, the van was stolen along with the only copy of his handwritten. At eight, I had no way of knowing the un-doing of his soul that this loss triggered. I do now. Maybe.

Even though I wasn't there, I imagine the thirty-two year-old version of him, crazy, wacked-out curly hair whipping in the whirlwind of open windows and endless possibility, crafting the story that would move people to laughter and tears and win the hearts of Academy voters… He tried to convince USC that he was paperless but worthy. He tried to unbreak what was unfixable. Broken heart and all he taught me to love baseball and jazz and perfect imperfections. But most importantly he taught me that I had something important to do and that it was my job to figure it out and go do it, because if I didn't then it wouldn't get done, and wouldn't *that* be a shame?

When we were children, my father called me the Public Defender, and my sister the Professor. Funny that, all these years later, Susan is a fierce legal advocate for individuals who are too often overlooked and marginalized, and I am the teacher. I am the teacher because of Nancy Davenport, H.R. Taylor ("You can call Mr. Taylor, or you can call me sir."), Coz DiFazio, and Deb Thorstenson; innovative teachers and coaches and healers, all. I am the teacher because of Danny McGean, Meera Kallapura, Jeffrey Stix (or are you Eric?), and Ebony

Middleton; leaders, gamechangers, and caretakers, all. In fact, there are hundreds of names for the hundreds of faces that made me glad, every day, to call myself teacher.

No one does this alone. There is no way to adequately or thoroughly acknowledge everyone. But let me try.

I owe the deepest debt of gratitude to Katharine and her students who every single day shared their most vulnerable and genuine selves so that we all might learn something. The grace and humor with which they all – especially Katharine – approached our relationship gave me the confidence to trust that their stories would resonate with others in the same way that they resonated with me. I felt welcome in their midst every single day, and I carry them with me.

My sister has been a rock since she was five. At some point, I really gotta figure out how to return the favor. And Steve, I'm so grateful that you love so deeply, and live so fully.

I cannot even imagine what this would have been like without Paul and Annie. I mean, seriously. What? No.

Reg, Katharine, Lena Logan, and Henry gave me a roof over my head. And hugs, dinner, book reports, hugs, violin & trumpet performances, and hugs. We should have the Teletubbies over for dinner realllll soon.

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Andy Shouse is one motorcycle-ridin' badass with a heart of gold and a vision for the most concise argument. I am better because of you.

And finally, Mark Windschitl is the most amazing, compassionate, faithful, honest, and devoted advisor a person can have. Science teachers and learners owe him. Big.

DEDICATION

For my dad, who *should* have been the first in the family to earn a PhD.

and

Connie Fix, who certainly saved my life.

Introduction

There is a pressing need to address the complex issues that arise as a result of the increasing diversity of learners in science classrooms, and the persistent gaps in achievement they experience. Many studies focus on the experiences of English Learners[1], science instruction, and the use of innovative curricula, but not together. In particular, there is very little research that examines the relational and collaborative experiences of English Learners in problem-based science classrooms. With the advent of Next Generation Science Standards and a broader call for equity in classrooms, schools are looking to problem-based curriculum to draw *all* students into deeper and more authentic and rigorous science education.

Within this context I am interested in the relationships that educators and students cultivate in the process of teaching and learning because a better understanding of these interactions will help us to better serve our most vulnerable children. My goal is to learn from Katharine Bryant[2], a fifth-year high school teacher who has taken an intentional equity-stance for her English Learner students, and her students, English Learner and English Fluent alike, in their problem-based science classroom.

This dissertation is an attempt to understand the experiences of English Learners in Katharine's multilingual, problem-based science classroom. In order to do that, I examine these experiences from three different perspectives: that of the teacher, that of the students, and finally, that of the researcher.

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[1] I want to acknowledge that there are many ways to identify students who do not speak English fluently, many of which carry implications about student perception and ability. My use of the term English Learner is meant only to, as simply as possible, let the reader know that I am referring to a student who had been assessed by trained members of the Pacific School District and was at the time receiving English Language Learner support services. I made a decision to spell out English Learner because I believe that students should not be reduced to an acronym. I dropped "language" from the term in an effort to streamline.

[2] All names of people and places are pseudonyms.

At the end of the 2012-2013 academic year, Katharine came to realize that when her English Learner students were successful, more often than not it was because of what *they* did, instead of what *she* did. Katharine sees herself as an advocate, collaborator, and facilitator with a specific set of skills that enable her to invite English Learner students to full classroom membership by scaffolding participation in a way that does not reduce the intellectual rigor of the work at hand. This became her "non-negotiable" equity stance over the summer preceding the study, a stance that remained quite durable throughout the year.

Collaborating with Katharine was a rare opportunity to follow the movement of a teacher's idea unfolding – equitable teaching and learning for her most vulnerable students – from the ideal to the realities of implementation. While it is certainly trickier to investigate all of these elements simultaneously, the payoff is in getting to see the whole by digging into what Katharine intended, what students experienced, and how they responded. Katharine had a vision for what her relational and instructional practice could look like. That vision was fueled by the hope that her students would be better for it.

Katharine's students were generous and sincere participants in this research, answering questions that were not always easy to answer.

My goal was to understand how Katharine came to her equity stance, how that equity stance influenced her instructional decisionmaking, and how students experienced her instructional practice. I also wanted to understand the nature of classroom collaboration between English Learner and English Fluent students. The examination of collaboration was of particular interest given the premium placed on it in a problem-based science context. Collaboration, the cornerstone of problem-based instruction, is a powerful classroom strategy but we do not have a clear understanding of its impact upon English Learner students in a problem-based science context.

My motivation for pursuing this research stems from my own experiences as a middle school science teacher. During my years as a teacher I leveraged relationships with students towards the goal of supporting their academic growth. I learned quickly that relationships – though powerful – are not enough. We owe it to our students to care for them as people and as learners. As educators we benefit when we have a deeper understanding of the realities facing our most vulnerable students; in this case, English Learners.

Beyond the academic and personal goals driving this research is the desire to engage the academic community in a conversation about problem-based learning as an equitable practice. I hope to achieve these ambitious goals by seeking answers to these questions:

1. In what ways does a teacher's equity stance influence her teaching and impact her English Learner students, specifically with respect to their scientific discursive participation?
2. What characterizes the collaborative work of English Learner and English Fluent students in a problem-based science classroom?

Pursuit of answers to these questions has also led me to question problem-based instruction and claims about its potential to address issues of equity. While dozens of studies claim that problem-based instruction can better meet the learning needs of struggling students, no studies examine problem-based instruction in multilingual science classrooms.

Summary of Study Design

This qualitative naturalistic case study follows one teacher and her four Biology-Chemistry classes throughout the 2013-2014 academic school year. Over the course of the school year I spent over 200 hours in Katharine's classes, observing, recording, surveying, and interacting with Katharine and her students. Nearly twenty percent of her roster were students I had known from my participation in another science class during the previous academic year. For those twenty students, that means we had spent an additional sixty hours together. I wanted to take full advantage of the longitudinal opportunity before me.

The case study approach affords a deep look at the how and why of contemporary teaching and learning events in this multilingual science classroom. A naturalistic approach requires the researcher to get close to the research subjects because they are best understood in the environment in which they live, work and learn (Matza, 1982). It also benefits from "patient, careful and imaginative life study," a commitment I had made to the teacher, the students, and the research from the very beginning (Blumer, 1954 p.8). There was very little control on the part of the researcher with respect to these events. Even as a participant-observer, I relied upon Katharine's disclosures in order to make sense of the connections between her reflective sensemaking, instructional practice and pursuant reflection. I had a certain degree of influence – though not control – with the students, which I tapped only to ensure the integrity and anonymity of their written and spoken comments. I relied upon these disclosures in order to make sense of their perceptions of, and responses to, Katharine's relational and instructional moves.

While there are multiple actors, this is indeed a single case: that of one teacher and the students whom her teaching influences. The case is unique: not many teachers take a bold equity stance to meet the needs of their most vulnerable students, especially at the risk of alienating historically successful students.

This study has the potential to reveal a great deal about the nature of teacher-student relationships and student-student relationships in a problem-based context. The naturalistic approach is divided into three stages: exploration, inspection, and confirmation. Both sections follow these stages. In Section One, the exploration of semi-structured and informal interviews with Katharine is what led to the examination of what transpired in the classroom, and how students responded. The confirmation involves triangulation of data in defense of the claims. In Section Two, the exploration of student frustration about groupwork is what led to deeper examination of English Learner and English Fluent student beliefs, perceptions, and interactions regarding their collaborative work together.

This study illustrates the experiences of English Learner students in a problem-based multilingual science classroom by painting two different, yet connected, pictures. In one, the focus is on the whole: teacher decisionmaking, teacher implementation, student perception, student response, and observing the potential shifts in student discursive practices over time. In the other, the focus is on student experiences that represent the complex nature of collaboration among English Learner and English Fluent students.

Synopsis

This dissertation includes two sections written in the style of stand-alone articles. I ask the reader's indulgence when you come across areas that appear redundant between the two sections. I explore different aspects of my data and write about these elements for different audiences ranging from teachers and teacher leaders looking for information to support individual or departmental practices, to teacher educators looking to develop in novice teachers a repertoire of meaningful classroom strategies for working with English Learner students, to researchers within the science education community who are working to advance our collective understanding of the complex experiences of English Learners in science classrooms. The structure of this dissertation is as follows:

Section 1: At the crossroads of caring and rigor: One teachers journey towards equitable teaching and learning for her English Learner students in a multilingual, problem-based science classroom

In this section I situate my study within the broad call among researchers to support equitable teaching through a relational approach, one that privileges student voice. The research focuses on Katharine Bryant, a high school Biology-Chemistry teacher, and Katharine's four classes of multilingual students as they navigate a school-wide initiative to implement problem-based curriculum. I examine the specific and intentional moves that Katharine makes to leverage a caring relationship with her English Learner students to make sure that they are heard in her class – literally and symbolically.

This is a mixed methods study of a teacher striving to integrate an equity stance for her teaching practice in which I ask:

1. In what ways does an equity-conscious science teacher establish a caring relationship with her English Learner students in order to cultivate a sense of belonging and inclusion in a problem-based science classroom, and what makes certain efforts successful?
    a. What do English Learner students report about teacher-driven strategies to cultivate a caring learning environment, and scaffold discursive participation for English Learner students in a problem-based science classroom?
2. In what ways do English Fluent students adopt teacher-modeled scaffolding strategies when working with their English Learner peers?
3. In what ways do English Learner students participate discursively over the course of an academic year in a problem-based science classroom, and in what ways does this discursive participation change over time?

Section 2: Red light, detour, speed bump, go: The nature of collaboration in multilingual, problem-based science classrooms

In this section I examine the affordances and constraints of English Learner and English Fluent collaboration in a problem-based learning context. This study can help us to better understand the support that English Learner and English Fluent students need when working together on problem-based curriculum.

In a problem-based scenario, students are presented with an ill-defined problem that has many possible solutions. By design, problem-based curriculum shifts the balance of instruction *away* from the teacher and *towards* the students such that teachers become “facilitators” more than “instructors” (Barrows, 1996). Students are expected to engage in collaborative and self-directed research, developing emergent expertise which is shared with the group. What these challenges have in common are the scientific skills and knowledge that students must utilize in order to construct, de-construct and re-construct solutions. Students have the opportunity to master discrete scientific elements like literature review, experimentation, data collection, and analysis during the process of generating the group’s proposed solution.

This process requires significant peer-to-peer collaboration, a pedagogical tool that is well established in the literature as an effective strategy to support learning (Boaler & Staples, 2008; Cohen, 1994, 1998; Gutiérrez, Baquedano-Lopez, Alvarez, & Chiu, 1999). Decisions about division of labor and approach to analysis and problem-solving are done as a group. Work is divided among the members of the group, and students are expected to navigate research and analysis individually and bring their new expertise back to the group and share it. However, very little attention has been paid to how English Fluent students are not well prepared to scaffold and support their English Learner peers, and vice versa. Nor has the literature examined how English Learner and English Fluent students *feel* about the obstacles and opportunities embedded in their linguistic collaboration.

Specifically, I ask:

1. What types of collaborative experiences do English Learners encounter while working with their English Fluent and English Learner peers?
    a. How do English Learner and English Fluent students characterize their experiences adapting to the demands of peer-to-peer collaboration in multilingual groups?

2. What informal communication strategies do English Fluent students take up when working with their English Learner peers in a problem-based environment?
    b. What aspects of intentional and incidental peer-to-peer collaboration do English Learner and English Fluent students identify as productive or prohibitive to their intellectual work?

Section 1

AT THE CROSSROADS OF CARING AND RIGOR: ONE TEACHER'S JOURNEY TOWARDS EQUITABLE TEACHING AND LEARNING FOR HER ENGLISH LEARNER STUDENTS IN A MULTILINGUAL, PROBLEM-BASED SCIENCE CLASSROOM

Introduction

Educators, and the researchers who collaborate with them, are working against a durable socio-cultural image of what science is, who does it, and how it gets done. This paper is, at its heart, a story about one teacher who tried to disrupt the notion of who gets to be good at science.

There is a current gap in the literature specifically with regard to the experiences of English Learners[3] in problem-based science classrooms, as well as in our understanding of the nuanced nature of teacher-student interactions, and student-student collaboration, in a problem-based science classroom. This naturalistic case study was carried out in an innovative high school but is situated in the broader context of the call to better meet the educational needs of our English Learner students in order to bridge gaps in achievement that have existed for decades. Instructional strategies that have come before have, as yet, failed to ameliorate those gaps; in fact, they are worse by some measures.

In this study I seek to better understand the process by which an equity-conscious teacher reasons about how to *take* an equity stance that drives her implementation of both typical and extraordinary scaffolding practices in order to support equitable classroom opportunities for her English Learner students. I am also interested in whether or not students, particularly English

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Learner students, develop an awareness of these particular moves, and whether or not English Fluent students take up any of the teacher's scaffolding moves when working with English Learner peers. Finally, I am interested in identifying connections that the teacher's moves have to the development of discursive participation (written and oral communication) among English Learner students in a problem-based science curriculum.

Specifically, I ask:

- In what ways does an equity-conscious science teacher establish a caring relationship with her English Learner students in order to cultivate a sense of belonging and inclusion in a problem-based science classroom, and what makes certain efforts successful?
    - What do English Learner students report about teacher-driven strategies to cultivate a caring learning environment, and scaffold discursive participation for English Learner students in a problem-based science classroom?
- In what ways do English Fluent students adopt teacher-modeled scaffolding strategies when working with their English Learner peers?
- In what ways do English Learner students participate discursively over the course of an academic year in a problem-based science classroom, and in what ways does this discursive participation change over time?

Background Literature

English Learner students experience durable and persistent gaps in achievement

Schools in the U.S. are experiencing a dramatic shift in the demographic make-up of their student populations. Between 1979 and 2008, the number of school-age children who spoke a language other than English at home increased from 3.8 to 10.9 million; which means that for more than one in five students between the ages of five and seventeen, English is but one language they speak every day (NCES, 2011). English Learner students, particularly those from Hispanic backgrounds, represent one of the fastest growing populations in the U.S. public school system. By 2030 it is expected that 40% of all public school students will be English Language Learners (Thomas & Collier, 2002).

International and national studies on science achievement have shown substandard performance of U.S. students overall, with gaps in achievement between English Learner and English Fluent students within the U.S. (Campbell, 2000; NCES, 2011; Schmidt, 1997). The gaps in performance between English Learner and English Fluent students on the National Assessment of Educational Progress (NAEP) Science assessment are as problematic today as they were in 1996[4]. English Learner students underperform their English-speaking peers, scoring 20-40 points below across grade levels. The data is even more striking in math and reading where gaps *increase* from grade to grade; from a gap of 25 points in 4th grade, to 41 points in 8th grade, and from 38 points in 4th grade to 45 points in 8th grade, in math and reading respectively (NCES, 2011). If current trends in student science achievement are not addressed, by 2030 we should expect that 40% of all public school students will significantly underperform their English-speaking peers.

Gutiérrez (2009, p.9) however, warns against "gap gazing" as perpetuating a deficit model anchored to negative storylines about our marginalized students. When we can no longer predict a student's success based upon a single characteristic, then says Gutiérrez, we will have achieved equity (2007). In order for teachers to establish an equity stance, Gutiérrez advocates for specific actions in schools – identifying issues of identity and power, getting to know your students, fostering student autonomy, viewing students as successful – that together establish a teacher's equity stance (R. Gutiérrez, 2009).

This can be challenging work when teachers do not share linguistic or cultural experiences. Students bring with them a myriad of life experiences that are situated in the context of language and culture. Students have a wide variety of access to cultural and economic

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[4] Science scores are scaled from 0-300; math and reading scores are scaled from 0-500 (NCES, 2011).

resources and will arrive in the classroom with varying levels of experience with science and varying degrees of comfort with the norms of scientific practice (NRC, 2007). Teachers also bring with them an equally rich – but significantly different – array of culture, resources, and experiences. This disparity is especially notable among the language differences between teachers and the students in their classrooms where, according to a 2006 Census Bureau report, 20% of PK-12 students spoke a language other than English at home, but only 11% of teachers did (Kominski & Shin, 2008 p.6). A vast majority of teachers are white, female, English-speaking, and well educated (NCES, 2009 p.6). Such differences may mean that teachers will struggle to recognize the strengths that diverse learners bring with them to the classroom, especially in science, where a premium is placed on the use of scientific language and convention. The need for culturally responsive pedagogy in science classrooms has never been more important.

All students benefit from being scientifically literate

The goal of science education is to enhance *all* students' scientific literacy; that is, to help students grasp essential science concepts, to understand the nature of science, to realize the relevance of science and technology to their lives, and to willingly continue their science study in school, or beyond school (NRC, 1996). When teachers "provide equitable opportunities, students are capable of engaging in scientific practices and constructing meaning in science classrooms (NGSS, 2013, pp. 1, Appendix D). The recently developed Framework for K-12 Science Education and Next Generation Science Standards established fewer, clearer standards and called on teachers to make shifts in instructional practice in order to ensure that all students are college and career ready upon graduation (NGSS, 2013, pp. 1, Appendix D). Science teachers facilitate the work of students to engage in the practices of science, including the use of scientific discourse.

There are less altruistic goals of the new standards as well: to produce the next generation of scientific thinkers and encourage robust economic growth. A report by the Carnegie Foundation in 2009 cited a reduction in the United States' economic edge and lagging performance of students in science as primary causes for concern that the nation would be unable to maintain innovation and economic growth (CMSE, 2009). The report challenged U.S. educators to think more broadly and inclusively about which students can be a part of this movement towards higher levels of math and science learning.

Laughter and Adams (2012) advocate that STEM be used, not to produce functionaries for our economy or to outperform other nations, but to support students' abilities to problem-solve about issues of social significance. "Too often science teachers do not see issues of social justice as being part of science, which represents a significant hindrance to ever developing a sociopolitical consciousness among science students" (Laughter & Adams, 2012, p. 1128). Given that culturally responsive pedagogy seeks to empower students to find their sociopolitical voice, students miss an opportunity to consider the sociopolitical terrain of science if teachers fail to create a space for them to do so.

New standards mean new strategies and a new call for equitable teaching and outcomes

Neither the *Framework* nor the Next Generation Science Standards mandate a particular pedagogical philosophy or curricular model. Next Generation Standards encourage teachers to foster STEM skills and practices alongside content (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014; Sneider, 2015 ix). Like the Framework and Next Generation Science Standards, problem-based learning, in and of itself, is not a curriculum; rather it is a pedagogical tool. Supported by an increase in scholarly research of the design and outcomes of problem-based learning, schools have been turning to this strategy to bridge gaps in achievement, inspire lifelong learning, produce students who are college and career ready, and invite students to be active participants in their education, elements that are not always readily apparent in classrooms that utilize a more teacher-driven pedagogy.

Project and problem-based learning affords teachers the opportunity to generate dilemmas that encourage students to investigate, explain, and resolve problems while working collaboratively (Barron, 2010; Evensen & Hmelo-Silver, 2000; Krajcik et al., 1998; Lambros, 2004). The goal is to present students with problems that are relevant to the domain of science *and* to students. This requires teachers to have deep knowledge of science as well as of their students. Problem-based instruction also gives students the opportunity to engage in the practices of science in particular – reasoning, argumentation, and explanation – in the process of finding solutions to problems. Students are presented with an ill-defined problem to solve and explain during a process of gathering, analyzing, and using evidence and reasoning. Students are capable of this work but they need to be apprenticed to these practices by teachers who have deep knowledge of them, while simultaneously understanding the needs of diverse learners (Windschitl & Calabrese-Barton, 2014).

Problem-based learning emerged as an educational tool in medical schools in the 1950's (Hmelo-Silver, 2004; Torp & Sage, 1998). Over the past two decades, there has been a growing body of research that reflects the movement of both project and problem-based units into secondary level education (Barrows & Myers, 1993; Savery, 2006; Savery & Duffy, 1995). Unfortunately that research does not include information about the participation of English

Learners, and we are left with several gaps in our understanding about the experiences of these individuals in problem-based contexts. Despite the gaps in research, some schools are transitioning to the development of a problem-based curriculum with the belief that doing so will better meet the academic needs of their most vulnerable students, including non-native speakers, children of color, and students with special needs.

Designing and implementing problem-based instruction that it is relevant to students as well as the domain of science requires a sophisticated set of skills, including content knowledge and pedagogical finesse. Teachers who are capable of navigating the space between their own expectations and assumptions and the reality of student expectations and understanding, are more likely to help students learn. When teachers draw upon their students' funds of knowledge, they send a message that they are important contributors to the classroom community, and belong to that community, as doers of science (Moll, 1992).

The power of problem-based learning lies in the possibilities afforded teachers to present students with problems that are authentic to the domain, and are simultaneously meaningful to students. Its advantages over traditional teaching include its ability to foster retention and application of new skills and understanding. Problem-based learning also has the potential to encourage students to see themselves as life-long learners as they engage in self-directed learning. Problem-based learning *can be* a learning environment where students investigate, explain, and resolve meaningful problems through collaboration (Barron, 2010; Evensen & Hmelo-Silver, 2000; Lambros, 2004).

A gap in the problem-based literature attending to English Learner students

Problem-based learning studies in higher education settings have shown that there are several potential benefits for English Learners, including increased questioning skills, better self-directed engagement, and improved confidence in spoken language (Allen & Rooney, 1998; Azman & Shin, 2011; Kang, DeChenne, & Smith, 2012). Studies conducted in secondary settings indicated deeper learning through peer-interaction and collaboration, but noticed that students continued to struggle with the structure of problem-based instruction.

Studies conducted in Malaysia and Taiwan sought to compare traditional teaching methods to problem-based instruction with mixed results, on the plus side claiming that problem-based learning may be useful in providing context for emerging literacy (Othman & Shah, 2013; Pease & Kuhn, 2011).

Research conducted in language classrooms revealed benefits that went beyond those of an academic nature, reporting that friendships that formed during the process of academic collaboration were sustained as a result of their unified purpose (Allen & Rooney, 1998). Furthermore, the discursive aspects of their collaboration – discussion and presentation – were effective in building confidence with spoken language ability (Allen & Rooney, 1998). Similarly, Le Vasan et al report that students appreciate having a voice and the ability to offer opinions and debate issues within the classroom (2006).

Problem-based and project-based instruction

There is a substantial body of literature reflecting generally positive the experiences and outcomes of English Learners in a problem-based environment within medicine and law at the higher education level (Goodnough & Cashion, 2006). Literature that examines English Learners in problem-based classrooms at the secondary level is so limited that it requires expanding the scope to include consideration of project-based learning as a proxy for problem-based instruction. Without it, we would not have much literature to reference.

Problem-based units typically do not have a set solution, whereas project-based units center around the culmination of a project that affords limited personal influence. Bothfeatures engagement with authentic challenges and strategies used to position science as problematic are similar. Table 1 shows the contrasts between project-based instruction, problem-based instruction, the vision of problem-based instruction at Cielo Vista, and the vision of problem-based instruction in Katharine's classroom.

To define project-based instruction, I draw upon the work of Krajcik (1994), and Larner and Mergendoller (2010), for Krajcik's enduring body of project-based research, and Larner and Mergendoller's attention to equity and the experiences of English Learners within a project-based curriculum. For problem-based instruction, I turned to the common themes established in the work of Barrows and Tamblyn (1980), Boud and Feletti (1998), and Savery (2006): authentic, ill-structured problems, students work and learn in small groups, teacher as facilitator, self-directed learning which is then shared with the group. Again, the focus of the work of these researchers has not addressed the opportunities and challenges of problem-based science instruction for English Learners.

To understand the vision for problem-based instruction at Cielo Vista and in Katharine's classroom, I turned to the Cielo Vista's Seven Key Elements. Note that Katharine's vision of problem-based learning is consistent with that of the school, and she privileges three of the Key Elements: student voice, culturally responsive and inclusive instruction, and authentic problems.

Table 1

Overview and comparison of project-based and problem-based approaches to instruction in general, at Cielo Vista, and in Katharine's classroom

Project-based learning described in the literature	Problem-based learning described in the literature	Vision of problem-based learning at Cielo Vista	Problem-based learning as designed by Katharine
• Real-world problem, simulated or authentic • Creation of final product, performance or event • Emphasis on student autonomy • Longer and multifaceted lessons	• Authentic, ill-structured problems • Students work and learn in small groups • Teacher as facilitator • Self-directed learning which is shared with the group	• Authentic problem • Authentic assessment • Culturally responsive and inclusive • Academic discourse • Student voice • Collaboration • Access to expertise	• Authentic problem, authentic assessment • Culturally responsive and inclusive • Student voice • Academic discourse • Collaboration • Access to expertise

(Barrows & Tamblyn, 1980; Boud & Feletti, 1998; Dolmans & Gijbels, 2013**;** Savery, 2006)

Note: To understand classroom events, and to provide context for the development of a conceptual framework, I reference the components of the equity stance taken up by Katharine: culturally relevant pedagogy, student voice, caring, scaffolding, and participation.

Equitable teaching and culturally relevant pedagogy

Culturally responsive pedagogy matters. In the late 1980's, early 1990's Gloria Ladson-Billings was in search of a "paradigm shift" (Willis & Lewis, 1998, p. 61) At the time she was troubled by the abundance of literature about student failure – particularly among Black students – that was so persistent, it was difficult to step away from a deficit model that framed all that was wrong with students. "I wanted to stop asking the question, 'What's wrong?' and begin to ask the question, 'What's right?' as a way to begin to build on the literature and begin to better prepare teachers for success with our children" (Willis & Lewis, 1998, pp. 61-62). Katharine, too, was searching for her own version of a paradigm shift, building on what she imagined was *possible* in her classroom.

"A theory of culturally relevant pedagogy would necessarily propose to do three things – produce students who can achieve academically, produce students who demonstrate cultural competence, and develop students who can both understand and critique the existing social order" (Ladson-Billings, 1995, p. 474). In a culturally responsive classroom, teachers believe that all students can learn and it is, therefore, up to the teacher to figure out how to make that happen. The teachers in Ladson-Billings' project believed that ensuring academic success was their primary responsibility. They conceptualized achievement as something beyond student performance on standardized tests, cultivating a broad range of skills that included reading, writing, speaking, computing, posing and solving problems at sophisticated levels (Ladson-Billings, 1995). Teachers who anchor their work in culturally relevant practices are, in effect, saying to their students "I have faith in your ability to learn, I care about the quality of your learning, and I commit myself to making sure that you will learn" (Gay, 2000b, p. 45).

Sometimes academic success comes at the expense of students' cultural and psychosocial well-being (Fine, 1986; Fordham, 1988) as students of color struggle with the perception of "acting white," and lacking the cultural capital for academic success (Bourdieu, 1984). This makes it all the more critical for schools and teachers to ensure that structures are in place to support the academic success of their increasingly diverse classrooms while protecting their cultural integrity (Ladson-Billings, 1995).

Culturally relevant *science* pedagogy matters. According to the National Science Foundation, 75% of all scientists and engineers are white, and 60% of them are male (NSF, 2004). Science textbooks in the U.S. are replete with the theories and discoveries of European white men, with maybe a perfunctory nod to the contributions made by men and women of color, and even rarer mention of non-native speakers. The invisibility of self takes a toll on students who do not see themselves represented in science, leading them to believe that the only way to belong is to alter who they are.

By the time students reach high school they have a fairly durable idea of what they can and cannot do, whether academic, social or political. In the current system of urban science education, students "walk into schools and are physically and emotionally forced to subdue their 'selves' and 'realities' in order for schools to maintain existent structures that ultimately function to the detriment of student engagement in the classroom" (Emdin, 2009a), which is not at all what a culturally relevant pedagogy calls for.

Teaching and learning are social endeavors that exist within a cultural context. Regardless of its effectiveness, neither is done in isolation: there is at least one teacher and at least one student, both of whom bring a wide range of prior knowledge and life experiences. As such, teaching and learning are social practices that exist in a cultural context, arguably, many cultural contexts.

The engineering of a new cultural context, for example a science classroom, is essential to the deconstruction of power held and maintained by the majority. Michel Foucault wrote about language as a device used to allow only those who spoke the language to not be oppressed. This is especially true in the sphere of science, where content-specific literacy is not only privileged but exclusive, virtually eliminating all who don't speak the language from membership – full or partial, in spite of the fact that students frequently have facility with concepts, if not the "formal" language to communicate that facility (Carraher, Carraher, & Schliemann, 1985). This privilege assumes that differences in communication skills should be viewed as a deficit, and links not knowing how to say with not knowing at all. Conversely, viewing students as having facility and privileging *all* student talk, positions talk about ideas and concepts that transcends correct use of academic and scientific vocabulary. A culturally relevant pedagogy attempts to disrupt this particular form of oppression by affording access to urban students through known language and experiences.

Carol Lee observed cultural responsiveness among teachers in the ways that they honored peripheral participation by appreciating emerging mastery as part of the process, not as a deficit of knowing (2001). "The foundations of cultural modeling assume that the culture that students bring from their home and community lives, their assumptions about schooling from prior educational experiences, and specific practices and activity within classrooms over time interact in complex ways to create a *hybrid culture* within the classroom. This hybrid culture needs teachers to believe in the endless possibility for transformation and academic success" (Lee, 2001, p. 134).

Katharine's idea of equitable, culturally relevant pedagogy began with her vision of scientific discursive participation by her English Learners in whole class and small group situations. She viewed participation in her class as the gateway to participation in other aspects of student's lives, both in and out of school. Inasmuch as Katharine certainly advocated and supported the cultivation of student voice in her classroom, she also encouraged students to find their voice and speak their truth beyond the walls of her classroom. Katharine was explicit with her students in establishing her expectation for their academic success, and her dedication to working with them to ensure their success. Katharine was also explicit in telling students that she viewed them as culturally competent, though without much articulation about what cultural competence means, or how one navigates multiple cultural contexts and the competencies that each requires and develops. And while Katharine encouraged students to question and challenge the status quo, these moments were most often relegated to specific students who were already testing the waters of transformation. Her strengths, then, were anchored to her belief that her

English Learners should be successful, and that the evidence of that success would be heard, literally.

Elevating student voice, literally and symbolically

One goal of this research is to attempt to honor the complexities inherent to the intersection of English fluency and scientific literacy while articulating the experiences of English Learners in a multilingual problem-based science classroom. The work included in this paper examines the implications of student voice – both literal and symbolic – for English Learner students in a multilingual problem-based science classroom through two lenses: 1) that of the teacher, and 2) that of the students. More specifically, it is an examination of specific teacher moves made with an intentional equity stance towards the support of discursive participation for English Learner students, and the experiences of three Intermediate Level English Learners throughout the academic year.

There are three ways to think about student voice: socio-emotional, socio-political, and academic. Researchers have documented the importance of teacher-student and peer-to-peer relationships, with ample evidence that students benefit from having caring teachers and experiencing inclusive interactions with their peers (Gay, 2000b; Hughes & Barrois, 2008; Noddings, 1984; Sage & Kindermann, 1999). A recent body of research has emerged that speaks to the role that students can play in school governance and reform (Cook-Sather, 2002; Fielding, 2001; Mitra, 2004). What is less understood is the emergence of literal scientific discourse by means of the teacher honoring and privileging the academic voice of English Learners.

When I speak of academic voice, I mean to push beyond the idea that *any* student voice is good student voice. Given the choice between students being heard or not being heard, being heard is almost always preferred. Rather, I examine student voice in the form of discursive participation that reveals the student's deeper connection to domain-specific discourse, whether it is spoken, written, performed, or illustrated. Though not unique to science, the practices of analyzing and interpreting data, utilizing evidence to support or challenge a claim, engaging in reasoned argumentation and explanation, elevate student voice from simple participation to scientific discourse. This is hard work and not always representative of what is happening in science classrooms. With specific, intentional, and transparent support, it is possible.

The work of many equity scholars have shown us that English Learner students find success when given the opportunity and support to pose their own questions that are relevant to them as individuals and as members of a greater community (Lee, 2005; Nasir, Roseberry, Warren, & Lee, 2006; Roseberry, McIntyre, & González, 2001; Warren & Roseberry, 1993; Warren, Roseberry, & Conant, 1989). These cases of success are too far and too few in-between.

Because the practices of scientific argument, explanation, and the evaluation of evidence differ from those in everyday life, students need to learn domain-specific practices and language for productive participation in the discourses of science. Students need to feel supported in order to take academic and social risks, support that can be both relational and instructional.

A relational approach to differentiating instruction: caring matters in science classrooms

There is a strong relationship between student perception of teacher caring and learning outcomes (Gay, 2000b; Hughes & Barrois, 2008; Lessard et al., 2008; Noddings, 1992; Van Galen, 1996; Wentzel, 1997; Woolley, Kol, & Bowen, 2009), and there is a growing body of literature that targets the intersection of race/ethnicity and caring in schools (Bernal, 2002; Lewis et al., 2012; Rolón-Dow, 2005) by pushing back against a colorblind construction of what counts as caring (Beauboeuf-Lafontant, 2002; Solorzano & Yosso, 2002). There has also been a push to identify other factors that may interact with language skill and therefore increase educational mobility among Hispanic youth (Hakuta, 2011; Hakuta & August, 1997; Valencia & Buly, 2004). One of these factors, the social dynamics of learning, is listed prominently as an important yet often overlooked competency for teachers of Hispanic students (Gándara, Rumberger, Maxwell-Jolly, & Callahan, 2003; Genesee, Lindholm-Leary, Saunders, & Christian, 2005).

Individuals rely upon the experiences of others to learn and are best served when teachers help them attach current learning to something they already know (Vygotsky, Rieber, & Carton, 1987). In order for that to happen, teachers need to know what their students already know, a proposition that can be particularly challenging when teachers and their students do not share a primary language. It is a critical practice then that teachers engage in a conversation about what prior knowledge and experience is assumed and privileged, and for whose benefit it is assumed and privileged.

These relationships require a certain degree of vulnerability that may be more readily established among family members than among teachers and their students. One cornerstone of the research herein begins with a science teacher who is unwilling to allow her English Learner students to remain literally and symbolically silent, and believes that it will require a level of vulnerability on the part of her students that transcends that of typical teacher-student relationships. It is with this understanding that she sets out to initiate, cultivate and maintain caring relationships with all of her students, paying particular attention to the additional nurturing that she believes will benefit her English Learner students.

There are two facets to Katharine's caring for her students: her relational approach, and her instructional approach. Katharine's relational approach is defined by the things that she says and does to show students that she cares about them as people and as students. Katharine's instructional approach is defined by the things that she says and does to support, scaffold, and facilitate instruction. Katharine's specific relational and instructional moves will be discussed in greater detail below.

Instructional practice to scaffold learning

Because science has its own vocabulary and conventions for engaging in discourse, typical English Learner intervention and instruction – focusing on introductory vocabulary and sentence structure – may not meet the needs of emerging young scientists. Students can have a grasp of concepts long before they have mastery of a second language or the conventions of the domain (Carraher et al., 1985). Van Lier (quoted in Walqui, 2006 p.165) recommends taking a take a multi-faceted approach represented below, thus ensuring that students have opportunities to develop science-specific conventions and reasoning skills, in their native language when necessary, while concurrently learning about conventional sentence structure (see Table 2). The features of scaffolding iterated here breaks down components of instruction and invites teachers to consider which aspects of their teaching can be made more accessible for their English Learners.

Table 2

Walqui and Van Lier's features of scaffolding instruction for English Language Learners (Walqui, 2007 p. 165)

Feature	Strategy
Continuity	• Repeating concepts in multiple contexts • Variation of explanation • Using different words • Connecting concepts to personal experiences in and out of school
Contextual support	• Safe and supportive environment • Multiple forms of access
Intersubjectivity	• Mutual engagement and rapport • Encouragement to participate • Cultivation of community of practice
Contingency	• Adjust tasks when warranted • Co-construct speech
Handover/Takeover	• Student assumption of control
Flow	• Increase in complexity of challenges as students progress

While there are numerous systems at work in a student's life, "teacher support has the most direct impact on student engagement" (Osterman, 2000, p. 344). A significant part of wrestling with the complexity of the issues at hand is the deconstruction of assumptions about who students are and what they can or cannot do. These assumptions can lead to the silencing of students (and their ideas) "to the extent that they are not viewed as people with thoughts, opinions, or ideas about science or the science classroom" (Emdin, 2008, p. 240), but as students that need to be fixed by education. Katharine is attempting to disrupt these patterns in her own classroom through the implementation of culturally relevant pedagogy that elevates the literal and symbolic voice of her students.

Though there has been some disagreement about the presence and nature of scaffolding in problem-based instruction (see Kirschner et al, 2006 and Hmelo-Silver et al, 2007), we know that scaffolding is, in and of itself, an important instructional tool. Saye & Brish (2002) characterize scaffolding as either *soft* or *hard*, where a soft scaffold might include the teacher moving through the room to engage students in a series of questions that check for understanding (quoted in Simons et al, 2007). Hard scaffolds on the other hand, are those instructional moves that are concrete resources that can be used by students, like a working glossary or modified reading. Simons & Klein found that students who were in groups that either required scaffolding, or had scaffolding available to them, fared better than students who were unguided (Simons 2007).

Participation and engagement

In spite of what we know about the impact of teacher support, gaps in achievement endure; between white students and students of color; between native and non-native speakers; between "regular" and special education students (Anderson, Medrich, & Fowler, 2007; Noguera & Wing, 2006; Rothstein, 2004). Of particular concern then is the reality that students of color, non-native speakers, and students with special needs are frequently treated differently in classrooms and that teachers have very different expectations regarding the character and frequency of their contributions.

The terms participation and engagement are often used interchangeably, though to do so invites criticism for overlooking the complexity of the nuanced differences between the two. For the purpose of this research, I consider the distinction between the two to be this: participation is any form of identifiable *doing* ie: speaking, writing, performing, etc. without regard to the depth or significance of the participation or the individual's attention to scientific practice. Engagement on the other hand, attends to the nature of participation; *what* is being said/done, is it related to the task at hand, is it relevant to science?

Participation is not a binary state of doing or not doing. There are dozens of ways to participate that vary within and across content-specific domains. Some are extremely productive

– designing, conducting, analyzing, and revising a lab procedure to isolate plant and animal cells for example – and can be quite challenging for students. Some are counter-productive – a student that bounces from lab group to lab group socializing and pulling classmates off task, for example – and therefore challenging for everyone.

Students need to be inducted into the habits and practices of the domains in which they are working, a task that is complicated in a multilingual, problem-based context due to the heavy import placed upon peer collaboration. While some skillsets carry from one domain to the next, every content area has conventions that are unique to it. When one of those practices has a steep learning curve that can prove problematic for students initially, students need to feel supported, by the adults in the room, and their peers.

Participation presents teachers with a powerful opportunity to position all class members as valued and valuable contributors. As such, it is incredibly important that teachers create a collegial atmosphere where students are certain of their value in classroom conversation, no matter at what level they are entering it. Teachers can also foster student-student relationships, recognize existing and evolving barriers, and offer strategies for repairing damaged academic collaborations. This is especially important in the context of understanding that students generate ideas, explanations, and illustrations as products of their learning. If students fail to see their personal connection with the peers who generate these rich tools, it can result in an unfortunate missed opportunity.

Conceptual Framework

Katharine had a vision for what English Learner participation could look and sound like in her classroom. She used a "Backwards Design" approach to figure out how to get there from where she and her students were (Wiggins & McTighe, 1998, p. 8). Katharine knew that in order to get English Learners to participate, they would have to take risks. This risk-taking would mean that students would have to navigate feeling vulnerable in contributing to groupwork and interacting discursively, and in turn, would need to be academically and socially supported. This was her starting point: "What do I need to do to make sure that students are academically and socially supported?" Using Katharine's question as orientation, I draw on five bodies of literature to frame the research in this paper (see Figure 1, below): culturally relevant pedagogy, student voice, caring, scaffolding, and participation & engagement.

The framework represents what we currently understand about caring, culturally responsive and inclusive instruction, scaffolding, and the significance of each in fostering student participation. We also know that participation is linked to learning outcomes. These relationships are represented by solid lines. The research included in this paper seeks to examine the relationships between teacher scaffolding built upon a caring foundation and discursive participation, as well as the significance of teacher-modeled scaffolding that may or may not be adopted by English Fluent students to support their English Learning peers. These relationships are represented by dashed lines.

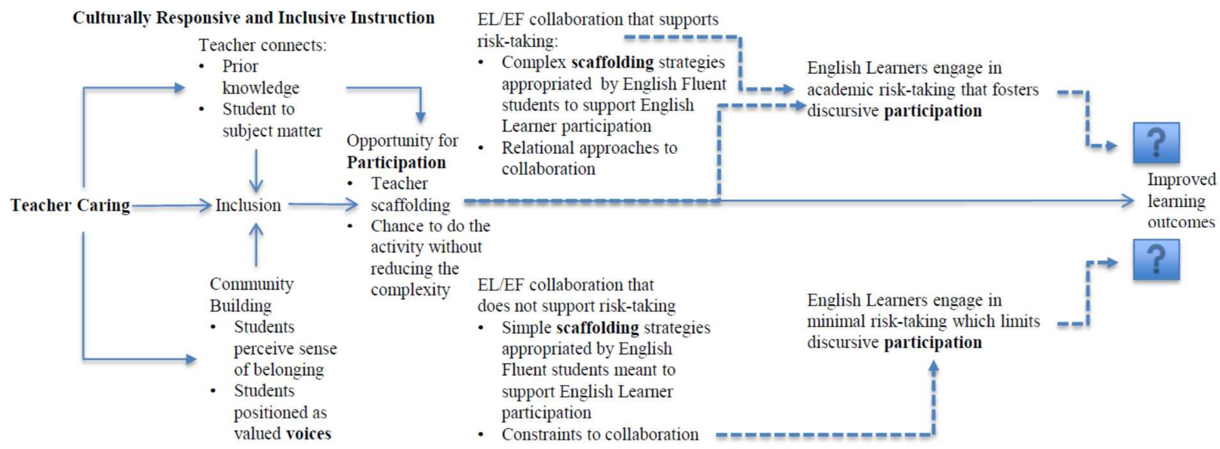


Figure 1 Conceptual framework to examine the relationships between teacher caring, culturally relevant and inclusive pedagogy, student voice, scaffolding, and participation in a problem-based science classroom.

Method

Research Design

This naturalistic case study follows one teacher and her four Biology-Chemistry classes throughout the 2013-2014 academic school year. In the course of the school year I spent over 200 hours in Katharine's classes, observing, recording, surveying, and interacting with Katharine and her students. Nearly twenty percent of her roster were students I had known from my participation in another science class during the previous academic year. For those twenty students, that means we had spent an additional sixty hours together.

This dissertation employs observational and survey methods (Erickson & Wittrock, 1986; Groves et al., 2011; Merriam, 2014; Patton, 1990) to collect qualitative and quantitative data across several settings. The settings for this study are: 1) the classroom of Katharine Bryant, 2) a variety of locations convenient to Katharine for both formal and informal interviews, and 3) the classroom of the school's ELL Support teacher. The bulk of the data for this study was collected in Katharine's classroom, with her 120 students, in the form of classroom observations, informal interactions with students, student surveys, and artifacts of student work.

This case study affords a deep look at the how and why of contemporary teaching and learning events in this multilingual science classroom. A naturalistic approach requires the researcher to get close to the research subjects because they are best understood in the environment in which they live, work and learn (Matza, 1982). It also benefits from "patient, careful and imaginative life study," a commitment I had made to the teacher, the students, and the research from the very beginning (Blumer, 1954, p. 8). Even as a participant-observer, I relied upon Katharine's disclosures in order to make sense of the connections between her reflective sensemaking, instructional practice and reflection. I had a certain degree of influence – though not control – with the students, which I tapped only to ensure the integrity and anonymity of their written and spoken comments. I relied upon these disclosures in order to make sense of their perceptions of, and responses to, Katharine's relational and instructional moves. I went into Katharine's classroom with broad questions about her relational and instructional approach to teaching and the impact that it may have on students, particularly those who historically had not experienced success in science.

Context. Cielo Vista is a comprehensive high school serving an economically, ethnically, and linguistically diverse population of approximately 1,000 students who live in a medium/large urban community in the Pacific Northwest. The demographics of Cielo Vista stand in contrast to those of the school district and city in which it is situated. Symbols of affluence are ubiquitous and serve as constant reminders of the economic, linguistic, and cultural diversity of the city. This diversity is mirrored at Cielo Vista, where 46% of its students qualify for free or reduced lunch, a rate that is twice that of the district school with the second-highest number of qualifying students, and almost ten times higher than that of the district school with the fewest (OSPI, 2014). During the 2013-2014 school year, forty-five different languages were spoken in the homes of Cielo Vista students and 40% of all Cielo Vista students spoke a first language other than English at home (OSPI, 2014).

Cielo Vista's Principal had been tracking in-district and in-school gaps in achievement over the past several years while wrestling with how to bridge the gap between what was getting done and what needed to be done. Troubled by these persistent gaps in achievement and decreasing enrollment, Cielo Vista High School administrators, teachers, students and parents made a collaborative decision to implement a problem-based learning curriculum throughout the school, across content areas.

To clarify the school's vision of problem-based learning, a living document was generated to articulate the attributes of successful problem-based Cielo Vista classrooms. This document, the Seven Key Elements, sets out a foundation of problem-based, collaborative practice for teachers, students and outside experts working together towards the design and implementation of authentic problems that honors students' cultural experiences and voice.

The Seven Key Elements established a framework that sought to define what Cielo Vista believes is characteristic of successful and productive classrooms. As a living document it was not meant to be concrete or fixed. It is meant to inspire and challenge teachers – and students – to think about teaching and learning in expansive and inclusive terms. The seven elements are: authentic problems, authentic assessment, access to expertise, collaborative groups, classroom discourse, inclusive, culturally responsive instruction, and student voice. Katharine focuses on inclusive, culturally responsive instruction and student voice. Katharine and her colleagues work with intention to generate problems for their students that are deeply anchored to the scientific practices articulated in the Next Generation Science Standards, and that are simultaneously interesting and relevant to their students (see Appendix A for an example of a problem-based assignment from Katharine's classroom).

To support this work, Cielo Vista applied for and received a major grant from the US Department of Education in the fall of 2010. The Investing in Innovation (i3) grant application was the school's way of staking a claim that all Cielo Vista students, upon graduation, can – and will – be prepared for college and careers in Science, Technology, Engineering and Math. Cielo Vista learning community believe that this is possible when teachers engage students with a problem-based learning curriculum that attends to the Seven Key Elements. The university based research team of which I am a part established a working relationship with the school for two reasons: to offer technical support to teachers and students as they move through the design and implementation process, and to execute research that memorializes and reports the process and progress along the way.

Participants.

The teacher. Katharine is one of nine members of the science department. Katharine is a fifth year teacher, dually certified in Science and Spanish. She has high expectations for each of her students and firmly believes that all students can be successful in science. The schools' shift to a problem-based curriculum and focus on the Seven Key Elements are consistent with Katharine's teaching philosophy to present students with scientific problems that are rigorous and relevant to students as well as the domain, and matched well with her equity-conscious commitment to cultivate a culturally responsive pedagogy that values student voice. Her 120 students, representative of the school's demographic make-up, are primarily sophomores; fifty-one speak a language other than English at home; twenty-one receive English Language Learner Support services.

The course. Katharine's classes were in Year Two of an integrated Biology-Chemistry course that met four times a week (three 55 minute classes, and one 90 minute class). Students were with different peers and a different teacher for Year One. Throughout the course of the Year Two they covered a variety of topics, including: research methodology, human body systems and functions, chemical bonding, microbiology, and carbon/nitrogen/water cycles, genetics, and others.

Typically, students were presented with a problem at the beginning of a unit, and assigned a group of students with whom to collaborate. Throughout the course of the unit, the group would assign tasks to individual members, work individually, and then return to the group to share what was learned. Whole-class instruction occurred regularly, though not frequently, which is to say that a bulk of content instruction happened within the group.

This paper focuses on the events surrounding four different learning events over the course of the year. They were:

- The NASA Activity: coming to consensus about supply list (see Appendix B)
  September 4th, 2013
  On the second day of school, Katharine assigned students to work in multilingual groups of four to work on a NASA inspired task. Students were presented with a scenario centered around a lunar crash-landing, available supplies, and a life-saving lunar trek to safety. Students were required to first rank the list of available items in order of what *they* would find most useful to least useful, and why. Students then worked as a *group* to compare their lists and come to consensus about the ranking of items.

- CO_2 Presentations about group reduction of carbon footprint (see Appendix C)
  January 23rd – 26th, 2014

On the front-end of the middle of the year, students worked in multilingual groups based on a shared area of interest like water usage, carpooling, diet, etc. to assess their current carbon footprint, propose a plan to reduce their individual carbon footprint, implement that plan, collect data, analyze data, draw conclusions, and present results to the class as a group.

- Socratic Seminars on Genetic Disease (see Appendix D)
  March 25th and 26th, 2014
  On the back-end of the middle of the year, students worked in pairs to prepare for a whole-class Socratic seminar on disease and genetics. Students were paired with a "coach" during the whole-class seminar who could pass them notes with information, data, questions, etc. Katharine presented students with a rubric for preparation and participation that included a requirement for students to have at least one event of verbal scientific participation. If her English Learner students appeared to be struggling during the seminar, Katharine began by slipping the student a sentence starter. In the event that the student did not avail themselves of the sentence starters, Katharine then slipped them a sentence in the form of a question that the student could then pose to the group and initiate a conversation with other students.
  A second round took place the following day with ten English Learner students and Katharine, using the same source materials but a slightly modified format that invited students to contribute whenever they wanted to. In this arrangement, there were no coaches.

- The Genetically Modified Organism Activity (see Appendix E)
  May 5th-10th, 2014
  At the end of the year, Katharine reunited the groups that worked together on the NASA activity at the very beginning of the year. These groups were tasked with researching and producing a television advertisement in support of, or against, the production, sale, and use of genetically modified organisms.

The students. There are seventy-nine different languages spoken at home within Cielo Vista's district; forty-five languages are represented within the school and twenty-one in Katharine's classes. English Learner students receiving services[5] represent fifteen percent of the total enrollment, a percentage that is consistent within Katharine's classes. For the purpose of this paper I grouped students into two categories: students receiving English Language Learner

[5] Washington state defines English Learner as "any enrollee of the school district whose primary language is (one) other than English and whose English language skills are sufficiently deficient or absent to impair learning" (RCW Chapter 28A.180.030). Students are assessed by trained members of the Cielo Vista staff in order to ascertain fluency level.

support services (English Learners), and students not receiving English Language Learner support services (English Fluent[6]). There were occasions when I further delineated the group of English Fluent students to examine differences among students who at one time qualified for English Language Learner support services, and students who never had qualified for such services.

English Learner students who enter the Cielo Vista at a Beginning or Intermediate level have one period of English Language Development with peers who also test at the Beginning or Intermediate level. At its core, the ELL Support class is intended to serve as academic language support in which English Learners take up and practice various strategies to engage in academic discourse across content areas.

Guo, Hei, and Bay are three Intermediate English Learners narrowed down from a larger set of students (*n* = 21) distributed throughout Katharine's four class periods. All three students were in Katharine's third period class (see Table 3). At the beginning of the 2013-2014 school year, Guo had been in the U.S. for one year, Hei for two years, and Bay for one and a half years. All three students had received failing grades in Science during the prior year, and were seen as "non-participants" by their previous year's teachers. The three exhibited a range of proficiency in testing, grades, and discursive participation within the first month of school.

Woojin, Belle, and Lanh are three English Learners narrowed down from the same subset of Katharine's students (see Table 3). Belle and Lanh were in the same class, Woojin was in a different class than the other five focal students. At the beginning of the school year, Woojin had been in the country as a foreign exchange student for only one month and had tested at an

[6] I acknowledge that even students born and raised in the United States can experience issues with written and/or verbal fluency. Furthermore, there are significant differences between casual, academic, and scientific fluency. I address these cases on an individual basis when they are relevant.

Intermediate level. Belle and Lanh had both been in the country for two years, all of which had been in the Pacific School District and Cielo Vista. The three were selected, first because they were not a part of the ELL Support class, but then also for their individual stories that indicated potential for growth or particularly interesting aspects of student participation.

Table 3

Characteristics of focal English Learner students

Name	Language	Gr.	Eng. Prof.	Selected for study because…
Guo	Vietnamese	12th	Int.	• Member of the 7th period ELL Support class • Received failing grade in Science previous year • Struggle persisted at beginning of 2013-2014 school year • Potential for growth • Asked brief questions of Ms. Bryant; quiet with peers in groupwork
Hei	Vietnamese	12th	Int.	• Member of the 7th period ELL Support class • Received failing grade in Science previous year • Struggle persisted at beginning of 2013-2014 school year • Potential for growth • Barely spoke even when spoken to by Ms. Bryant or peers
Bay	Korean	12th	Int.	• Member of the 7th period ELL Support class • Received failing grade in Science previous year • Struggle persisted at beginning of 2013-2014 school year • Potential for growth • Asked questions of Ms. Bryant, talked to peers freely in a social, not academic, manner
Woojin	Korean	11th	Int.	• Not a member of the 7th period ELL Support class • Foreign exchange student, not receiving ELL support services • Received above average grades during the first half of the year • Exhibited conceptual understanding in written work • Asked Ms. Bryant several questions one-on-one related to material • Potential for comparison
Belle	Mandarin Chinese	12th	Adv.	• Not a member of the 7th period ELL Support class • Third year in the school system • Received average/above average grades during the first half of the year • Exhibited conceptual understanding in written work • Engaged Ms. Bryant in conversation that exhibited curiosity about material • Interesting potential for comparison due to peer redirection
Lanh	Vietnamese	11th	Adv.	• Not a member of the 7th period ELL Support class • Third year at Cielo Vista High School • Received above average grades in Science previous year • Exhibited conceptual understanding in written work • Rarely spoke, even when spoken to • Interesting potential for growth and comparison

None of Katharine's students were currently placed at the Beginner level for the 2013-2014 academic year. Of the twenty-one students receiving support services, ten were Intermediate, eleven Advanced. Three Intermediate Level students listed above were selected in part because of their prior struggle in science and their potential for growth, but also due to their participation in the English Language Learner Support class that Katharine attended on a weekly basis, a strategy she took up that will be discussed in detail below. Once potential candidates were identified based on the evidence of their classroom participation, I created a tool to help me track and make sense of individual discursive contributions. I used that tool to track discursive participation of the focal students (see Appendix F).

Given Katharine's fluency in Spanish, the reader may wonder why I did not focus on her Spanish-speaking students. There were two reasons for this. First, in the event that Katharine's English Learners were to exhibit exceptional discursive participation, I anticipated her Spanish fluency muddying the attribution waters, so to speak. Second, of the 21 students receiving English Language Learner support services, only 3 were Spanish speakers, and one of them left the school mid-year, and another was also receiving Special Education support services. Two Spanish-speaking students joined Katharine's class mid-year, but I had no data for them for the first two learning events that were tracked.

Data Collection. Over the course of the 2013-2014 academic year I was in Katharine's classroom for over 200 hours, during which time more than 25 hours of audio, and an additional 25 hours of video recordings, were captured. More than three hundred pages of field notes were generated. Students were surveyed eight times throughout the year on a variety of topics ranging from interest in problem-based units to perceptions of teacher caring to collaborative groupwork.

Student work was collected throughout the year as well, and digitally recorded or physically copied. Informal interviews with the subject teacher were conducted daily and included in field notes. Eight hour-long semi-structured interviews were conducted – and transcribed – with the subject teacher, beginning in the summer of 2013. Two hour-long semi-structured interviews were conducted with the teacher of the English Language Learner support class that Katharine attended weekly. The findings for this study are drawn from four sources: teacher interviews, student surveys, classroom observations, and artifacts of student work (see Table 4).

Table 4

Data Collected

Type of Data	Total	Used in this study
Formal and informal interviews	• 10 hours (formal) • 80 hours (informal)	• 4 formal (4 hours) o August 5, 2013 o March 7, 2014 o April 25, 2014 o June 20, 2014 • 20 informal (10 hours)
Student surveys	8 surveys Total: 160 questions • 40 multiple choice/rank; • 120 open response	4 surveys • February 28, 2014 • March 15, 2014 • March 31, 2014 • June 20, 2014
Classroom observations	• 20 hours of table talk • 20 hours of presentations • 300 pages of field notes	• NASA Activity table talk (2 hours) • CO_2 table talk & presentations (6 hours) • Socratic Seminars (2 hours) • Political Pro/Con Ad for Washington Law Initiative I466 regarding Genetically Modified Organisms table talk (2 hours) • Field Notes (40 pages)
Artifacts of student work	• CO_2 group posters (24 pages) • 1466 group assignments (40 pages)	• CO_2 group posters (4 pages) • 1466 group assignments (40 pages)

Teacher interviews. Semi-structured teacher interviews were conducted with Katharine throughout the year to collect data about her decision to take an equity stance, her intentions to implement relational and instructional strategies, and reflections about the process. With the exception of the one phone interview, interviews were recorded and transcribed for analysis.

Formal interviews were semi-structured, starting with a broad question and crafting follow-up questions based on her responses that would keep the conversation focused on-topic. Examples of initial questions included: “What are your goals for this year; why are they important to you, and how do you plan on getting there?” “How significant is the integration of literacy and science in your classroom, and what do you do to attend to literacy?” and “What surprised you the most about the results of this survey, what troubled you, what are your next moves?” These questions were meant to address elements of my research questions, specifically with respect to her equity stance, caring, instructional and relational moves, and culturally responsive instruction.

Informal interviews took place almost daily throughout the year. I attended Katharine’s classes four days a week. Her classes met first, second, third, and fifth period. The break between third and fifth meant that we almost always discussed the events of the day up to that point. These conversations covered a broad range of topics; sometimes Katharine would reflect on specific instructional and relational moves she had attempted. On occasion, she would ask for feedback about content related to the current unit. We most frequently discussed Katharine’s personal and academic interactions with students. Katharine’s sixth and seventh periods were planning periods, meaning that she was available to discuss fifth period, or further discuss prior events of the day at the end of the day. These debriefing sessions were used to address actions that represented implementation of Katharine’s intentional moves.

In April I met with the ELL Support teacher to discuss his perceptions and experiences of having Katharine in his class for an hour and a half every Thursday. This formal semi-structured interview was conducted in his empty classroom, recorded, and transcribed for analysis. I began with three broad questions about: 1) the state of support for English Learners throughout the school, 2) his perception of Katharine's work with students in his classroom, and 3) his perceptions of what Katharine's additional involvement meant for his students. This interview offered a unique third-person perspective of Katharine and the students, generating a more detailed picture of English Learner experience and growth, particularly with respect to access, and interactions with Katharine outside of the physical boundary of the science classroom.

Student surveys. I administered a series of eight student surveys throughout the year to collect data that would elicit student feedback about Katharine's relational and instructional strategies, group work, and participation. Data from four of these surveys are included in this study (see Appendix G for the complete surveys).

The results of each survey drove the nature and theme of questions for pursuant surveys. For example, in January we asked students to write about the nature of groupwork; "What makes someone a good group member?" and "What makes you a good group member?" Student responses to those questions drove a series of questions in the March survey that asked students to write about the strategies they use when helping a classmate who is struggling, e.g., "How do you help classmates who are confused?", as well as questions about the ways in which they support English Learners in their groups, e.g., "How do you help students in your group who are learning English?" and "When I have someone in my group learning English, I…". Rather than ask students how they navigated feelings of vulnerability, we fashioned questions that invited students to write about doing, or not doing, things that typically make students feel vulnerable like sharing ideas or asking questions.

Classroom observations of students. Focused classroom observations were documented in three forms: audio recordings, video recordings, and Field Journal notes. Audio and video recordings captured during the NASA Activity, CO_2 presentations, Socratic Seminars, and I466 presentations were selected for analysis and transcribed. Additional observations were conducted throughout the course of the year, beginning in September and continuing throughout the year. Data collection was most intensive during September (64 hours), mid-January to late-March (72 hours), and mid-May to mid-June (24 hours).

My systematic approach to journaling Field Notes meant that I began every class with a question about Katharine's relational or instructional moves, or English Learner interactions with their peers.

Classroom observations were helpful for observing the implementation of Katharine's intended plan of action. Observations were also useful in providing data about student-teacher and student-student interactions, particularly with respect to capturing moments of relational and instructional moves by the teacher. Finally, classroom observations also provided data that spoke to the evolution of student participation over time.

Artifacts of student work. Artifacts of student work from four different group projects and the Independent Research Project were collected throughout the year and photographed or reproduced xerographically when possible. These pieces of student work were helpful in adding another perspective when examining the trajectory and sophistication of student participation, particularly among students who were more likely to *write* about science, than *talk* about science. Artifacts include student work from:

- NASA Activity – photographic images of student responses to the task assignment.
- CO_2 Carbon Footprint Reduction Group Posters – group posters, completed as a group –

to varying degrees – and presented to the rest of the class accompanied by an explanation by members of the group.

- Washington State Law Initiative I466 about Genetically Modified Organisms group assignments – photographic images of the worksheets that included anticipated tasks required for successful completion of the I466 advertisement. The assignment sheet included the names of group members assigned to specific tasks.
- Washington State Law Initiative I466 about Genetically Modified Organisms group work – videorecordings of group work preparations, final products and presentations.

Data Analysis. My coding strategy was to draw from an established body of work among caring, student science learning, and participation researchers to develop a core set of codes that would shed light on my research questions. This set of initial codes helped me to engage with the data initially within an existing framework so that the events that were relevant to Katharine and her students would still be privileged. In addition to this iterative process that remained grounded to theories about teacher caring, student perception of caring, and student collaboration and participation, I turned to Content Analysis to shed light on significance through frequency; of student actions, of student talk, and of student practice. All of my coding served the purpose of revealing truths about one or more of three things:

1. Katharine's planned and implemented relational and instructional moves.
2. The degree to which students recognized, appreciated, replicated, and utilized those moves in service of their own learning or the learning of their peers.
3. Evidence of a trajectory of participation, and the sophistication of that trajectory, over the course of the year.

I began my analysis with these three broad elements. My coding scheme, described below, is an attempt to understand the relationships between the parts of the whole, by illuminating what is important to the teacher and her students through what they say and do.

As data were analyzed, hypotheses were challenged, tested, revised and reexamined.

Coding schemes for teacher interviews. I coded in multiple phases throughout the year, beginning with Katharine's initial interview discussing her goals for her English Learner students. I developed an initial set of codes based on my research questions that were based upon the caring literature of Valenzuela, Gay, and Lewis, the equity research of Roseberry & Warren, Nasir, and Gutierrez, and Newman, and the student voice research of Rudduck, and Fielding. Three topics emerged during this first conversation: 1) *success* 2) *equity*, and 3) *safety*.

I returned to these three themes to articulate, in Katharine's words, how she defines success, equity, and safety. This resulted in the following codes:

- *rigor* (e.g., content may be modified, but will not be watered down)
- *voice/participation* (e.g., students will be heard, literally)
- *representation* (e.g., students will see their work within the group; students will see themselves and their culture within science)
- *connection* (e.g., students will feel connected to, and a sense of belonging within, the classroom; Katharine will work to create a home-school connection to support students)
- *caring* (students will feel cared *for*, and cared *about*, as people and as learners)
- *participation as outcome* (e.g., for Katharine, the standard of measurement for better outcome)

During a second round of coding I was looking for actions that Katharine intended to take with respect to success, equity, and safety. Before heading into the classroom, I wanted to know what Katharine hoped for her practice, and for her students. Taking my cue from Katharine's plan of action, I coded for talk about:

- *accessibility* (e.g., before school, during class, during lunch, in tutorial)
- *teaching strategies* (e.g., explaining, translating, changing words)

- *supporting groupwork and collaboration* (e.g., modeling effective communication, taking students through the process of recognizing their collaboration personality, redirecting negative peer feedback, etc)

Coding schemes for student surveys. I coded student surveys in multiple phases throughout the year, as surveys were administered, analyzed, and used to design new surveys and track student perception and thinking. During the first round of coding student surveys, I used themes that emerged from Katharine's interviews, particularly with respect to student perceptions of caring. These codes included: *caring* (e.g., students report feeling cared *for* and/or cared *about* as people and/or learners), *connectedness* (e.g., students report feeling a sense of connection), *belonging* (e.g., students report a sense of belonging, welcoming, comfort), *voice* (e.g., students report events of speaking), and *representation* (e.g., students report events of their work representing at least part of the group's work).

The goal of the next two rounds of coding was further articulation of the first round codes. Third round codes added the step of trying to determine whether or not students felt that they had something to contribute, and identifying whether they were an English Learner or English Fluent student. I coded: *caring* (e.g., Ms. Bryant cares/doesn't care for me), *connectedness* (e.g., see connection between self/science, science/home, self/classroom), *belonging* (e.g., feel welcome, feel appreciated, feel sense of community), *voice* (e.g., see role as contributor, feel have something to say – will/will not say it), and *representation* (e.g., see self/culture in science, see self/culture in assignments and problems, feel heard by teacher, classmates).

For all pursuant surveys, I used themes that emerged from the previous survey to drive the coding process. For example, while coding the second survey, I started with the coding scheme above, but added codes about groupwork. I coded: *groupwork/collaboration: positive* (share work, bounce ideas/brainstorm, learn from peers, get to work with friends), and *negative* (inequitable distribution of work, not invited to participate, pace is too fast, and issues of asking for help or helping others).

Coding schemes for student talk. Before I discuss coding schemes, I want to describe how I framed the nature of student talk (Table 5).

The nature of talk. At its simplest, talk is a binary state: one talks or does not talk. Here, I want to expand the binary to attend to a trajectory where students move from silence to rigorous scientific discourse. Students do not leap from one termini of a trajectory to the other; there are steps along the way, particularly for English Learner students. Talk takes on different elements and characteristics, attending to social and academic needs (see Table 4 for examples).

Table 5

Examples of student talk along the nature of talk continuum

Type of talk	
Silence	• Student does not voluntarily speak • Student responds by gesture or facial expression • Student responds with one word answer
Primarily social talk	• "How was your weekend?" • "I heard you are in the play." • Game talk • Television, movie, music talk
Simple academic and/or scientific contributions	• Asks yes/no questions • Answers questions with one-three word responses • Science is observational, not explanatory
Novice scientific talk	• "I know blood has salt and the ocean has salt. Does salt have something to do with it?" • How does water get to your home? "The mountains. Rain water." • "Maybe we should come up with a theory and find things to prove the theory"
Rigorous scientific discourse	"There is some controversy with the use of genetically modified organisms. In our story we turn to Dr. Smarty Pants to explain their work with genetically modified marmosets, and follow with an explanation of how the science works. We end with our position in support of I466 using evidence from this report and additional research we conducted."

The five stages of second-language acquisition: What participation might sound like.

There is a level of analysis unique to English Learners: attending to the stages of second-language acquisition (Krashen, 1981) (see Table 6). One of the driving forces of problem-based learning is the commitment to, and leverage of, groupwork. In turn, one of the qualities of groupwork is the division and allocation of work. *How* work gets allocated is what I am looking here. It would be difficult to characterize intellectual load along a continuum. Instead, I adapt Krashen's (1981, p.) model to track the interactions of the focal English Learners across five different learning events, examining and comparing interactions between the English Learner and Katharine, the English Learner and their English Fluent peers, and finally, both in comparison to the student's Krashen stage. I do this to identify differences in the character and quality of participation in different contexts, with different participants.

Table 6

The five stages of second-language acquisition

Stage (time range in country)	Typical contributions	What this looked and/or sounded like in science	
		With EF peers	With Katharine or EF peers
Preproduction or silence (0-6 months)	Respond to: show me, circle the…, where is…, who has…	EL does not volunteer to speak; EF does not ask or persist in asking questions	n/a
Early Production (6-12 months)	Respond to: yes/no questions, either/or questions, who… what…, how many…	"Do you want to get some pictures together for the PowerPoint?" "Do you want to do references or the PowerPoint?"	"Is this right?"
Speech Emergence (1-3 years)	Respond to: why…, how…, explain… using phrases and short sentences	"How are we going to divide the work?" "Do you understand this math? Can you explain it to me?"	"Why are some (genetic) tests okay direct to consumer, or why are some states banning it?" "How about… what if you don't want to? (know about the results)?
Intermediate fluency (3-5 years)	Respond to: what would happen if…, why do you think that… providing answers that have more than one sentence	n/a	"What if there's a disease and there's no correction for it?"
Advanced Fluency (5-7 years)	Respond to: decide if…, retell…	n/a	"Decide what kind of change you want to make to reduce your carbon footprint. What are you going to do? How are you going to do it? How are you going to measure it? What do you need to know before you start?"

Adapted from Krashen, 1981

Classroom observations were either transcribed from audio/video files and coded, or coded from scanned Field Notes. I coded classroom observations in multiple phases throughout the year, as observations were made, analyzed, and used to triangulate data, design new surveys, and track student perception and thinking. During the first round of coding classroom observations, I used themes that emerged from Katharine's interviews, particularly with respect to student perceptions of caring. See previous lists that *caring*, *connectedness*, *belonging*, *voice*, and *representation*.

Another approach to the analysis of classroom observations that I utilized was content analysis (Carley, 1993; Krippendorff, 2012). I used this approach to examine the nature of how students were contributing to classroom talk, as well as the frequency with which they were contributing. For example, for the Socratic Seminars I wanted to examine the differences in the nature and frequency of talk between the English Learner only seminar and the whole class seminar.

When doing the content analysis, I used the following codes based upon the desired types of scientific talk described as signaling proficiency in science in *Taking Science to School* (NRC, 2007), and further articulated in the Next Generation Science Standards. I coded first for participation, then for the nature of that participation, including: *questioning* (e.g., introducing a question that is problematic with or without evidence; questioning someone else's assertion with or without evidence; seeking clarification; driving the conversation), *answering* (e.g., responding to a posed or originated question, with or without clarification, reasoning, or evidence), *reporting* (e.g., restating or retelling information gathered from another source), *building* (e.g., adding a thought or evidence to a claim initiated by someone else), *contradicting* (e.g., making a statement against someone else's statement, with or without evidence), *reasoning* (e.g., transparent/thinking out loud process of making sense of the task at hand, in real time; navigating an argument), *statement* (e.g., a statement made without an implication of veracity), *assertion* (e.g., an absolute statement made, with or without the use of evidence), *evidence* (e.g., the use of evidence to support or refute a claim made by yourself, a peer, or another source), *agreeing* (e.g., agreeing with a peer because you believe they are correct, whether or not they are), *affirming* (e.g., encouraging or supporting contribution from a peer, and *approximating science talk* (e.g., incomplete talk that indicates and effort to use the above elements unsuccessfully, or inaccurately).

Coding schemes for scaffolding. We draw on Van Lier's features of scaffolding for English Learners to examine the implementation and appropriation of scaffolding in Katharine's classroom. Specifically: *continuity* (e.g., repeating concepts in multiple contexts, variation of explanation, using different words, connecting concepts to personal experiences in and out of school), *contextual support* (e.g., safe, supportive environment, multiple forms of access), *intersubjectivity* (e.g., mutual engagement and rapport, encouragement to participate, cultivation of community of practice), *contingency* (e.g., adjust tasks when warranted, co-construct speech), *handover/takeover* (e.g., Student assumes control), and *flow* (complexity of challenges increase as students progress).

Coding schemes for artifacts of student work. I coded artifacts of student work in multiple phases throughout the year, as data was collected, analyzed, and used to triangulate hypotheses, design new surveys, and track student perception and thinking. Again drawing from *Taking Science to School (NRC, 2007)*, and the Next Generation Science Standards, I coded for: *using scientific language*, *using evidence to support/refute a claim*, *using reasoning*, *argumentation and/or explanation*, *questioning findings*, *assumptions*, *data*, etc. I also examined the degree to which students engaged in these scientific practices accurately or appropriately.

Findings

Three claims emerged from the data related to the actions Katharine took, what students reported about these actions as significant to them, and the reported impact Katharine's actions had upon students and their learning. Specifically:

> **Claim #1** Katharine cultivated a caring community within which her English Learner students saw her as both approachable and accessible. English Learner students took advantage of Katharine's accessibility by going to her, or inviting her to them, which gave her the opportunity to scaffold instruction in ways that encouraged them take intellectual and social risks.
>
> **Claim #2** English Learner students who had access to Katharine during the ELL Support class moved from silent observer early in the year, including the use of evidence to support a claim, anticipating and challenging arguments, reasoning, and explanation, towards equal collaborators within their groups more rapidly than did English Learner students who were not part of the ELL Support Class.
>
> **Claim #3** The caring orientation of Katharine's classroom also yielded outcomes that were unexpectedly unproductive and problematic.

Cultivating a caring community

I begin with my first claim, that Katharine cultivated a caring community unique to problem-based science instruction that encouraged students to see her as approachable and accessible. Katharine established a timeline to initiate and implement her relational stance (see Figure 2). Her efforts started well before the beginning of the school year by reaching out to English Learner students and families in an effort to create a sense of connection between school and home, and home culture and science. In order to nurture these connections, Katharine believed that they had to be explicit. The principal elements of Katharine's communication with her English Learner students and families focused on her love of language and culture, and her ability to speak Spanish. “I wanted students and their parents to know that I was serious about this. That I wanted to make a strong connection between home and school and science. I wanted them to know that I was here for them, whenever they’d need me.”

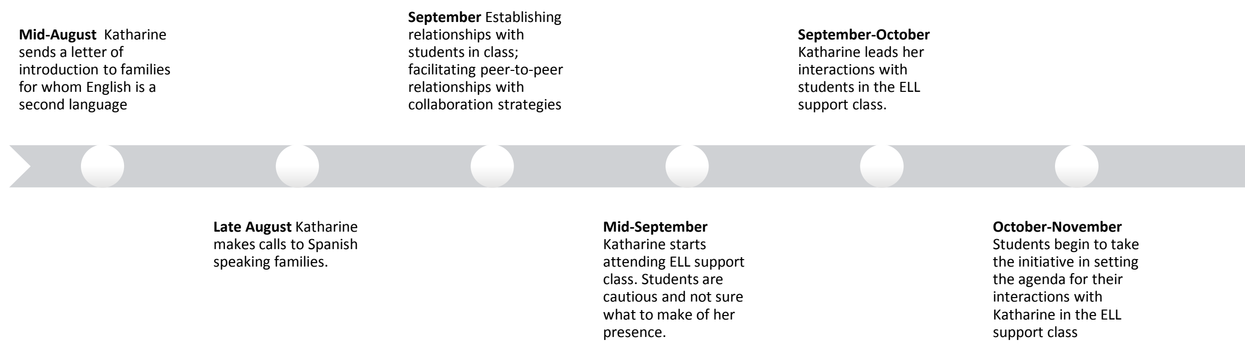


Figure 2 Katharine’s timeline for the implementation of her relational approach to instruction for the first three months of school

I observed Katharine execute a series of moves beyond her initial outreach intended to cultivate a sense of belonging, privileging of voice and culture, and connectedness (see Table 7 for examples). Katharine modeled and structured groupwork and collaboration, welcomed students, and worked to get to know them as people as well as learners.

Table 7

Examples of Katharine’s attention to belonging, privileging of English Learner voice, and connectedness

Belonging	• Asking students “What can I do to help you learn?” and “What do I need to know about you to make your experience in this class successful?” • Acting on their responses while marking those actions, “Remember when you said that it helps when you have an outline? Well, here’s an outline!” and “I read that you love softball… I love softball! I play softball in a league! Do you play in a league? God I hope not, you’d crush me!”
Privileging of voice and culture	• Making a decision to forge ahead even though some White students were feeling overlooked and uncared for. • Using Spanish to explain concepts to Spanish-speaking students.
Connectedness	• Reaching out to English Learner students and families in writing • Reaching out to Spanish speaking students and families with phone calls • Asking students about their science experiences in other countries. • Using student’s prior experiences explicitly while teaching, “So, Ai was telling me that in Japan she learned about cancer and is really interested in studying more about that. Ai, can you tell us something that you remember about cancer and cancer cells?”

Throughout the month of September in particular, Katharine made a concerted effort to identify students who were struggling and approach them during class to invite discussion. She reminded students one-on-one about visiting during Tutorial, where she was available every day until at least 4:00pm, often much later.

Also during the month of September, Katharine made numerous moves on a daily basis to establish a caring relationship with *all* of her students, paying particular attention to ask her English Learner students about their lives and science experiences that may have differed from those of the English Fluent students in her class. Katharine was very transparent in these efforts, going so far as to say: “I want to know these things about you so that I can help you share them (the experiences) with your peers, and so that I can take them into consideration when we design problems that are relevant to you, too.”

When she was able to incorporate these pieces into instruction, she pointed it out so that there was little chance students would miss making the connection. An example of this was evident when Katharine responded to student feedback about a problem-based unit not feeling relevant to them by dramatically changing the unit. She introduced the redesigned unit to the students, asking for further input on the proposed changes saying “See? I listen. We listen. We changed this because of you!”

Instructional support as caring. Katharine set out to expand her repertoire of scaffolding techniques that resonated with students by identifying what students found helpful, and then building upon that strategy to further encourage student participation and engagement. From the outset, her strategies for scaffolding to maintain the rigor and complexity of the work included: adapting readings to simplify the language without simplifying the concepts, offering students the opportunity to read content in their first language prior to reading in English, explaining concepts to students in Spanish, finding reasonable entry points for very novice speakers, having sentence starters ready to get students thinking about the direction of the conversation, etc. Katharine also set out to take advantage of the time that problem-based instruction opened up to make more one-on-one contact with students during class. Katharine also endeavored to connect students to complex scientific ideas and practices by finding out what her students were interested in and knowledgeable about, and then providing opportunities for students to connect the two.

Katharine used a wide variety of both soft and hard scaffolding strategies. Her soft strategies were readily apparent during every class; she frequently re-phrased complicated concepts, used student experiences to make connections to content, checked for understanding as well as general well-being. Katharine's hard scaffolding strategies included having modified readings available, bookmarking websites that could be viewed in a students' first language, reflecting on ways that expectations could be realistic while maintaining rigor.

For her English Learners specifically, Katharine engaged in a series of instructional scaffolding practices that were consistent with Van Lier's features of scaffolding (cited in Walqui, Conceptual Framework p. 165) (see Table 8).

Table 8

Examples of Katharine's strategies following Walqui and Van Lier's features of scaffolding instruction for English Language Learners (Walqui, 2007 p. 165)

Feature	Strategy	Examples of Katharine's efforts
Continuity	• Repeating concepts in multiple contexts • variation of explanation • using different words • connecting concepts to personal experiences in and out of school	"Concentration, how much stuff of one thing is in a given area… so here we're talking about the concentration of 9 grams of NaCl – sodium chloride…. salt… – in a liter of water. Another way to think of it is who puts on the most perfume or cologne at home? Do they put it on in the bathroom? In the bedroom? Is it a high concentration or a low concentration?"
Contextual support	• Safe and supportive environment • Multiple forms of access	"Nice collaboration! *This* is how we help each other…" Available before school, during lunch, after school, during class, and during the ELL Support class.
Intersubjectivity	• Mutual engagement and rapport • Encouragement to participate • Cultivation of community of practice	Real-time presentation and generation of a "personal story mind map" in front of the class. Guided students through the multi-day process of identifying their collaboration personalities to foster communication and understanding.
Contingency	• Adjust tasks when warranted • Co-construct speech	Consistently modifies materials to make reading easier without diluting content Provided students with sentence starters, either on paper, or in conversation.
Handover/Takeover	• Student assumption of control	Practice of constant reflection to keep track of which students need more support and which students are ready to be pushed.
Flow	• Increase in complexity of challenges as students progress	Preparation of materials that increase in sophistication; less translation; asking students to explain in English following conversation in native language.

Student response to Katharine's "accessibility through approachability."

Accessibility and approachability are very different features of interpersonal academic relationships. Accessibility is structural: does the teacher make themselves available to their students? Is the teacher physically present and prepared to interact with students? Approachability is relational: does the teacher convey implicit and explicit messages to students about their desire to interact with them? Across a variety of survey questions, students repeatedly wrote of Katherine's accessibility as evidence of her caring about them, what she does to help them learn, and how she helps them. Over the course of the year, being able to take advantage of Katharine during Tutorial alone was mentioned ninety-two times as evidence of Katharine's help. Students also spoke of Katharine's accessibility during class, a strategy I observed during every period, as Katharine moved through the classroom while students were working in groups, sitting in available desks or squatting to the student's eye level to check in. Sometimes the conversation was personal or social, but mostly the conversations were academic in nature: "How are you doing? Is this making sense? Explain to me what you're doing. What are your next steps?" Students could not answer her questions with a yes or no. Katharine's questions required thought, analysis, and a plan. Students wrote of Katharine's ability to help them make sense of topics that were stumping them. Twelve students spoke about questions; that she answers them, to be sure, but also that she *does not* answer their questions but "restates," "probes," "pushes," and "helps" students by asking questions that "help get to the answer."

Like students' responses to the question about their perception of caring, students wrote of the ways in which Katharine helps them learn. Though many responses were repeated, there were a variety of responses. Thirteen students wrote of Katharine's efforts to explain the content in a way that would ensure their success, writing that "(she) explains things very well and will provide clarification if it's needed," and "changes sources into easy version," "explaining in Spanish." "She always find(s) the easiest way to explain," wrote several students, and "asks you questions about topics you don't understand and she explains in different ways." "She gives paper with notes to help," acknowledged one student. Students spoke of her instructional materials and instructional practices like her use of "examples," modification of materials for access, "hands-on" activities, "pre-written" or scaffolded notes, "checking for understanding," "helping when (they are) stuck," and "review."

Perceptions of caring. When asked what Ms. Bryant does to show that she cares, 46% of the 100 (21% EL) surveyed students wrote about the ways in which she helps them, personally (accountability with understanding, asking about their lives, talking about problems) and academically (explains the material, works to make sure that students understand). Sixteen students (16%) left the question blank, and only one student reported believing that “she doesn’t care about me.” When asked “What is your favorite thing about this class?” the most common answer other than content, was Katharine, whether they were referring to her personality, her relationship with them, her efforts as a teacher, or some other reason not articulated. Nearly half of the eleven responses came from English Learner students. Students wrote about the quality of their classroom relationships using words like “comfortable,” “welcome,” and “friendliness.”

To further identify student perception of caring, I asked students to rate, on a seven point Likert scale, the degree to which they agreed with the following statements: “I think Ms. Bryant cares about me as a person,” and “I think Ms. Bryant cares about me as a learner.”

Table 9

Perceptions of caring, by groups (Range = 1-7)

Group	Cares about me as a person – Winter	Cares about me as a person – Spring	Cares about me as a learner – Winter	Cares about me as a learner – Spring
All	M=4.92 SD=1.72	M=5.16 SD=1.67	M=4.60 SD=2.06	M=4.79 SD=1.59
ELL	M=5.47 SD=1.26	M=5.58 SD=1.3	M=5.42 SD=1.9	M=5.58 SD=1.39
EF	M=4.78 SD=1.79	M=5.06 SD=1.73	M=4.40 SD=2.04	M=4.61 SD=1.58
Breakdown by gender				
All Girls	M=4.41 SD=1.72	M=4.86 SD=1.67	M=4.41 SD=1.97	M=4.51 SD=1.42
ELL girls	M=5.4 SD=1.52	M=6.2 SD=1.3	M=5.6 SD=1.67	M=5.8 SD=1.3
EF girls	M=4.29 SD=1.63	M=4.70 SD=1.64	M=4.26 SD=1.94	M=4.35 SD=1.37
All boys	M=5.37 SD=1.56	M=5.42 SD=1.50	M=4.76 SD=2.14	M=5.04 SD=1.71
ELL boys	M=5.5 SD=1.22	M=5.36 SD=1.28	M=5.36 SD=2.0	M=5.5 SD=1.45
EF boys	M=5.32 SD=1.68	M=5.45 SD=1.59	M=4.54 SD=2.16	M=4.87 SD=1.77

Perceptions of caring (see Table 9) varied between English Learners and English Fluent students, as well as between boys and girls. In general, while almost every group expressed a greater sense of teacher caring at the end of the year – English Learner boys showed a small decrease in perception of Katharine's caring about them as people – English Learner girls showed the greatest increase in perception of caring as both people and learners. Every student from the English Learner Support class cited Katharine's presence in that class as evidence of her caring and/or helping them learn. English Learner students also reported a greater perception of Katharine's caring than did English Fluent students. English Learner students as a group also mentioned her typical classroom strategies like one-on-one interaction and consistent after-school availability as evidence of her caring and teaching strategy to facilitate participation and learning. Perceptions of caring increased across the board for "cares about me as a person," more so than "cares about me as a learner."

Students were also asked to reflect on their perceptions of feeling welcome and valued in in Katharine's classroom. Again, using a seven point Likert scale, English Learner students reported slightly higher perceptions of feeling both welcome and valued (M=4.75 and M=4.57 English Learners, respectively, and M=4.70 and M=4.37 English Fluent). Minor differences notwithstanding, this places the bulk of the students in the "good" to "great" category.

English Fluent students used generally positive terms when reflecting on their English Learner peers. "I know they have great ideas, they just can't communicate them," wrote Alex. "I wish I spoke their language." In fact, 25% of English Fluent students mentioned that they wished they spoke *their* language, not that they wished English Learners spoke English/better English.

The productive impact of caring. "I'm ELL student," wrote Hei, "she take care of me a lot. She cares about my personal story and my grade, a lot." In addition to what follows here, all of the student participation documented below is evidence of Katharine's English Learners taking social and intellectual risks. These events are tied directly to the students, like Hei, who explicitly state that they felt brave or capable enough to try. English Learner students wrote frequently about the impact of Katharine's caring upon their learning experiences. (She) "made me brave, doing work," wrote Hei on a different occasion. "She helps me a lot," wrote Akiko, an Intermediate level speaker. "She helps me every single time," wrote Cho, an Advanced level speaker. "She helps my learning because if I don't understand, she calls me to Tutorial."

In a conversation with Anh, another of Katharine's Advanced English Learners, one afternoon she mentioned that the current year was "so much different" than last year. I asked her how so, to which she replied: "Last year I was always afraid to talk too much. I know that what I say doesn't always make sense to everyone else. (Laughs) It doesn't always make sense to me! So I wouldn't speak it. But this year I will because I know that everyone will not think I am stupid for what I say."

Another Intermediate student, Rudy, said to me that "other teachers tell me to come to Tutorial, but Ms. Bryant, she will not stop until I come. Sometimes I think she does not like me so much until I think that she must like me to want to see me in Tutorial so much." Students recognized Katharine's caring approach, as well as its connection to her instructional approach. Students saw the two elements of participation linked together, support for the doing, and the doing.

The evolution of English Learner participation over time: From observer to collaborator

In this section I offer evidence about English Learner participation broadly, and narrowly. To examine broad participation, I compare English Learner and English Fluent student participation in two independent Socratic Seminar sessions held in late-March. To examine participation narrowly, I tracked the participation of three focal students: Guo, Hei, and Bay over the course of the year.

I collected data at five points during the course of the school year. The goal in collecting data was two-fold: 1) capture student activity at various points in time, with enough time in-between to allow for growth, and 2) to make sure that the work-at-hand would provide students with the opportunity to engage in scientific practices. Students were reunited with the same students from their groups on the first day of school for the group work at the end of the year in order to eliminate as many variables as possible when comparing student participation at the beginning of the year and again at the end of the year.

A claim emerged from the data with respect to the ways that English Learner student participation evolved over the course of the year. Specifically:

> **Claim #2** English Learner students who had access to Katharine during the ELL Support class moved from silent observer early in the year, including the use of evidence to support a claim, anticipating and challenging arguments, reasoning, and explanation, towards equal collaborators within their groups more rapidly than did English Learner students who were not part of the ELL Support Class.

Socratic Seminar highlights English Learner emerging scientific discourse. Midway through the year during the DNA unit, students were assigned a problem regarding whether or not to advise a client to take advantage of genetic testing. To encourage students to cultivate a reasoned argument about the pros and cons of genetic testing, Katharine had students participate in a Socratic Seminar (see Appendix D).

Katharine expected this format to be challenging for her English Learner students. In fact, all of the English Learner student contributions were extraordinary in that whole class contributions were rare for them.

To ensure opportunities for participation, Katharine was prepared to scaffold students into the conversation by having sentence starters printed on small slips of paper that she would quietly hand to students who appeared to be struggling or reluctant to speak up. If the sentence starters did not encourage students to talk, Katharine had entire sentences printed on slips that students would only have to read in order to drive further conversation. Few students received sentence starters, and only three needed a full sentence. One of the three who required a full sentence did not avail himself of the sentence, instead remaining silent throughout the seminar.

During our informal debrief of the day, Katharine wondered if participation would have been significantly different among the English Learner students if they had had more time, or if the conversation had moved more slowly. She noticed that English Learner students frequently looked like they were preparing to say something but then the conversation would shift, leaving them frustrated. She wondered if the conversation would have been different if all of the students had been English Learners.

There were three phases of talk during the English Learner only seminar: 1) a clunky start with a lot of teacher-driven questions, pauses, and paper shuffling, 2) discussion about genetic testing, and 3) discussion about religion and science that, while interesting, analysis of which falls outside of the scope of this study.

We enter the conversation here with the students considering the benefits of genetic testing, having already offered cost-benefit as one thing to consider. Up to this point, the students had wondered what the restrictions on direct-to-consumer genetic tests were, and why people would choose to test for certain genetic traits. Katharine, building on their prior discussion about the cost-benefit analysis element, asked the group if she should pay $10,000 to get tested for a disease she had shown no signs or symptoms of having.

Hei:	We can prevention other diseases with all of the tests but we don't have that much money. So we don't have to do that… Only in pretend. We should do with breast cancer… With a small part of the test.
Tai:	I don't really agree because some diseases, you can know before it happens. So you have to do the test. Like cancer. Sometimes it's very small and it's not moving to another part… What do you call that?
Katharine:	If it moves to another part? Metastasize.
Tai:	Yeah. Maybe it's not moved to another part. Maybe you now know that. If you don't do the test, you won't know.

Hei's argument is that the $10,000 can be used to "prevention" other diseases that we *do* know about, like breast cancer, because we "don't have that much money" to spend $10,000 on every disease, real or pretend (imagined). Tai, on the other hand, thinks that it is worth knowing about some diseases while they are "very small" and have not had the chance to "move" yet. Tai appears to know that there is a scientific word for the movement of cancer, and asks for help in remembering it. Katharine gives him the word, which he does not use, instead restating his point that the cancer has not yet moved, and "if you don't do the test, you won't know." In this brief exchange, both students leverage established scientific concepts – disease prevention, the microscopic nature of cancer, metastatic cancer growth – to make their points with novice, but accurate, vocabulary.

Katharine pushes on these ideas of knowing, asking if their positions would change if the knowing is about a baby instead of self, and sets up for a shift in the conversation about certainty vs. likelihood, and prevention vs. reduction of risk.

Katharine:	What about people with Tay-Sachs disease? They are not sick. But if they have a baby, the baby could be very sick.

Hei:	Maybe you can… can… So maybe if the baby's sick the mother can know. The baby will look very sick.
Rudy:	Why the baby…?
Katharine:	Why is the baby sick? (Clarifying that this is the question Rudy is asking)
Rudy:	(Nods)
Hei:	Because they have weak genetics than adults because they're born and they need a lot of… I don't know how to say.
Armando:	Really it would be because the father or mother would have the… all-elles… alleles. X or Y?
Katharine:	Tay-Sachs isn't an XY disease.
Armando:	If you have that disease, maybe you do have that disease, you have the disease genetic.
Katharine:	How?
Kun:	You're the class teacher!
Katharine:	I know! How? (Laughter around the table) (Pause… Waiting for someone to answer)

In shifting the conversation to Tay-Sachs and the implications for unborn infants, Katharine is asking the students to reframe their thinking away from *knowing* about having a disease, to the *prevention* of a genetic disease by not passing on those genes to offspring. Hei states that, without testing, the mother might know just by looking at her baby: "the baby will look very sick." Rudy appears to be unsure of what is *causing* the baby to be sick, and so he asks, "why the baby…?" Katharine does not answer his question, but clarifies that he is asking why the baby is sick. Hei states that the baby has weaker genetics than its parents, and wants to make an additional point, but does not know how to say what she wants to say. Armando jumps in with an assertion that the baby is sick because of its alleles, and questions whether Tay-Sachs is associated with the X or Y alleles. Katharine clarifies that Tay-Sachs is not an XY disease. Armando responds by stating that if you have the disease, maybe that means that you have the "disease genetic." Again, Hei and Armando bring scientific thinking to the conversation. It reveals, at least, partial understanding – babies with disease will look sick, genetic diseases are cause by weaker genetics, some diseases are located only on the Y chromosome.

Katharine asks Armando how that happens and Kun adds humor by playfully saying that she should know the answer to that question, but Katharine is not distracted and restates the question, pauses, prompts again with a hint to think about a video they watched.

Katharine:	So what happened? You saw the video…
Kun:	Yeah.
Katharine:	(Pause) Lanh is saying something over there, he's just not saying it out loud. (The kids encourage/cheer him on)
Lanh:	Maybe the baby has shot and better protection, so that can happen?
Tai:	Cool.

Lanh, the most reluctant speaker of the group – in fact, this is his only contribution to the seminar – offers that the baby "has a shot and better protections." This is evidence of Lanh's partial understanding; he is implying that "a shot"- immunization – can protect an infant from genetic disease. Tai, whether because he agrees or just appreciates Lanh's contribution, validates Lanh's contribution with a sincere, if understated, "Cool."

This excerpt, in addition to showing sustained talk that is scientific in nature, is also representative of Katharine's ability to endure substantial pauses in order to give students the opportunity to gather their thoughts, craft a response, and speak it. This excerpt also includes a representative example of Katharine gently inviting her most reluctant contributor to participate, the encouragement of his peers to speak, and sincere assessment of what he has to offer.

Not including Katharine's contributions, there were fifty-eight turns-in-talk (see Table 9). I draw the reader's attention to the distribution of talk, and the rigorous and sophisticated character of contributions.

Table 10

Characterizing English Learner turns of talk during the English Learner Only Socratic Seminar

Student	Turns-of-talk	Sentences	Nature of talk
Marcela	4	5	Problematic questioning; Answering
Bay	6	7	Problematic questioning; Building; Reporting; Contradicting; Reasoning; Statement
Kun	7	7	Answering without clarification; Evidence; Reasoning; Agreeing; Problematic questioning
Si	5	5	Answering with and without clarification; Evidence; Problematic questioning of a contradiction at the table
Tai	4	7	Affirming – personal; Answering with reasoning; Contradiction with evidence; Asking for help; Considering alternative
Rudy	4	4	Evidence with reasoning; Statement; Problematic questioning; Clarifying question
Guo	4	4	Answering with and without clarification/evidence; Evidence/causation; Assertion without evidence; Question to drive the conversation
Hei	4	10	Questioning assertion, question with evidence; Asking for clarification Attempt at science talk; Assertion with evidence
Armando	2	2	Adding to the conversation with evidence or building
Lanh	1	1	Reasoning with evidence

In these fifty-eight turns-of-talk there were twelve attempts to use or question evidence, nine events of problematic questioning, and six assertions made with and without leveraging evidence. The conversation, once established, did not stray from the issue of genetic testing. By comparison, these ten students spoke few times during the whole class seminars, and the nature of their contributions, particularly when you take into account that three students received sentence starters from Katharine, were far less sustained and significantly less sophisticated.

Comparing English Learner and English Fluent student participation during the Socratic Seminars.

Whole-class and English-only Socratic Seminar. Ten of Katharine's English Learners participated in an English Learner-only version of a Socratic Seminar, replicating a classroom activity that had taken place as a whole-class event the day before. I selected a Socratic Seminar whole class session that was comprised entirely of English Fluent students in an effort to maintain integrity of the comparison. In Table 11 I draw the reader's attention to four things: 1) the English Learner group did not have a student who managed the group, whereas the English Fluent group had a self-appointed "director," 2) the average length of responses was noticeably different, 3) English Learners were more likely to ask problematic questions that required more than a simple yes/no/brief response, and 4) English Fluent students were more likely to make an assertion and link evidence to that claim.

Table 11

Characterizing the nature of turns-of-talk during whole class English Fluent and partial class English Learner Socratic Seminars

Whole Class (English Fluent) 13 students	Partial Class (English Learner Only) 10 students
Frequency of contribution • 2 of 13 English Fluent students do not speak • Frequency of talk by individuals: 18, 8, 5, 5, 5, 4, 3, 3, 2, 2, 2 • Average length of response was 31 words per turn-of-talk	Frequency of contribution • All 10 students contributed at least once • Frequency of talk by individuals: 7, 6, 5, 5, 5, 4, 4, 4, 2, 1 • Average length of response was 14 words per turn-of-talk

Nature of contribution
• 11 counter claims/contradictions;
    • 6 with rationale but not evidence
• 1 event of problematic questioning
• 14 assertions made
    • 8 with evidence
• 8 attempts to use or question evidence
	Nature of contribution
	• 6 events of contradiction
	    • 2 with evidence
	• 9 events of problematic questioning
	• 6 assertions made
	    • 3 with evidence
	• 12 attempts to use or question evidence

Tracking participation among three Intermediate Level English Learners who had additional access to Katharine. In this section I present the findings for three Intermediate students, all of whom were members of the ELL Support class that Katharine attended weekly. In general, all three experienced movement from silence at the beginning of the year towards rigorous scientific discourse. For all three, their most rigorous scientific discourse was during the English Learner only Socratic Seminar. Likewise, all three experienced a regression of sorts following the English learner only Socratic Seminar. While all three participated in group preparation of the final product for the Genetically Modified Organism Activity, only Irene was a visible contributor. The contributions made by each of the these students was not as rigorous as their prior work had shown them capable of. The findings for these three students examines three elements of their participation over the course of the year, namely: the nature of their discursive participation, the nature of their interactions with their English Fluent peers, and the nature of their interactions with the English Learner peers and/or Katharine.

Guo. Guo's participation over the course of the year advanced, regressed, advanced, and then regressed slightly again. According to Krashen's five stages of second-language acquisition Guo was in the "Speech Emergence" phase, where we would expect him to be able to use phrases and short sentences to answer "why," "how," or "explain" questions. With his peers, Guo was most often in the "Early Production" phase, using simple sentences to answer yes/no, either/or questions. Working one-on-one with Katharine or with his English Learner peers, Guo exhibited the ability to meet the expectations of the Speech Emergence phase. During the NASA Activity, Guo did not initiate conversation. One of the boys in his group made one attempt to include Guo in the conversation, but did not persist after Guo's contribution. Examination of Guo's worksheet revealed that he had prioritized the entire list, and had included brief, two-three word explanations for why he had prioritized each item in the manner in which he had.

Guo's participation during the CO_2 presentations was on-par with that of his three group members. He prepared his slides himself, included appropriate data in support of his claim, and stated a well-reasoned argument in support of reducing time spent in the shower in service of economic friendliness and reduction of carbon footprint.

Guo's participation during the whole class Socratic Seminar was minimal. He met standard by making the requisite contributions, but did not exceed standard by extending his participation within the group discussion.

During the English Learner only Socratic Seminar however, Guo participated several times, making assertions, reiterating points made by others, asking problematic questions, making the group laugh. His participation in the English Learner only seminar was appreciably different. Guo's contributions to the English Learner only Socratic Seminar are frequent and brief, designed to move the conversation along, add humor, and reiterate points.

Marcela:	How about… what if you don't want to?
Bay:	I think Mr. Obama should make the tests free for all the citizens. So that everyone can take it.
Teacher:	What kinds?
Kun:	The kinds to test do you have the genetic disease.
Teacher:	But there was a lot of genetic disease in the article.
Guo:	Test them all!

Finally, during the final project of the year, Guo was partnered with the same three boys that were in his group at the beginning of the year for the NASA Activity. During collaboration in preparation of a video commercial in support of genetically modified organisms – specifically Zebra Fish. During the two minute commercial, Guo is visible or audible for a few seconds at the end of the video when he says "Vote no for I-466!" Two of the boys, both English Fluent students, share the remainder of the screen/talk time, explaining the science behind Zebra Fish and their contributions to society. The remaining student, an English Learner no longer receiving services, is not represented at all. This evidence runs contrary to the group work that I observed during the preparation phase, where Guo and the other student were involved in research and planning of the video. Guo's participation over the course of the year exceeded expectations given the fact that he had only been in the country for a year at the beginning of the school year. His attempts at science talk are supported by scaffolding from Katherine, situations where his ability to think critically and respond to "why," "how," and "explain" questions using evidence to support his assertion evidenced his growth.

Hei. Hei's participation over the course of the year made a big jump, followed by a little jump and then a big jump, followed by a small regression. According to Krashen's five stages of second-language acquisition Hei was in the "Speech Emergence" phase, where we would expect her to be able to use phrases and short sentences to answer "why," "how," or "explain" questions. With her peers, Hei was most often in the "Early Production" phase, using simple sentences to answer yes/no, either/or questions. Working one-on-one with Katharine or with her English Learner peers, Hei exhibited the ability to meet the expectations of the Speech Emergence phase, on occasion advancing to "Intermediate Fluency" evidenced by her engagement with problems that asked her to consider "what would happen if," and "why do you think that..." During the NASA Activity, Hei did not initiate conversation, but responded both times that the two girls in her group asked her a question. Her answers were brief – "I chose the oxygen first," and "I don't like milk." Hei nodded in agreement when either of the two girls made an assertion or explained their thinking. Examination of Hei's worksheet revealed that she had prioritized the some of the list, and had included brief, one-two word explanations for why she had prioritized the items she had done. Her group members, one English Fluent girl and one English Fluent girl whose family speaks Chinese Cantonese in the home, were friendly and patient but did not push Hei to say more than she did.

Hei's participation during the CO_2 presentations was not on par with those of her group members. Her participation during the preparation phase was passive and her contribution was minimal, though present, and representative. By that I mean, Hei did her own work.

During the whole class Socratic Seminar, Hei did not speak. Katharine gave her a slip of paper with a sentence starter on it with several minutes remaining to her "round." Because she did not use it, Katharine gave her another slip of paper with a complete sentence on it. Hei did not use it either. During the English Learner only seminar Hei contributed dozens of times, asserting claims with evidence, asking problematic questions, persevering even when she was visibly struggling to find language for the ideas in her head.

Hei:	Maybe you can… can… So maybe if the baby's sick the mother can know. The baby will look very sick.
Rudy:	Why the baby?
Teacher:	Why is the baby sick? (Clarifying)
Hei:	Because they have weak(er) genetics than adults because they're born and they need a lot of… I don't know how to say.

During the final project of the year, Hei was partnered with the same two girls that were in her group at the beginning of the year for the NASA Activity. During the NASA Activity, Hei did not initiate conversation, and her group members, after two attempts, stopped inviting Hei to contribute. During the group's preparations for the I466 pro/con GMO labeling advertisement, Hei's group members did not have to persist in order to get Hei to join in the planning and implementation of their advertisement.

The following is a clip from that advertisement, representing about two minutes of a four minute ad. I draw the reader's attention to the various types of *scientific content* contributions made by each of the three girls.

Hei: So, Doctor, what about this monkey is so great?
Biming: Well, really, the best thing about the marmoset is how human-like they are. Since monkeys and humans are such similar species, having the marmosets gives us an almost exact genetic look at how genetic modification will affect humans.
Hei: Then why will we want to test on animals? What good does it do?
Biming: Well, right now we are trying to figure out how to cure diseases such as cancer and Alzheimers, through genetic modification. By testing marmosets we can figure out how to plant the desired gene into their DNA and have it go so deeply embedded in their DNA that they pass it on to their offspring.
Hei: How does it genetic modification?
Biming: First we collect some plasmid from a bacteria (illustrating the process on a whiteboard while speaking). Then a restriction enzyme cuts a desired gene from the plasmid and separates the two. The same restriction enzyme cuts the (missed) plasmid to insert the desired gene by using ligase enzyme to glue them back together. Then the new plasmid is put into bacteria, and the organism is given the bacteria by (missed) transfer DNA.
Hei: Doesn't that change and hurt the monkey?
Biming: Why no! The marmosets have no pain during this process. The marmosets are very happy in captivity and very easy to work with. They are small so they can be handled more easily. And they are calm. The monkeys are much more fertile. And we have much more information to go on.
Hei: Thank you Dr. Smarty-Pants. Any last words?
Biming: Yes! Genetic modification is a very important part of disease research and I466 wants to end that. For the sake of the afflicted, vote no on I466.

Hei drives the conversation, and asks questions that anchor what the two other group members have to offer, but the character of Hei's talk is talk *about* science, while the character of the group member's talk is talk that *explains* science. In fact, during preparation of the presentation, Biming and Katharine did most of the research and decisionmaking, relying on Hei only for planning and performing.

Hei's participation across the year evidences her ability to engage in rigorous scientific discourse, particularly in intimate situations. Her participation in the English Learner only Socratic Seminar was a revelation, as her prior contributions to groupwork or whole class discussion had, up to that point, been minimal.

Bay. Bay's participation over the course of the year followed a similar pattern to that of Guo – progression, regression, progression, slight regression – with greater growth in the moments of progression. According to Krashen's five stages of second-language acquisition, Bay was in the "Speech Emergence" phase where we would expect him to be able to use phrases and short sentences to answer "why," "how," or "explain" questions. With his English Fluent peers, Bay was most often in the "Speech Emergence" phase. Working one-on-one with Katharine or with his English Learner peers, Guo exhibited the ability to push his participation past the Speech Emergence phase into "Intermediate Fluency." During the NASA Activity, Bay did not initiate conversation. One of the girls in his group made several attempts to include Bay in the conversation, persisting to make sure that the group heard what he said. Examination of Bay's worksheet revealed that he had prioritized the entire list, and had included brief, two-three word explanations for why he had prioritized each item in the manner in which he had.

Bay's participation during the CO_2 presentations was on-par with, maybe even slightly better than, that of his three group members. He prepared his slides himself, included appropriate data in support of his claim, stated a well-reasoned argument in support of his initiative to reduce his carbon footprint. His presentation was cheerful and energetic.

During the whole class Socratic Seminar, Bay's participation met standard. It was clear from his contributions that he had a good understanding of the primary source documents used for the discussion.

During the English Learner only Socratic Seminar, Bay's contributions are rapid and brief. Bay was one of three students to contradict or challenge assertions or claims made by students at the table, though not always with evidence to support his counter-claim or challenge, and he added data, drawn from the readings, to the conversation. Bay also asked questions of the groups that invited more people to talk.

Bay:	Why do people take the DTC test?
Teacher:	Why? (Clarifying)
Si:	Because you have some problems. If you have problems…
Marcela:	Maybe if they want to protect if you have the disease. (Agreement around the table)
Bay:	They know the cost is expensive but they know, they know…
Kun:	If caught early on, you prevent to die.
Rudy:	If you have some problems, like if you can't prevent what's going to…
Han:	You'll die.
Si:	You'll die. (Emphasizing)
Bay:	But it's not always…

The conversation changes direction with Bay's prompt that you may not always die, leaving the unspoken question: under what circumstance, then, if you are not guaranteed to die? Other students around the table pick up this thread, beginning with a question: "So, do you think everyone needs to take the genetic test?"

During the final project of the year Bay was reunited with the same group members that he was with during the NASA Activity on the first day of school: an Advanced English Learner girl, and an English Fluent girl. His participation during the preparation phase was on par with that of his group members. The group discussed and made decisions together. Research and analysis were divided evenly. On-screen representation in the group's video was not equal. Surprisingly, perhaps, the Advanced English Learner was the face and voice of the group, using a whiteboard to illustrate her explanation that was co-constructed by the group.

Bay's participation across the year, particularly with respect to his attempts at advanced reasoning and argumentation with Katharine and his English Learner peers, reveal growth that is supported by Katharine's scaffolding.

Tracking participation among three English Learners who did not have additional access to Katharine. In this section I present findings for three students who did not have access to Katharine via the ELL Support class. All three students experienced limited movement along the trajectory of participation, with Woojin and Lanh exhibiting minimal verbal participation, and Belle attempting to participate more deeply, but encountering resistance from her peers. Woojin and Lanh were silent even at the end of the year working with group members who were familiar with, and to, them. Belle, on the other hand, made several attempts to participate, only to be redirected by members of the group. Like Guo, Hei, and Bay, the contributions made by each of these students was not as rigorous as their prior work had shown them capable of. The findings for these three students examines three elements of their participation over the course of the year, namely: the nature of their discursive participation, the nature of their interactions with their English Fluent peers, and the nature of their interactions with the English Learner peers and/or Katharine.

Woojin. The nature of Woojin's verbal participation when working with his peers was primarily simple academic science talk that did not reflect the deeper conceptual understanding evidenced by his written work. According to Krashen's five stages of second-language acquisition Woojin should have been in the "Early Production" stage, but his interactions with Katharine showed that he was in the "Speech Emergence" phase. Therefore, we would expect him to be able to use phrases and short sentences to answer "why," "how," or "explain" questions, all of which he did in fact do with Katharine. With his peers, Woojin was most often in the "Early Production" phase, using simple sentences to answer yes/no, either/or questions.

During the NASA Activity, Woojin did not initiate conversation. None of Woojin's group members attempted to engage him in the group's work. Examination of Woojin's worksheet revealed that he had prioritized the entire list, and had included brief, two-three word explanations for why he had prioritized each item in the manner in which he had.

Woojin exhibited limited participation during the preparation of CO_2 presentations. He made few verbal contributions, and his written work was clear but offered only simple scientific skills like recording and reporting data, with limited explanation and discussion of his findings.

Woojin's participation during the whole class Socratic Seminar was minimal. He met standard by making the requisite contributions, but did not exceed standard by extending his participation within the group discussion. Woojin was not available to participate in the English Learner only Socratic Seminar.

During the final project of the year, Woojin was reunited with the same group members that he was with during the NASA Activity on the first day of school: an English Fluent boy, and an English Fluent girl. His participation during the preparation phase was again limited. The English Fluent students discussed and made decisions together, asking Woojin to agree with their decisions by saying "Is that okay with you?" Research and analysis were divided evenly among the English Fluent students and Woojin was not expected to meaningfully contribute. On-screen representation in the group's video was not equal. Woojin was not a part of the final product.

Belle. Belle's participation over the course of the year could best be described as frustrated. During the NASA Activity, Belle was partnered with two English Fluent girls and an English Fluent boy. When Belle would make a suggestion, one of the two girls would counter

Belle's rationale and then look to the other girl for confirmation. The boy nodded in agreement, speaking only when asked a direct question.

Belle: I thought a gun would be not a good idea because it is space and the gun would not work anyway.
Ellie: But you could use a gun to propel you in the opposite direction. So you shoot it in the opposite direction that you want to travel and there you go, right Margaux?
Margaux: Right! What did you put for matches?
Belle: Matches won't work either (quietly).
Margaux: What? No. I think matches could be used to start a fire, like if you get cold. (Turns to Elizabeth) Right?

Belle's participation during the CO_2 presentations was on-par with, maybe even slightly better than, that of her three group members. Working independently, Belle prepared and presented her slides herself, included appropriate data in support of her claim, stated a well-reasoned argument in support of her initiative to reduce her carbon footprint. Her presentation was thorough and professional.

During the first half of the Whole Class Socratic Seminar, Belle was partnered with Lizzie, an English Fluent student. One of the roles meant to be played by an individual's partner was that of a coach. The coach sat behind the participating member during their half of the seminar session and offered advice, feedback, and suggestions to make contributing and participating more manageable. To begin, Katharine posed a question to the group: "What does all of this (genetic testing) have to do with DNA to RNA to protein? Lizzie appeared confused, and looked to the people to her left and right. Belle offered her a note on which was written: "Proteins would be different if dna → rna aren't regular." This input, as well as a second note were both ignored by Lizzie. During the second half of the Whole Class Socratic Seminar, Belle's contributions were salient and fit into the flow of the conversation. Belle was not available to participate in the English Learner only Socratic Seminar.

Reunited with her original group members from the NASA Activity, Belle was assigned the task of creating a series of illustrations for their political advertisement. I observed the group discussing their plans for writing, creating, and editing the advertisement. While still drawing, Belle interjected a suggestion to do a voice-over that they could layer on top of her illustrations. “That sounds really hard,” replied Ellie. “I don’t know how to do that. At all. No way. Do you (to Margaux, an English Fluent girl)?” “Not me. Let’s think of something else. But still use your drawings.”

Lanh. During the NASA Activity, Lanh completed the worksheet working alone like the rest of his group members. His completed worksheet included rankings of supplies and brief, two-four written word rationales for his ranking decisions. During the group conversation, however, Lanh did not volunteer at all. When his group members – two English Fluent boys and an English Fluent girl – attempted to draw him into the conversation, Lanh stared only at his paper, never making eye contact. His group members did not ask any for any further input, nor did they attempt to gather information from his completed worksheet. Two group members made comments to me about not wanting to make him uncomfortable, or feel bad about participating.

Lanh’s group members were different for this project. During the group’s preparation of the presentation, Lanh did not volunteer any input other than to agree to keep track of the length of his showers for two weeks (one baseline week, one intervention week). Lanh did not respond to group members’ requests for information or data from him. Group members did not ask Lanh if he understood the problem, the task, or the proposed presentation. Nor did they work one-on-one with him to practice CO_2 usage calculations. During the presentation, everyone else in the group had data, analysis, and discussion to present for their unique sets of data. When I asked him why he had not completed the task he quietly said “Lazy.”

Lanh looked visibly uncomfortable and did not contribute at all during the Whole Class Socratic Seminar, in spite of Katharine’s provision of a sentence starter, initially, as well as a complete question towards the end of the session. During the English Learner Only Socratic Seminar, Katharine prompted his contribution by first pointing out that it appeared that he had something to say, and then waiting for him to say it. His contribution during the English Learner only Socratic Seminar was minimal, but relevant to the conversation.

Lanh was reunited with the same group members he was with for the NASA Activity. Although this particular foursome has not worked together since the beginning of the year, Lanh had been in groups with these students one at a time throughout the academic year. Lanh does not volunteer or contribute in any significant way when the group brainstorms, divides the work, assembles the advertisement, or presents the final product. The members of the group assigned him the task of finding images to “dress up” the advertisement. One of the group members turned to me and said quietly, “I’m just looking out for him. Don’t want him to feel uncomfortable.” A second group member also took on the responsibility for finding appropriate images. None of Lanh’s group members asked him if he understood the assignment or the group’s plan of action. I saw no record of images collected by Lanh, or presented to the group.

Claim #3: The unproductive impact of caring.

One of Katharine’s classes required more re-direction and structure than the other three. This class also had the greatest number of English Learners in it. When surveyed, this class reported having very strong perceptions of Katharine’s caring about them (all classes: M=4.79, Block G: M=5.81, range 1-7). This small but significant piece of data will be discussed in the next section.

Another type of an unproductive outcome – shielding by peers – was observed on the first day of school, and persisted throughout the year. I use the term shielding here to indicate any time that an English Fluent student made a move that prevented an English Learner from contributing to the intellectual and conceptual work of the group as a form of "protection," preventing the English Learner from feeling awkward, uncomfortable, or "bad about not being able to help." For example, during the NASA Activity on the first day of school, while I was observing a group of four made up of three English Fluent students and an English Learner, when it became necessary for students to explain to each other their rationale for making the selections they had made, Lanh – an Advanced English Learner – stared at his paper, not making eye contact with his group members. "Don't worry about it," said Charles, "I can read what you wrote I think." Charles then smiled at me and mouthed, "I don't want him to be uncomfortable."

This would not be the last time that Lanh was shielded from participation, in spite of the fact that his written and spoken English were both very strong. At the end of the year, reunited with this same group for the Genetically Modified Organism Activity, Lanh was again shielded from participation, assigned to gathering images and making the references slide for the group's presentation. I happened to be videorecording the group on this day, and after Lanh's assignment had been made, Charles turned to me and said quietly, "I'm just looking out for him."

Throughout the year I observed numerous times in which English Fluent students would take on more responsibility in order to make sure that their English Fluent group members would not "feel bad." One morning in September, I noticed that one of Katharine's students seemed overwhelmed. When I asked her how she was doing, she said "There's just so much to do, I don't know how I'm going to get it all done." "On the project," I asked? She nodded. "Why are you doing all of the work?" "No. I mean. Katie is doing some of the work, but Marcella…she can't really and I don't want her to feel bad that she can't so I'm trying to do it all."

This phenomenon was not unique to English Fluent students. There were moments when more advanced English Learners, no longer receiving ELL Support services, would take on the work of their English Learner peers. During a January observation of groupwork on the CO_2 project, I heard Denali say "I got this. Can you just do the calculations? I can do the slides if you do the calculations. Less writing for you. I think that's easy for you and this is easy for me, ok?"

Problematic perceptions of caring. On the first survey, 10 students reported a 1 or 2 (scale of 1-7, where 1 represented "not at all" and 7 represented "totally") in response to both caring questions. Eight of the ten were white females. Katharine challenged herself to process the significance: "Yeah." (Pause). But I'm also not surprised, given that girls often feel overlooked. Not just in science class, but in *class* (emphasis hers). Where teachers use more wait time with boys. Those classic sorts of studies. I mean, I hope I'm not perpetuating a stereotype." Several minutes passed as we carried on a conversation about other aspects of the data. "Back to the white girls," she said as I organized papers. "I'm also not surprised about the white girl thing because last year and this year, I want to push kids, in some regard… The girl thing is a girl thing – I want girls to be in science. But I don't know that I'm really targeting white girls. Because they're still privileged, right?" Katharine continues to think out loud, cultivating her rationale for her equity stance.

> So I am probably more excited about Desiree coming in and working her tail off. I am more excited about getting the Latino males in a good place for, you know, changing their life basically. So I would say that children of color… Across the

> spectrum… Boy/girl, whatever… I would probably push and interact with those kids more. And so the white boys might be feeling like if we were really to look at the data, the white boys might be feeling less either attached or connected…
>
> I don't think there's anything wrong with it. What I'm trying to do is even the playing field. You come with privilege, I'm going to still love you. But, I'm not going to pick on you, and say, like you could do better. It's not the same intentionality. Whereas I can see Filiberto and say, did you know that there are scholarships for Pacific islanders? And maybe those conversations… First-generation college goers, because I am… Yeah. And with the population we serve, yeah.

Moving forward, Katharine focused on nurturing her relationships with girls in her classes. As a reminder to the reader, Katharine had no idea who the eight girls were, only that eight girls had reported a sense of her not caring. She did this by checking in with girls at the beginning of class as they entered – "How are you doing?" "Coming from gym? Go grab some water!" – or "dropping by" their desks or tables to check in during class. During the "drop-ins," Katharine used some piece of information that she knew about the student – class day events, upcoming performances, books they were reading – to authenticate the conversation. Results among seven of the eight girls at the end of the year – one was not available for the final survey – showed a significant uptick: "cares about me as a person" improved from M=2.0 in the Winter, to M=3.7 in the Spring, and "cares about me as a learner" improved from M=2.25 in the Winter, to M=4.4 in the Spring.

There were a handful of students whose perception of teacher caring diminished somewhat over the course of the year. Eight students, four boys, four girls reported: "cares about me as a person" moved from M=4.0 in the Winter to M=1.88 in the Spring, and "cares about me as a learner" moved from M=4.38 in the Winter, to M=3.01 in the Spring.

None of the eight were students currently receiving ELL support services, though three of the eight were girls who formerly received ELL support services, and three of the eight were

White males. The three white males indicated that Katharine had given them help and/or asked how things were going as evidence of her caring midway through the year, and at the end of the year simply stated that "she doesn't" care. "I can't blame her. It's her job to care about the kids who need it," wrote one of the three.

These problematic and unproductive findings were unexpected and left us with more questions than we had findings. A caring stance can be interpreted a number of ways and we are left to wonder what that means for teaching and learning. Caring can leave some students feeling not cared about even when they recognize and acknowledge that others are being cared for. Whether with the best or worst of intentions, sometimes caring yielded unfortunate results and missed opportunities.

Discussion

Over the course of the year I observed more than 200 of Katharine's classes. For 20 of her students, the 2013-2014 academic year represented my second year with them. The longitudinal nature of this study affords a particular insight that would not have been possible had I been present for a single lesson or unit. These moments of observation and interaction with Katharine and her students are rare opportunities that offer a unique level of analysis. Persistence in the classroom made it possible to see things that would not have been readily apparent over shorter time frames.

In this section, I organize my discussion according to the claims and anchored to a second version of my conceptual framework, namely: cultivating a caring community, Katharine's relational and instructional moves, and the productive and unproductive impact of Katharine's caring approach to instruction.

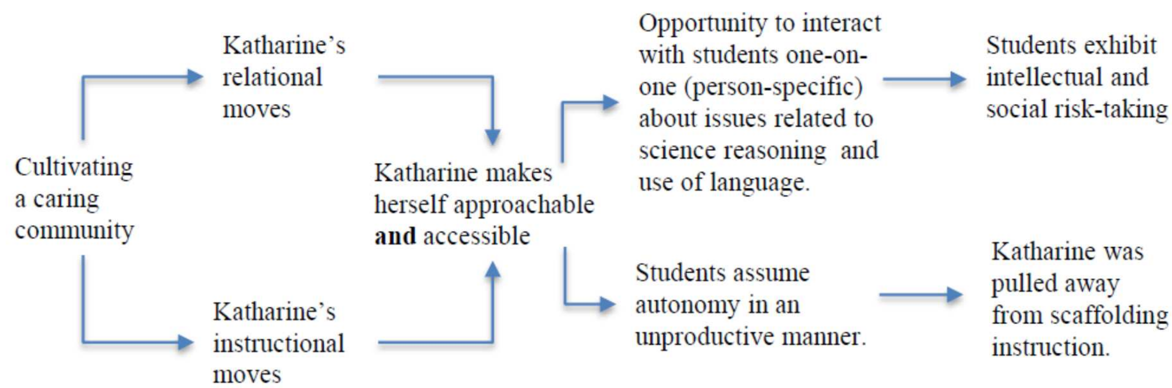


Figure 3 Revised version of conceptual framework examining relationships between teacher caring, relational and instructional moves, and the productive, unproductive, and problematic outcomes of a caring approach to instruction.

Cultivating a caring community

It is a widely held belief that caring relationships between teachers and their students are necessary, or at the very least helpful, for students to feel connected to school and content (Gay, 2000b; Hughes & Barrois, 2008; Lessard et al., 2008; Noddings, 1992). Valenzuela contends that the lack of a caring approach to teaching is actively *preventing* students, particularly Hispanic students, from doing well in school (1999); that students need to feel cared *for* at school, in order to care *about* school.

The distinction between caring *for* and caring *about* translates to teachers in classrooms. Teachers certainly care about their students; they care whether or not their students are safe, well-fed, and have done their homework. Teachers who care *for* their students on the other hand, are driven to action; they refer their students for available services, they have snacks available for students who might be hungry, they find out why homework is not handed in, and work with students to find new ways to connect students to the content and understanding.

Katharine's actions were broadly characterized by her relational and instructional moves, both of which she believed to be integral to her caring approach to instruction. Students recognized her caring approach, often conflating relational and instructional elements when asked to provide evidence of her caring. Like Gay's "warm demanders," (2000) students perceived Katharine's scaffolding and instructional support as caring in the same way that they saw her personal interest in their lives as indicative of her caring. This is an important revelation about science classrooms, particularly problem-based science classrooms that disrupt typical teacher-driven classroom norms and expectations. It is not unusual for students to find the transition from a traditional lecture-lab-exam format to a problem-based curriculum challenging (Hmelo-Silver, et al 2007). A caring approach may help to ease that transition.

The presence of caring has been shown to trigger "can-do" dispositions that facilitate student participation and engagement (Bandura, 1997). Katharine did not view her caring approach and the success of her students as discrete components. Indeed, Katharine had deeply held convictions about the connection between her relationships with her students and their academic outcomes. Katharine believed that in order for her English Learner students to be successful, they needed – deserved – to be heard, and that the kind of rigorous scientific discourse that she was looking for would require her English Learner students to embrace their vulnerability and take risks, and that these risks would lead to academic growth.

Students reveal their recognition of Katharine's caring in the ways that they talk about her relational and instructional moves to help the as learners and as people. This is important distinction because Katharine set out to establish relationships with her students that sent a clear message of concern for students as people and as learners, and she is profoundly aware of the reality that English Learner students are too often viewed as deficient. To the contrary, Katharine has a deeply held belief that these students have been silent – literally and symbolically – for too long, even if as the result of best intentions.

Katharine's caring approach to an equity stance for her English Learners is not, necessarily, what makes her story unique. There are countless science teachers who care deeply for all of their students and seek equitable experiences for them that are built upon substantial, culturally relevant pedagogy (Roseberry et al., 2001; Warren et al., 1989). What makes Katharine unique are the actions she is willing to take in service of supporting her English Learners. Her two-pronged relational and instructional approach helps us answer what happens in-between teacher caring and student action.

Katharine's relational and instructional moves

Though Katharine's relational moves to establish meaningful connections with students are most noticeable during the first month of the school year, her efforts to establish a caring environment and cultivate rapport and with her students are visible and audible throughout the year. Katharine's students, particularly her English Learners, recognized these efforts and appreciated them.

Katharine designed her instructional approach to be transparent and supportive so that students would see her efforts and recognize them as contributory to their social and academic success in science. These moves can be seen as strictly instructional – scaffolding, holding high expectations – or as primarily relational – frequent check-ins, sharing of personal stories – but for Katharine, her actions are meant to integrate the instructional and relational – communicating with students and families in Spanish, making herself available at school during the day and well after the end of the school day, holding students accountable to high standards while remaining flexible.

The transparency of Katharine's actions, relational and instructional alike, was also a form of modeling personal and academic interactions she hoped students would adopt. The findings show that, on an instructional level, there were only isolated events of substantive and supportive scaffolding. Relationally, on the other hand, students in Katharine's classes felt connected to one another. The students' use of words like "welcome" and "valued" convey and overall sense of connectedness that is as much a reflection of the their relationship with Katharine as it is a reflection of their relationships with each other.

This is an important finding because, in spite of the fact that English Fluent students did not take up Katharine's scaffolding strategies, they appeared to have appropriated her caring stance. As a result, contrary to what Olsen (1997), Valdés (2011), and Yoon (2008) have found to be true in bilingual classrooms – that English Fluent students presume a deficit stance for their English Learner peers, assume power and control over collaborative work, and that English Learners can feel stigmatized, anxious, unwelcome, and ignored – we found that English Fluent students were frustrated with their collective inability to communicate. There was no mention of English Learners not having anything to contribute. Indeed, English Fluent students reported a belief that their peers had important ideas. We know this to be true as was evidenced by student discourse during the English Learner only Socratic Seminar when students shared their ideas about genetic testing, disease, vaccinations, and the connections among these topics. Unfortunately, English Fluent students did not have the opportunity to observe those interactions.

We also considered the possibility that students did not adopt Katharine's strategies because they considered them ineffective. The data did not support this possibility. In fact, the data indicate that students believed that Katharine's strategies were helpful. When asked what strategies they used to support their peers, the strategies that students listed were consistent with their answers to a similar question in which we asked students to identify strategies Katharine used to help them learn.

The assumption that English Learners were incapable of communicating is still a deficit stance, regardless of its source. We are left to consider: what are the next steps necessary to disrupt – once and for all – English Fluent student assumptions of a deficit stance? Walqui reminds us that students need to be taught how to learn (2006, p. 169), explicitly. This is especially true in situations where students are navigating conversational, academic, and scientific language, content, and specific cultural context unique to science. Walqui is speaking about teachers and their English Learner students, but the same holds true for English Fluent students, particularly with respect to appropriation and implementation of effective scaffolding strategies.

The productive impact of caring

Katharine's active participation in the English Language Learner Support class was her attempt to implement a multi-faceted approach to science instruction beyond the boundary of her classroom. Her efforts to re-imagine what it means to be good at science, who gets to be good at science, and her role in supporting her English Learners are successful in that English Learners see themselves as capable and willing to take risks in science.

A majority of the risk-taking largely happened in the intimate spaces of one-on-one scaffolding cultivated by Katharine. This is consistent with the findings of Swanson, Branchini & Lee (2013) who found that English Learners contributions stayed primarily in their small groups. They also found that English Learners – in a non-problem-based high school science classroom – were proficient in gathering, listing, and citing evidence, but struggled to link that evidence to a claim or explanation (2013). Katharine's English Learners, on the other hand, exhibited the ability to use evidence in support of a claim, or to generate a rationale for an explanation. For example, when Hei suggested that we could better spend our money on established interventions instead of spending it on genetic testing that is expensive and does not tell us much information, Tai disagrees. In support of his disagreement, Tai points out that there are diseases we can catch through genetic testing before it "(moves) to another part." In another exchange, Si points out that people use the DTC (direct to consumer) tests because if you have problems…" he trails off and Marcela builds on Si's argument by saying that it's expensive, but "they know… They know."

That Katharine's English Learners do link evidence to their arguments may be a product of navigating problem-based instruction for nearly seven months by the time they took part in the Socratic Seminars.

Neither is it surprising that in those moments when risk-taking broke through whole-class conversation, the risk-takers were most often students who participated in the ELL Support class attended by Katharine on a weekly basis. We are left to consider what strategy or support was missing that prevented most English Learners from engaging in the type of scientific discursive participation that was observed during the English Learner-only Socratic Seminar.

The unproductive impact of caring

We were not expecting to unveil unproductive or problematic elements that arose from Katharine's caring stance. Two interesting cases arose. In one, the class of Katharine's that required the most structure and redirection, that also had the greatest number of English Learners in it, was also the class that Katharine inherited a full month into the school year. As a result, this class did not engage in all of Katharine's intentional, relational moves. Katharine assumed control of the class, I asked her if she planned on doing any of the relationship building that she had done with the other classes, to which she replied, "I don't think so. They're a natural control group now, aren't they? Let's see what happens." When analyzing the perceptions of caring data, we fully expected this group to report the lowest perceived sense of caring. What we found was that they had the highest sense of perceived caring, a trend that endured through the end of the year.

It is our hypothesis that this particular group of students equates teacher intervention – structure, redirection, etc. – with caring. Where it becomes problematic however, is in the reality that all of the structure and all of the redirection require Katharine's attention. If she is focused on structured class time, or attending to off-task students, she is not available to scaffold and support instruction in small group or one-on-one configurations.

The problematic impact of caring

We expected to find some tension from English Fluent students in the context of Katharine's privileging of English Learner voice. On the first survey, 10 students reported a 1 or 2 in response to both caring questions. Eight of the ten were white, English Fluent females. This raised a red flag for Katharine, not because they were white, or English Fluent, rather, because they were girls. As a woman, in science, Katharine was troubled by the notion that her de-privileging of girls would further alienate them from the field of science, more so than her, or her classroom.

She gave this serious thought and decided that alienating a small segment of students who were making satisfactory progress was an acceptable trade-off. Still, the fact that eight young women felt that she did not care bothered Katharine because she sees herself as a proxy for science writ large. As a woman teaching science, she wanted to make sure that girls felt that science was a place where they belonged. Her small relational shifts – checking in with the girls, making connections about life events, etc. – with this group made a tremendous impact in their perceptions of caring over the next several months.

Student participation over time

There was a noticeable difference in the evolution of participation between English Learners who were a part of the ELL Support class that Katharine attended weekly, and the English Learners who were not a part of the class (see Figures 4-9). For the three focal students of this study (see Figures 4-6), progress was punctuated by growth and setbacks. The setbacks experienced by all three after the English Learner only Socratic Seminar were missed opportunities more than regressions of ability. Guo's group members failed to recognize his growth, choosing to shield him from being challenged by full project participation. Conversely, Hei's group recognized her desire to be involved in the development and portrayal of their political advertisement, but didn't provide the same opportunities for rigorous participation. Bay's group leveraged the interest of one of the group members, Aoki, allowing her to take the lead in development and on-screen portrayal.

When positioned against their initial participation – I remind the reader that all three were virtually silent during the NASA Activity on the first day of school – the growth and development of their scientific discourse is encouraging. Add to that the reality that all three had been in the country for 12-24 months and the significance of their emerging scientific rigor is remarkable. Hei and Bay were diligent in their interactions with Katharine in the ELL Support class. By October, both had specific goals in mind by the time Katharine arrived, no longer needing her guidance to direct the time that they had together. Guo, on the other hand, allowed Katharine to direct their interactions.

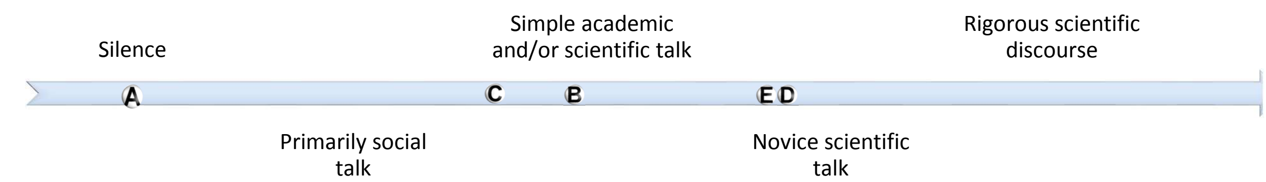


Figure 4 Linear representation of the nature of Guo's talk over the course of the year.[7]

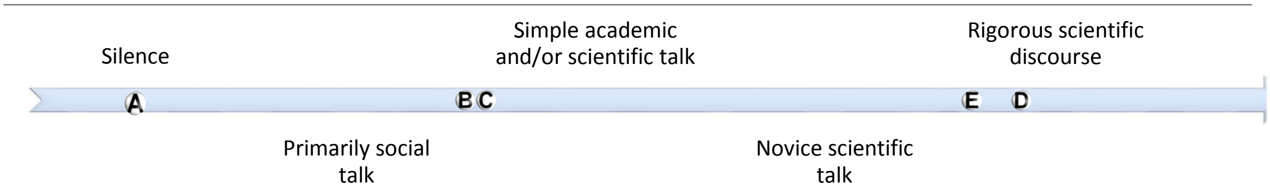


Figure 5 Linear representation of the nature of Hei's talk over the course of the year.

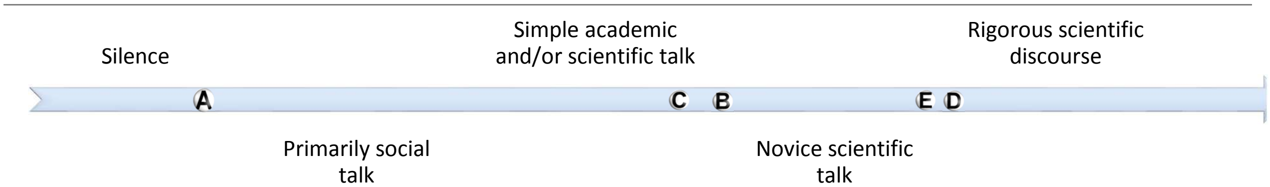


Figure 6 Linear representation of the nature of Bay's talk over the course of the year.

In contrast, I offer the following "mini cases" of three English Learner students who were not a part of the ELL Support class. They are: Woojin, Belle, and Lanh (see Figures 4, 5, and 6).

Woojin was an Intermediate English Learner who did not qualify for ELL support services due to his status as a foreign exchange student. Belle was an Advanced English Learner

[7] Legend Note: Each dot represents a theoretical "stop" as students move from silence towards rigorous scientific discourse.
A. NASA Activity (September) B. CO_2 Presentations (late January) C. Whole Class Socratic Seminar (late March) D. English Learner Only Socratic Seminar (late March) E. Genetically Modified Organism Activity (late May)

who regularly had creative and innovative ideas and suggestions that were rejected by her English Fluent peers because they were "too difficult," or "not what I want to do." Lanh also was an Advanced English Learner who repeatedly exhibited exceptionally clear conceptual understanding in writing, but rarely spoke out loud. In fact, over the two years that I had observed him in Science class, I heard him speak maybe ten times.

I chose these three because I believe they offer insight in two different ways: one, all three students did not have access to Katharine in the ELL Support class and therefore are a natural comparison group, and two, all three students faced very different barriers to participation that were relational and instructional in nature.

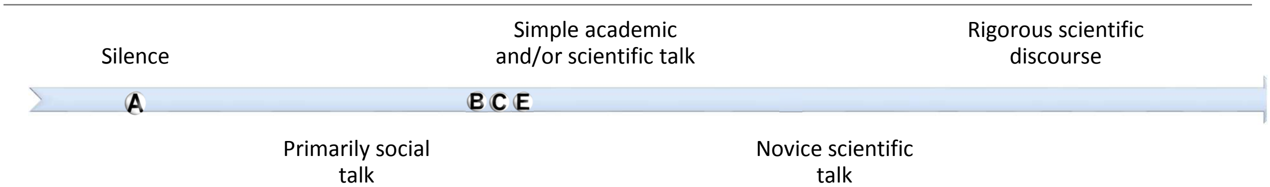


Figure 7 Linear representation of the nature of Woojin's talk over the course of the year.[8]

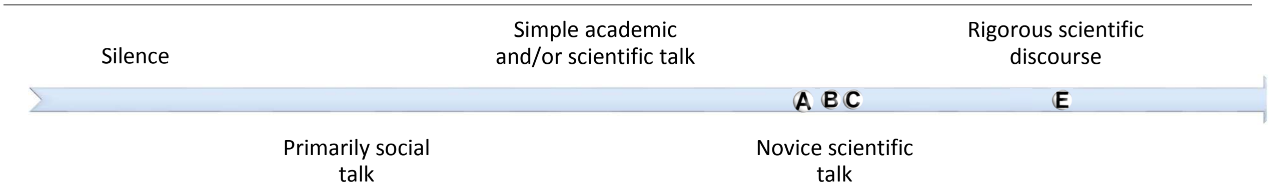


Figure 8 Linear representation of the nature of Belle's talk over the course of the year.

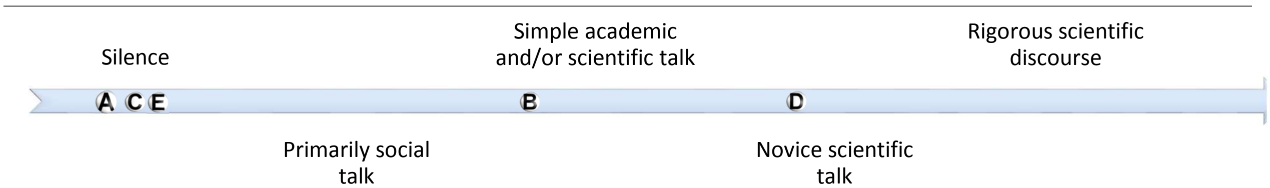


Figure 9 Linear representation of the nature of Lanh's talk over the course of the year.

[8] Legend Note: Each dot represents a theoretical "stop" as students move from silence towards rigorous scientific discourse.
A. NASA Activity (September) B. CO_2 Presentations (late January) C. Whole Class Socratic Seminar (late March) D. English Learner Only Socratic Seminar (late March) E. Genetically Modified Organism Activity (late May)

Like Guo, Hei, and Bay, Woojin started the year in silence, and like the three he experienced initial development in his participation. Where he differs is in the fact that his participation remained the same – simple academic/scientific talk – for the remainder of the learning events.

Unlike Guo, Hei, and Bay, Belle's participation was strong from the beginning. In addition to artistic creativity, she established discursive scientific participation that was at least novice, often pushing into rigorous participation only to be met by resistance from her English Fluent group members who either objected to the perceived difficulty of her suggestion.

Finally, Lanh had the strongest conceptual understanding, but restricted his participation based largely upon his personality type. Lanh's shy demeanor fed into the shielding dynamic assumed by many of his English Fluent peers. It was clear that he always felt uncomfortable, and his English Fluent peers wanted to do whatever they could to make him the least uncomfortable that he could be.

All three were not engaging in the kind of discursive participation imagined as possible by Katharine. What puzzles me is whether or not additional support from Katharine would matter for these three students.

Shielding as a well-intentioned but problematic deficit stance

Shielding, in this instance, should not be confused with sheltering instruction for English Learners. Where sheltered instruction provides specific supports to transition English Learners into full participation, shielding prevents it. English Learners often feel anxious, overwhelmed and unwelcome working in multilingual classrooms and their English Fluent students presume a deficit stance for their English Learner peers, assume power and control over collaborative work (Olsen, 1997; Valdés, 2011; Yoon, 2008).

A significant component of Katharine's relational approach was to re-frame some, if not all, of these feelings and issues of power. English Fluent students reported being concerned about their English Learner peers, statements that were supported by observations of their collaborative work. Unfortunately, in spite of their best intentions, the silencing of English Learners endured. The actions of English Fluent students, meant to be supportive, prevented capable English Learners from sharing their work.

Shielding was an unexpected outcome and warrants further examination, particularly coupled with what we knew about the strengths of the otherwise silenced students as observed during the English Learner only Socratic Seminar.

English Learner only Socratic Seminar

It was the conversation that emerged during the English Learner Socratic Seminar that unveiled the nature of scientific discourse that Katharine's English Learners were harboring. Until that moment, we had observed moments of discursive practices among her English Learners, though those moments were primarily reserved for one-on-one interactions with Katharine – in class and in the ELL Support class – or, more rarely, small group exchanges. It was a revelation in that we now had evidence that her students initiating and maintaining a sustained conversation that stayed true to the topic of genetic testing and related concepts.

It was an authentic example of the kinds of interactions I had seen Katharine and her students engage in prior to, and since; representative of Katharine's ability to scaffold talk in real time – "…(It's) not moving to another part…What do you call that?" "If it moves to another part? Metastasize" – and refrain from fixing or repairing partial understandings, choosing instead to let the students in conversation fill the gaps.

Conceptually, students leveraged ideas about vaccinations in discussing whether or not to test for genetic diseases – better vaccinations means less disease; knowing you are likely to get a disease might make you more likely to get a preventative vaccine or treatment. Students argued about the benefits of knowing versus not knowing – "If you don't know…you're gonna die!" – and paying a lot of money for knowing about something that may or may not happen when we could make better use of that money.

The forty minute conversation conceptually rivaled that of the whole class conversations, and exceeded it particularly with respect to how students managed their participation. Distribution of talk was far more equitable among the English Learners than among English Fluent students.

Still, we remained troubled by the fact that this kind of talk – sustained scientific discourse – among English Learners did not translate to whole class conversation, and we are left to wonder what supports – relational, instructional, or structural – are needed in order to make it happen.

Limitations

There are, of course, limitations to the findings in this paper. My qualitative analysis, though grounded in the literature and carefully considered, is not flawless. I tried to be true to the spirit of what was said, without being overly generous or overly critical. Moving forward, I hope to recruit some assistance from colleagues to engage in a process of interrater reliability testing.

When surveys are used, there exists the possibility of bias in the writing of the tool, as well as in the self-reporting. While I have no reason to believe that any student engaged in satisficing, it remains a possibility. Moving forward, I could be more critical of my survey instruments so that an increased number of questions verify each other.

The sample size, one teacher and her 120 students represented a robust case study but is too small to generate any generalizable trends.

Finally, my role as highly invested, long-term community member and participant observer open up the possibility that I influenced data and/or impacted outcomes. I tried to be clear about those moments where it was possible that my input might have played a role.

Conclusion

I was discussing the data of this paper with a colleague who asked me: "Are you saying that content teachers should be spending time in ELL classes with their students? Because there are some pretty powerful policy implications in there if you are." "No," I replied. "No, I'm not saying that at all. The kids are." Every student who was in the ELL Support class that Katharine was able to attend weekly repeatedly spoke of the significance of having that time with her. Furthermore, the data show that the trajectory of participation for those students was noticeably more advanced than that of students who were not a part of the class. Finally, English Fluent students made several comments about how hard Katharine worked to help out the English Learner students.

Teachers care deeply about their students. What makes this story so remarkable is that Katharine navigated her own feelings of vulnerability in order to take relational and instructional action in order to care for her students. Taking action can seem overwhelming – teachers are stretched thin, to be sure – or uncertain. Students may reject your caring, or take advantage of it in ways that are unproductive. Katharine faced all of these dilemmas even, if not especially, when she was puzzled by what to do moving forward. The two things that anchored her caring stance were relational and instructional moves. Whenever Katharine was troubled by a lesson, a class period, or a student she asked herself "What do I need to do to meet the personal or academic needs of this student?", and then she would do it.

The reflective nature of Katharine's practice is also a unique feature to who she is as a teacher. Her desire to shift the narrative of how English Learners participated in her science class, and who assumed responsibility for the success of historically marginalized students, was a direct result of her reflection on the events of the prior academic year. Katharine's questions about her instructional practice, and her desire to be effective, drove this work in many ways, inspiring research that spoke practice to theory, and theory to practice.

Moving forward, I am left with a handful of questions that fuel my interest in this body of research going forward. For example, can a teacher's equity stance be transferred to her students? If so, what needs to be done in order to facilitate that process? How can we transform the unproductive and problematic elements of a caring approach to teaching? How can we further support English Learners in making their participation public? How do we help English Learners whose personality determines their desire to verbally participate to increase their verbal participation? And finally, if problem-based instruction relies so heavily upon collaboration, and teachers and students feel ill-prepared to support English Learners in the process of collaboration, can problem-based instruction be an equitable teaching strategy?

SECTION 2

RED LIGHT, DETOUR, SPEED BUMP, GO: THE NATURE OF PEER COLLABORATION IN MULTILINGUAL, PROBLEM-BASED SCIENCE CLASSROOMS

Introduction

This naturalistic case study takes place in Katharine Bryant's[9] classroom at an innovative high school, but is situated in the broader context of the call to better meet the educational needs of English Learner[10] students in order to bridge gaps in achievement that have existed for decades. Various instructional strategies have, as yet, failed to ameliorate those gaps; in fact, they are worse in some instances (Fry, 2003; Ruiz de Velasco & Fix, 2000). Gaps in achievement have endured through federal and state initiatives that mainstreamed English Learners with varying degrees of discrete support while simultaneously holding them accountable to state-administered tests offered only in English (Gandara, 1997). Classroom teachers have navigated direct instruction, standards-based instruction, inquiry-based instruction, kit-based instruction, and now problem-based instruction to name but a few of the major instructional shifts of the past twenty years.

Collaboration is the cornerstone of problem-based instruction, shifting instructional responsibility from the teacher to the students (Barrows & Tamblyn, 1980; Barrows & Tamblyn, 1980; Boud & Feletti, 1998; Dolmans & Gijbels, 2013, p. 215; Savery, 2006; Savery & Duffy, 1995). Teachers operate as facilitators, a role that also creates opportunities for teachers to scaffold instruction for students who are struggling, including English Learners. Problem-based

[9] All names of people and places are pseudonyms.
[10] I want to acknowledge that there are many ways to identify students who do not speak English fluently, many of which carry implications about student perception and ability. My use of the term English Learner is meant only to, as simply as possible, let the reader know that I am referring to a student who had been assessed by trained members of the Pacific School District and was at the time receiving English Language Learner support services. I made a decision to spell out English Learner because I believe that students should not be reduced to an acronym. I dropped "language" from the term in an effort to streamline.

learning in and of itself is not a curriculum; rather it is a pedagogical tool that, ideally invites teachers to consider the varied experiences of their students and to articulate expectations in a manner that brings each student into full membership and participation for challenging and authentic tasks.

Problem-based instruction has a history of success in higher education medical, legal, and business programs, even among English Learners (Hmelo-Silver, 2004; Torp & Sage, 1998). Over the past twenty years, a growing body of research reflects its emergence in secondary classrooms, across content areas. Very little attention, of yet, has been paid to the experiences of English Learners, less still of English Learners in science classrooms. Researchers have not yet examined the implementation of problem-based instruction in multilingual science classrooms, therefore we know little about English Learner experiences in this context. In spite of the dearth of research, there is a widely held belief that problem-based instruction holds promise as an equitable teaching strategy. This may be the case because it affords teachers opportunities to present students with problems that are authentic to the domain, and are simultaneously meaningful to students.

If, as Bransford and Schwartz say, "it takes expertise to make expertise," the expertise needs to be available and accessible to students in order for them to take advantage of it. Without accessibility, even the best expertise is of little use.

Students enter classrooms with personal histories of both productive and unproductive collaboration, and with beliefs about what they, and – perhaps more importantly – what their peers, can and cannot do. Collaboration is the cornerstone of problem-based instruction, with a subtle implication that students will scaffold instruction for their peers, and yet, as a research community, we have not yet examined the experiences of English Learners and their English Fluent peers as they navigate this terrain.

This research examines the nature of discursive transactions between English Learner and English Fluent students in a multilingual, problem-based science classroom. More specifically, it is an examination of what students *say* and *do* in their attempts at intersubjective understanding of scientific subject matter. Students' attitudes and beliefs about the nature of collaboration are explored as part of this complex phenomenon.

In this study this I ask two groups of questions:

1. What types of collaborative experiences do English Learners encounter while working with their English Fluent and English Learner peers? How do English Learner and English Fluent students characterize their experiences adapting to the demands of peer-to-peer collaboration in multilingual groups?
2. What informal communication strategies do English Fluent students take up when working with their English Learner peers in a problem-based environment? What aspects of intentional and incidental peer-to-peer collaboration do English Learner and English Fluent students identify as productive or prohibitive to their intellectual work?

Background Literature

English Learners experience significant gaps in achievement

Schools in the U.S. are experiencing a dramatic shift in the demographic make-up of their student populations. Between 1979 and 2008, the number of school-age children who spoke a language other than English at home increased from 3.8 to 10.9 million; this means that for more than one in five students between the ages of five and seventeen, English is but one language they speak every day (NCES, 2010). English Learner students, particularly those from Hispanic backgrounds, represent one of the fastest growing populations in the U.S. public school system. By 2030 it is expected that 40% of all public school students will be English Language Learners (Thomas & Collier, 2002).

Over the past twenty years English Learners have consistently underperformed their English Fluent peers across science, reading, and math. International and national studies on science achievement have shown substandard performance of U.S. students overall, with gaps in achievement between English Learner and English Fluent students within the U.S. (Campbell, 2000; National Center for Education, Institute of Education, & Westat, 2011; Schmidt, 1997). The gaps in performance between English Learner and English Fluent students on the National Assessment of Educational Progress (NAEP) Science assessment are as problematic today as they were in 1996[11]. English Learner students are outperformed by their English-speaking peers, scoring 20-40 points below across grade levels. The data is even more striking in math and reading where gaps *increase* from grade to grade; from a gap of 25 points in 4th grade, to 41 points in 8th grade, and from 38 points in 4th grade to 45 points in 8th grade, in math and reading respectively (NCES, 2011).

Examining issues of equity pushes us to move beyond deficit narratives about marginalized students towards equitable actions driven by attention to identity, power, and student autonomy. Gutiérrez reminds us that when we can no longer predict a student’s success based upon a single characteristic, then says Gutiérrez, we will have achieved equity (2007).

Students bring with them a myriad of life experiences and abilities that are situated in the context of language and culture (Cummins, 1986, Norton & Toohey, 2011). All students have a wide variety of access to cultural and economic resources and arrive in the classroom with varying levels of experience with science and varying degrees of comfort with the norms of scientific practice (NRC, 2007). Often, students do not enjoy the same access to resources or facility with English as do their English Fluent peers. Language differences can constrain

[11] Science scores are scaled from 0-300; math and reading scores are scaled from 0-500 (NCES, 2011).

participation and collaboration, leaving students who do not speak English marginalized (Ogbu, 1978). Navigating these differences may mean that students will struggle to recognize the strengths that each other bring with them to the classroom, especially in science where a premium is placed on the use of scientific language and convention. The need for culturally responsive pedagogy so that students might benefit from one another's experiences has never been more important.

New standards, new strategies

The goal of science education is to enhance *all* students' scientific literacy; that is, to help students grasp essential science concepts, to understand the nature of science, to realize the relevance of science and technology to their lives, and to willingly continue their science study in school, or beyond school (NRC, 1996). The recently developed Framework for K-12 Science Education and Next Generation Science Standards established fewer, clearer standards and called on teachers to make shifts in instructional practice in order to ensure that all students are college and career ready upon graduation (NGSS, 2013, pp. 1, Appendix D). Historically, science teachers facilitated the work of students. In problem-based classrooms, students also facilitate the efforts of their peers as they work together to engage in the practices of science towards their solution of a proposed problem.

Project and problem-based instruction establishes authentic, ill-structured problems, students work and learn in small groups, teacher serves as facilitator, and students engage in self-directed learning which is then shared with the group, (Barrows & Tamblyn, 1980; Barrows & Tamblyn, 1980; Boud & Feletti, 1998; Dolmans & Gijbels, 2013; Savery, 2006; Savery & Duffy, 1995). It affords teachers the opportunity to generate dilemmas that encourage students to investigate, explain, and resolve problems while working collaboratively (Barron, 2010; Evensen & Hmelo-Silver, 2000; Krajcik et al., 1998; Lambros, 2004). The goal is to present students with problems that are relevant to the domain of science *and* to students.

In this classroom, the teacher's design and implementation of problem-based instruction is consistent with elements established in the literature, specifically her attention to ill-defined problems that have no set solution, providing students with the opportunity to work collaboratively while still holding them accountable to members of their group as well as science, and facilitating instruction rather than driving it.

Problem-based instruction also gives students the opportunity to engage in the practices of science in particular – reasoning, argumentation, and explanation – in the process of finding solutions to problems. Students work to solve an ill-defined problem and engaging in a process of gathering, analyzing, and using evidence and reasoning. Students are capable of this work but they need to be apprenticed to these practices by teachers who have deep knowledge of them, while simultaneously understanding the needs of diverse learners (Windschitl & Calabrese-Barton, 2014).

The power of problem-based learning lies in its advantages over traditional teaching, including its ability to foster retention and application of new skills and understanding. Problem-based learning also has the potential to encourage students to see themselves as life-long learners as they engage in self-directed learning. Problem-based learning *can be* a learning environment where students investigate, explain, and resolve meaningful problems through collaboration (Barron, 2010; Evensen & Hmelo-Silver, 2000; Lambros, 2004). If problem-based instruction is to meet the promise of its potential, we need to identify the ways in which both English Learner and English Fluent students experience problem-based science instruction. The growing body of problem-based research does not include information about the participation of English Learners, and we are left with several gaps in our understanding about the experiences of these individuals in problem-based contexts.

A gap in problem-based literature: equitable strategy for English Learners?

Problem-based learning studies in higher education settings have shown that there are several potential benefits for English Learners, including increased questioning skills, better self-directed engagement, and improved confidence in spoken language (Allen & Rooney, 1998; Azman & Shin, 2011; Kang, DeChenne, & Smith, 2012). Studies conducted in secondary settings indicated deeper learning through peer-interaction and collaboration, but noticed that students continued to struggle with the structure of problem-based instruction.

Studies conducted in Malaysia and Taiwan sought to compare traditional teaching methods to problem-based instruction with mixed results, on the plus side claiming that problem-based learning may be useful in providing context for emerging literacy (Othman & Shah, 2013; Pease & Kuhn, 2011). Research conducted in language classrooms revealed benefits that went beyond those of an academic nature, reporting that friendships that formed during the process of academic collaboration were sustained as a result of their unified purpose (Allen & Rooney, 1998). Furthermore, the discursive aspects of their collaboration – discussion and presentation – were effective in building confidence with spoken language ability (Allen & Rooney, 1998). Similarly, Le Vasan et al report that students appreciate having a voice and the ability to offer opinions and debate issues within the classroom (2006).

Potentially problematic problem-based instruction

In this study I am examining an aspect of teaching and learning that is undertheorized and not well understood, specifically: the experiences of English Learners in a problem-based science classroom. Problem-based learning poses several potential barriers for English Learners in multilingual science classrooms, including: the verbal demand of problems themselves, the need to navigate unique scientific language, novel interactions with experts, and high-stakes interactions with group members and classroom peers. As a research community we have not sufficiently vetted problem-based learning as an inherently equitable practice.

There is evidence in the literature that English Learners may benefit from a more traditional approach. In Ravitz & Mergendoller's research in high school problem-based economics classes, all students experienced success with the exception of English Learner students. Furthermore, some of those English Learner students had been successful in other classes and prior to the implementation of the problem-based unit (Ravitz & Mergendoller, 2005).

We do not have a deep understanding of the implementation of problem-based learning writ large, much less in multilingual classrooms (Hung, 2012), nor have we identified many successful strategies to support English Learners in multilingual science classrooms, or we *have* and no one is using them because significant gaps endure. Finally, we have not invited students to share their experiences and feelings about collaboration with peers who speak a different first language.

Scaffolding

Human development is an intrinsically social process (Vygotsky 1978). We start out by engaging in social interaction first, relying on others to apprentice our understanding in a variety of contexts. This support enables the learner to take risks, relying on the expertise and history of those around us. Over time, learners grow more confident, internalizing the language structures that teachers use to assist performance, becoming experts with experiences to share with those who follow. This process is embodied in the relationships we have with the people who teach us. Developing individuals rely upon the experiences of others to learn and are best served when teachers help them attach current learning to something they already know (Vygotsky, Rieber, & Carton, 1987). In order for that to happen, teachers – whether they are adults or peers – need to know what their students already know, a proposition that can be challenging when teachers and their students do not share a primary language. It is important to not only know what students know, but to be able to effectively use what they know to support their learning (Hmelo-Silver, 2011). Hmelo-Silver articulates the importance of scaffolding and illustrates the many ways that teachers can scaffold during problem-based instruction, including: "modeling, coaching, eventually fading some of their support," providing just-in-time explanations, and structural support (Hmelo-Silver, Duncan & Chinn, 2007 p. 101-102). It is critical practice then that teachers engage in a conversation about what prior knowledge and experience is assumed and privileged, and for whose benefit it is assumed and privileged. To do so is evidence of a sophisticated teaching practice, even for veteran teachers. It is all the more challenging for high school students with no formal teaching experience.

Making sense in science is, in some respects, a matter of finding one's voice and being able to use words to effectively convey what you *mean* to say (Gee, 2011). Often students have a grasp of concepts long before they have mastery of a second language or the conventions of the domain (Carraher et al., 1985). Because science has its own vocabulary and conventions for engaging in discourse, typical English Learner intervention and instruction – focusing on introductory vocabulary and sentence structure – may not meet the needs of emerging young scientists. Van Lier recommends a multi-faceted relational and instructional approach that includes cultivating community, making students feel safe, repeating concepts, adjusting tasks, etc. (quoted in Walqui, 2006, p. 165).

Most of what we know about scaffolding is anchored to what content teachers say and do to support their students. We know very little about what happens in a problem-based context, where there is a significant shift in instruction, away from the teacher and towards the students. In this context, scaffolding strategies were named and modeled by the teacher. Her strategies were consistent with the features defined by Van Lier (quoted in Walqui, 2006 p.195), namely: **continuity** (e.g., repeating concepts in multiple contexts, variation of explanation, using different words, connecting concepts to personal experiences in and out of school), **contextual support** (e.g., safe, supportive environment, multiple forms of access), **intersubjectivity** (e.g., mutual engagement and rapport, encouragement to participate, cultivation of community of practice), **contingency** (e.g., adjust tasks when warranted, co-construct speech), **handover/takeover** (e.g., Student assumes control), and **flow** (complexity of challenges increase as students progress).

Though there has been some disagreement about the presence and nature of scaffolding in problem-based instruction (see Kirschner et al, 2006 and Hmelo-Silver et al, 2007), we know that scaffolding is, in and of itself, an important instructional tool. Saye & Brish (2002) characterize scaffolding as either *soft* or *hard*, where a soft scaffold might include the teacher moving through the room to engage students in a series of questions that check for understanding (quoted in Simons et al, 2007). Hard scaffolds on the other hand, are those instructional moves that are concrete resources that can be used by students, like a working glossary or modified reading. Simons & Klein found that students who were in groups that either required scaffolding, or had scaffolding available to them, fared better than students who were unguided (Simons 2007).

Collaboration

Collaborative groupwork has gained widespread acceptance as an instructional tool that can foster active learning and substantive conversation. Oakes & Lipton (1990), writing about the deleterious effects of tracking, recommend groupwork as a tool for equity. Placing students in groups, however, does not transform them into co-constructors of scientific knowledge and understanding. Ideally, problem-based instruction fosters the valuing of other's ideas and regard for the reciprocity of collaboration.

Cohen warns us to be aware of the role that status can play in preventing students from establishing full membership within the group, offering two strategies to prevent or repair issues of status, namely: the multiple-abilities treatment, and assigning competence to low-status students. An integral component to the multiple-abilities treatment is student "buy in" of three ideas: 1) groupwork tasks require multiple skill sets, 2) no one person is the sole possessor of all skill sets, and 3) every person has *some* of the skill sets (Cohen, 1998 p. 20). This framework might require a shift in practice for teacher who may not have considered abilities in such a way, or have previously considered some students as incapable of doing the work.

Students enter into groupwork with a history of collaboration. Rubin (2003, p.557) illustrates a situation where groups were constructed around "weak students" whom other students viewed as disrespectful, lazy, or disengaged. “This was a difficult position to hold in a group setting and often led to a reduction in responsibility for those students” (Rubin, 2003 p.557). Assigning competence to low-status students may be challenging for teachers who, until faced with this task, may themselves hold students as low-status. There are three critical components to consider when assigning competence. They are: 1) the moment must be authentic and truthful, 2) it must be public, and 3) it must be relevant and applicable to the task at hand (Cohen, 1998 p. 21).

Collaborative groupwork has the most potential to facilitate participation when students feel a sense of inclusion and belonging (Boaler & Staples, 2008; Cohen, 1994, 1998; Gutiérrez, Baquedano-Lopez, Alvarez, & Chiu, 1999). Historically, teachers are the greatest support and connection to improved learning outcomes for their students (Osterman, 2000). All students rely on teachers to support and scaffold instruction, though English Learners are arguably at a greater risk for slipping through the cracks if teachers miss this opportunity (Belland, 2012; Buxton, 1998; Lee, 2005; Lee & Fradd, 1998; Yoon, 2008). This is especially true in problem-based classrooms where so much instruction takes place between and among peers.

Participation and engagement.

There is no collaboration without participation and engagement. For the purpose of this research, I consider the distinction between the two to be this: participation is any form of identifiable *doing* ie: speaking, writing, performing, etc. without regard to the depth or significance of the participation or the individual’s attention to scientific practice. Engagement on the other hand, attends to the nature of participation; *what* is being said/done, is it related to the task at hand, is it relevant to science (Engle, 2011)?

Participation is not a binary state of doing or not doing. There are dozens of ways to participate that vary within and across content-specific domains (Lave & Wenger, 1991). Students need to be apprenticed into the habits and practices of the domains in which they are working, a task that is complicated in a multilingual, problem-based context due to the heavy import placed upon peer collaboration. When those practices have a steep learning curve that can prove problematic for students initially, students need to feel supported, by the adults in the room, and their peers. Students generate ideas, explanations, and illustrations as products of their learning and if their peers fail to see their personal connection with the students who generate these ideas, it can result in an unfortunate missed opportunity. When cultural differences are honored and embraced, students are more likely to participate meaningfully, illustrated by Mr. M and his sixth-grade students' nutrition projects (Tan & Calabrese-Barton, 2010).

Vygotsky helps us to make sense of the transitions English Learner students move through as individuals are apprenticed by their peers into new mastery or understanding. Vygotsky proposed that apprenticeship happens in the zone of proximal development (ZPD), a theoretical space skills and abilities expand with help from a teacher, parent, peer, etc. In the ZPD, new skills are just beyond the reach of what we would be able to do without support. When English Learner students are sufficiently supported, the ZPD expands as new skills are acquired and knowledge is mastered. Conversely, in situations where apprenticeship is limited, expansion of the ZPD is limited as well. In traditional classrooms, teachers manage this apprenticeship, scaffolding new learning for students. In a problem-based context, the teacher still helps students to navigate apprenticeship, but more responsibility is placed on peer-to-peer collaboration.

Conceptual Framework

Because Katharine was so transparent in the execution of her equity stance, we examined whether or not her English Fluent students would adopt her relational or instructional moves. Using elements of Katharine's practice, I draw on literature from collaboration, scaffolding, and participation, as well as first-person accounts (see Figure 1) to help me make sense of the nature of English Learner and English Fluent student collaboration.

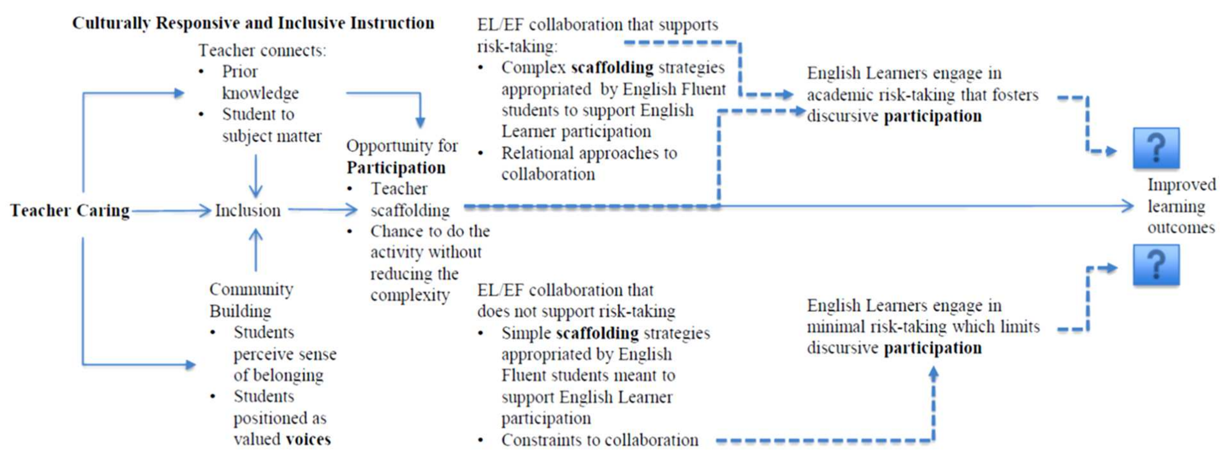


Figure 1 Conceptual framework to examine the relationships between teacher caring, culturally relevant and inclusive pedagogy, student voice, scaffolding, and participation in a problem-based science classroom.

The framework represents what we currently understand about caring, culturally responsive and inclusive instruction, scaffolding, and the significance of each in fostering student participation, in that caring is linked to a sense of inclusion (Gay, 2000; Noddings, 1984), which in turn is linked to participation (Valenzula, 1999; Boaler & Staples, 2008), which is linked to improved learning outcomes (Woolley, Kol & Bowen, 2009). However, we imagine teacher caring to be something that goes beyond inclusion, that includes both relational and instructional elements. The research included in this paper seeks to examine the nature of collaboration among English Learners and their English Fluent peers, as well as the significance of teacher-modeled scaffolding that may or may not be adopted by English Fluent students to support their English Learning peers. These relationships are represented by dashed lines because we do not understand the nuance and complexity of these interactions, nor the influence of these interactions upon participation. Given what we know about the effectiveness of scaffolding instruction for English Learners (Walqui, 2000; Walqui & Van Lier, 2010), it stands to reason that peer scaffolding can be a vital component of peer collaboration. Conversely, absent peer scaffolding, participation in groupwork may be constrained.

Method

Research Design

This case study follows one teacher and her four Biology-Chemistry classes throughout the 2013-2014 academic school year. Over the course of the school year I spent over 200 hours in Katharine's classes, observing, recording, surveying, and interacting with Katharine and her students. Nearly twenty percent of her roster were students I had known from my participation in another science class during the previous academic year. For those twenty students, that means we had spent an additional sixty hours together.

This dissertation employs observational and survey methods (Erickson & Wittrock, 1986; Groves et al., 2011; Merriam, 2014; Patton, 1990) to collect qualitative and quantitative data across several settings. The settings for this study are: 1) the classroom of Katharine Bryant, 2) a variety of locations convenient to Katharine for both formal and informal interviews, and 3) the classroom of the school's ELL Support teacher. The bulk of the data for this study was collected in Katharine's classroom, with her 120 students, in the form of classroom observations, informal interaction with students, student surveys, and artifacts of student work.

The case study approach affords a deep look at the how and why of teaching and learning events in this multilingual science classroom. It also benefits from "patient, careful and imaginative life study," a commitment I had made to the teacher, the students, and the research from the very beginning (Blumer, 1954). I relied upon disclosures from the students in making decisions about where to focus my attention, and in order to make sense of the connections between what students said, and what I observed students doing. I had a certain degree of influence – though not control – with the students, which I tapped only to ensure the integrity and anonymity of their written and spoken comments. I relied upon these disclosures in order to make sense of their perception of, and response to their peer-to-peer collaboration.

Context. Cielo Vista is a comprehensive high school serving an economically, ethnically, and linguistically diverse population of approximately 1,000 students who live in a medium/large urban community in the Pacific Northwest. The demographics of Cielo Vista stand in contrast to those of the school district and city in which it is situated. This diversity is mirrored at Cielo Vista, where 46% of its students qualify for free or reduced lunch, a rate that is twice that of the district school with the second-highest number of qualifying students, and almost ten times higher than that of the district school with the fewest (OSPI, 2014). During the 2013-2014 school year, forty-five different languages were spoken in the homes of Cielo Vista students and 40% of all Cielo Vista students spoke a first language other than English at home (OSPI, 2014).

Cielo Vista's Principal had been tracking in-district and in-school gaps in achievement over the past several years while wrestling with how to bridge the gap between what was getting done and what needed to be done. Troubled by these persistent gaps in achievement and decreasing enrollment, Cielo Vista High School administrators, teachers, students and parents made a collaborative decision to implement a problem-based learning curriculum throughout the school, across content areas.

To clarify the school's vision of problem-based learning, a living document was generated to articulate the attributes of successful problem-based Cielo Vista classrooms. This document, the Seven Key Elements, sets out a foundation of problem-based, collaborative practice for teachers, students and outside experts working together towards the design and implementation of authentic problems that honors students' cultural experiences and voice.

The Seven Key Elements established a framework that sought to define what Cielo Vista believes is characteristic of successful and productive classrooms. As a living document it was not meant to be concrete or fixed. It was meant to inspire and challenge teachers – and students – to think about teaching and learning in expansive and inclusive terms. The seven elements are: 1) authentic problems, 2) authentic assessment, 3) access to expertise, 4) collaborative groups, 5) classroom discourse, 6) inclusive, culturally responsive instruction, and 7) student voice. Katharine focused on inclusive, culturally responsive instruction and student voice. Katharine and her colleagues worked with intention to generate problems for their students that were deeply anchored to the scientific practices articulated in the Next Generation Science Standards, and that were at the same time interesting and relevant to their students (see Appendix A for an example of a problem-based assignment from Katharine's classroom).

To support this work Cielo Vista applied for, and received, a major grant from the US Department of Education in the fall of 2010. The Investing in Innovation (i3) grant application was the school's way of staking a claim that all Cielo Vista students, upon graduation, can – and will – be prepared for college and careers in Science, Technology, Engineering and Math. They believed that this was possible if teachers engaged students with a problem-based learning curriculum that attended to the Seven Key Elements. The university based research team of which I am a part established a working relationship with the school for two reasons: to offer technical support to teachers and students as they move through the design and implementation process, and to execute research that memorializes and reports the process and progress along the way.

Participants.

The teacher. Katharine is a fifth year teacher, dually certified in Science and Spanish. She is one of nine members of the science department. Katharine has high expectations for each of her students and firmly believes that all students can be successful in science. The schools' shift to a problem-based curriculum and focus on the Seven Key Elements was consistent with Katharine's teaching philosophy to present students with scientific problems that are rigorous and relevant to students as well as the domain, and matched well with her equity-conscious commitment to cultivate a culturally responsive pedagogy that values student voice. Katharine's 120 students, representative of the school's demographic make-up, were primarily sophomores; fifty-one speak a language other than English at home; twenty-one received English Language Learner Support services.

Katharine's classes were in the second year of a two-year integrated Biology-Chemistry course that met four times a week (three 55 minute classes, and one 90 minute class). Students were with different peers and a different teacher for year one. Throughout the course of the year, Year Two classes covered a variety of topics, including: research methodology, human body systems and functions, chemical bonding, microbiology, and carbon/nitrogen/water cycles, genetics, and others.

Typically, students were presented with a problem at the beginning of a unit, and assigned a group of students with whom to collaborate. Throughout the course of the unit, the group would assign tasks to individual members, work individually, and then return to the group to share what was learned. Whole-class instruction occurred regularly, though not frequently, which is to say that a bulk of content instruction happened within the group.

This paper focuses on the events surrounding four different learning events over the course of the year. They were:

- The NASA Activity: coming to consensus about supply list (see Appendix B)
  September 4th, 2013
  On the second day of school, Katharine assigned students to work in multilingual groups of four to work on a NASA inspired task. Students were presented with a scenario centered around a lunar crash-landing, available supplies, and a life-saving lunar trek to safety. Students were required to first rank the list of available items in order of what *they* would find most useful to least useful, and why. Students then worked as a *group* to compare their lists and come to consensus about the ranking of items.

- CO_2 Presentations about group reduction of carbon footprint (see Appendix C)
  January 23rd – 26th, 2014
  On the front-end of the middle of the year, students worked in multilingual groups based on a shared area of interest like water usage, carpooling, diet, etc. to assess their current carbon footprint, propose a plan to reduce their individual carbon footprint, implement that plan, collect data, analyze data, draw conclusions, and present results to the class as a group.

- Socratic Seminars on Genetic Disease (see Appendix D)
  March 25th and 26th, 2014
  On the back-end of the middle of the year, students worked in pairs to prepare for a whole-class Socratic seminar on disease and genetics. Students were paired with a "coach" during the whole-class seminar who could pass them notes with information, data, questions, etc. Katharine presented students with a rubric for preparation and participation that included a requirement for students to have at least one event of verbal scientific participation. If her English Learner students appeared to be struggling during the seminar, Katharine began by slipping the student a sentence starter. In the event that the student did not avail themselves of the sentence starters, Katharine then slipped them a sentence in the form of a question that the student could then pose to the group and initiate a conversation with other students.

A second round took place the following day with ten English Learner students and Katharine, using the same source materials but a slightly modified format that invited students to contribute whenever they wanted to. In this arrangement, there were no coaches.

- Genetically Modified Organism Activity (see Appendix E)
  May 5th-10th, 2014
  At the end of the year, Katharine reunited the groups that worked together at the very beginning of the year. These groups were tasked with researching and producing a television advertisement in support of, or against, the production, sale, and use of genetically modified organisms.

The students. There are seventy-nine different languages spoken at home within Cielo Vista's district; forty-five languages are represented within the school and twenty-one in Katharine's classes. English Learner students receiving services represent fifteen percent of the total enrollment, a percentage that is consistent within Katharine's classes. For the purpose of this paper I grouped students into two categories: students receiving English Language Learner support services (English Learners), and students not receiving English Language Learner support services (English Fluent[12]). There were occasions when I further delineated the group of English Fluent students to examine differences among students who at one time qualified for English Language Learner support services, and students who never had qualified for such services. None of Katharine's students were currently placed at the Beginner level for the 2013-2014 academic year. Of the twenty-one students receiving support services, ten were Intermediate, eleven Advanced.

Data Collection (see Table 2). Over the course of the 2013-2014 academic year I was in Katharine's classroom for over 200 hours, during which time more than 25 hours of audio, and

[12] I acknowledge that even students born and raised in the United States can experience issues with written and/or verbal fluency. Furthermore, there are significant differences between casual, academic, and scientific fluency. I address these cases on an individual basis when they are relevant.

an additional 25 hours of video recordings, were captured. More than three hundred pages of field notes were generated. Students were surveyed eight times throughout the year on a variety of topics ranging from interest in problem-based units to perceptions of teacher caring to collaborative groupwork. Student work was collected throughout the year as well, and digitally recorded or physically copied. Informal interviews with the subject teacher were conducted daily and included in field notes. Eight hour-long semi-structured interviews were conducted – and transcribed – with the subject teacher, beginning in the summer of 2013. Two hour-long semi-structured interviews were conducted with the teacher of the English Language Learner support class that Katharine attended weekly. (For a detailed description of the full data set, see Appendix G).

Data sources. The findings for this study are drawn from four sources: teacher interviews, student surveys, classroom observations, and artifacts of student work (see Table 1).

Table 1
Data Collected

Type of Data	Total	Used in this study
Formal and informal interviews	• 10 hours (formal) • 80 hours (informal)	• 2 formal (2 hours) o August 5, 2013 o June 20, 2014 • 4 informal (2 hours)
Student surveys	8 surveys Total: 160 questions • 40 multiple choice/rank; • 120 open response	4 surveys • February 28, 2014 • March 15, 2014 • March 31, 2014 • June 20, 2014
Classroom observations	• 20 hours of table talk • 20 hours of presentations • 300 pages of field notes	• NASA Activity table talk (2 hours) • CO_2 table talk & presentations (6 hours) • Socratic Seminars (2 hours) • Political Pro/Con Ad for Washington Law Initiative I466 regarding Genetically Modified Organisms table talk (2 hours) • Field Notes (30 pages)
Artifacts of student work collected	• CO_2 group posters (24 pages) • 1466 group assignments (40 pages)	• CO_2 group posters (8 pages) • 1466 group assignments (40 pages)

Teacher interviews. Semi-structured teacher interviews were conducted with Katharine throughout the year to collect data about her perceptions of peer-to-peer collaboration and groupwork. Interviews were recorded and transcribed for analysis. Formal interviews started with a broad question, for example: “What surprised you the most about the results of this survey, what troubled you, what are your next moves?”

Conversations took place almost daily throughout the year. I attended Katharine’s classes four days a week. Her classes met first, second, third, and fifth period. The break between third and fifth meant that we almost always discussed the events of the day up to that point. These conversations covered a broad range of topics; sometimes Katharine would reflect on specific instructional and relational moves she had attempted. On occasion, she would ask for feedback about content related to the current unit. We most frequently discussed Katharine’s personal and academic interactions with students. Katharine’s sixth and seventh periods were planning periods, meaning that she was available to discuss fifth period, or further discuss prior events of the day at the end of the day.

Student surveys. I administered a series of eight student surveys throughout the year to collect data about Katharine’s relational and instructional strategies, group work, and participation. Data from four of these surveys are included in this study (see Appendix H for the complete surveys).

The results of each survey drove the nature and theme of questions for pursuant surveys. For example, in January we asked students to write about the nature of groupwork; “What makes someone a good group member?” and “What makes you a good group member?” Student responses to those questions drove a series of questions in the March survey that asked students to write about the strategies they use when helping a classmate who is struggling, e.g., "How do you help classmates who are confused?", as well as questions about the ways in which they support English Learners in their groups, e.g., "How do you help students in your group who are learning English?" and "When I have someone in my group learning English, I…". Rather than ask students how they navigated feelings of vulnerability, we fashioned questions that invited students to write about doing, or not doing, things that typically make students feel vulnerable like sharing ideas or asking questions.

Classroom observations of students. Classroom observations were documented in three forms: audio recordings, video recordings, and Field Journal notes. Audio and video recordings captured during the NASA Activity, CO_2 presentations, Socratic Seminars, and I466 presentations were selected for analysis and transcribed. Additional observations were conducted throughout the course of the year, beginning in September and continuing throughout the year. Data collection was most intensive during September (64 hours), mid-January to late-March (72 hours), and mid-May to mid-June (24 hours).

My systematic approach to journaling Field Notes meant that I began class with a question about English Learner interactions with their peers.

Classroom observations were helpful for observing the implementation of Katharine's intended plan of action. Observations were also useful in providing data about student-teacher and student-student interactions, particularly with respect to capturing moments of relational and instructional moves by the teacher. Finally, classroom observations also provided data that spoke to the evolution of student participation over time.

Artifacts of student work. Artifacts of student work from four different group projects and were collected throughout the year and photographed or reproduced xerographically when possible. These pieces of student work were helpful in adding another perspective when examining the trajectory and sophistication of student participation, particularly among students who were more likely to *write* about science, than *talk* about science. Artifacts include student work from:

- NASA Activity – photographic images of student responses to the task assignment.
- CO_2 Carbon Footprint Reduction Group Posters – group posters, completed as a group – to varying degrees – and presented to the rest of the class accompanied by an explanation by members of the group.
- Washington State Law Initiative I466 about Genetically Modified Organisms group assignments – photographic images of the worksheets that included anticipated tasks required for successful completion of the I466 advertisement. The assignment sheet included the names of group members assigned to specific tasks.
- Washington State Law Initiative I466 about Genetically Modified Organisms group work – videorecordings of group work preparations, final products and presentations.

Data Analysis.

Coding schemes for peer support. My approach to the analysis of student feedback about what they do to support members of the group who are learning English was a four step process. I coded for comments that were *instructional* (e.g., I explain it a different way, I translate for them), *relational* (e.g., I try to build connections with them, I incorporate them into the activities), and *resistant* (e.g., I don't/can't/won't). An additional code emerged during this process, one which represented a *claim/assertion/belief* about teaching and/or learning (e.g., I do *x* because the best way to learn is to be immersed). During the second step, I characterized the nature of the instructional support; *simple* (e.g., "I explain it" without any indication of *how* they explain it, or "I speak more slowly"), or *complex* (e.g., "I translate/find someone who can translate for them," or "I check to see if they understand by asking questions"). I analyzed the content of responses with respect to frequency for the above codes as well as "*can't help,*" "*don't help*," and "*don't know how to help."* I also analyzed content of responses to identify specific strategies that students reported using.

The next step was to align English Fluent student feedback to their actual interactions with their English Learner peers. To remove the confounding factor of individual personalities and strengths of English Learner students, I examined the interactions between the English Fluent students with self-reported complex strategies and one English Learner. I did this because I did not want to add a layer of doubt given the possibility that an English Fluent student could be perceived as supportive when, in fact, their interaction was influenced by the typical actions of the English Learner.

As data were analyzed, theories were challenged, hypotheses were tested, confirmed, revised and reexamined. Once all was said and done, often, new hypotheses emerged. Hypotheses were also challenged, sometimes disconfirmed, and reexamined.

Table 2
Walqui & Van Lier's features of teacher scaffolding classroom instruction for English Learners (Walqui, 2007 p. 165)

Feature	Strategy
Continuity	• Repeating concepts in multiple contexts • Variation of explanation • Using different words • Connecting concepts to personal experiences in and out of school
Contextual support	• Safe and supportive environment • Multiple forms of access
Intersubjectivity	• Mutual engagement and rapport • Encouragement to participate • Cultivation of community of practice
Contingency	• Adjust tasks when warranted • Co-construct speech
Handover/Takeover	• Student assumption of control
Flow	• Increase in complexity of challenges as students progress

Coding schemes for teacher interviews. I coded in multiple phases throughout the year, beginning with Katharine's initial interview discussing her goals for her English Learner students. I developed an initial set of codes based on my research questions that were based upon the caring literature of Valenzuela (1999), Gay (2000b), and Lewis (2012), the equity research of Roseberry, Warren & Conant (1992), Nasir (2006), and Gutierrez (2007), and the student voice research of Rudduck (2007), and Fielding (2001). Three topics emerged during this first conversation: 1) *success* 2) *equity*, and 3) *safety*.

I returned to these three themes to articulate, in Katharine's words, how she defines success, equity, and safety. This resulted in the following codes:

- *rigor* (e.g., content may be modified, but will not be watered down)
- *voice/participation* (e.g., students will be heard, literally)
- *representation* (e.g., students will see their work within the group; students will see themselves and their culture within science)
- *connection* (e.g., students will feel connected to, and a sense of belonging within, the classroom; Katharine will work to create a home-school connection to support students)
- *caring* (students will feel cared *for*, and cared *about*, as people and as learners)
- *participation as outcome* (e.g., for Katharine, the standard of measurement for better outcome)

During a second round of coding I was looking for actions that Katharine intended to take with respect to success, equity, and safety. Before heading into the classroom, I wanted to know what Katharine hoped for her practice, and for her students. Taking my cue from Katharine's plan of action, I coded for talk about:

- *accessibility* (e.g., before school, during class, during lunch, in tutorial)

- *teaching strategies* (e.g., explaining, translating, changing words)
- *supporting groupwork and collaboration* (e.g., modeling effective communication, taking students through the process of recognizing their collaboration personality, redirecting negative peer feedback, etc).

Coding schemes for student surveys. I coded student surveys in multiple phases throughout the year, as surveys were administered, analyzed, and used to design new surveys and track student perception and thinking. During the first round of coding student surveys, I used themes that emerged from Katharine's interviews, particularly with respect to student perceptions of caring. These codes included: *caring* (e.g., students report feeling cared *for* and/or cared *about* as people and/or learners), *connectedness* (e.g., students report feeling a sense of connection), *belonging* (e.g., students report a sense of belonging, welcoming, comfort), *voice* (e.g., students report events of speaking), and *representation* (e.g., students report events of their work representing at least part of the group's work).

The goal of the next two rounds of coding was further articulation of the first round codes. Third round codes added the step of trying to determine whether or not students felt that they had something to contribute, and identifying whether they were an English Learner or English Fluent student. I coded: *caring* (e.g., Ms. Bryant cares/doesn't care for me), *connectedness* (e.g., see connection between self/science, science/home, self/classroom), *belonging* (e.g., feel welcome, feel appreciated, feel sense of community), *voice* (e.g., see role as contributor, feel have something to say – will/will not say it), and *representation* (e.g., see self/culture in science, see self/culture in assignments and problems, feel heard by teacher, classmates).

For all pursuant surveys, I used themes that emerged from the previous survey to drive the coding process. For example, while coding the second survey, I started with the coding scheme above, but added codes about groupwork. I coded: *groupwork/collaboration: positive* (share work, bounce ideas/brainstorm, learn from peers, get to work with friends), and *negative* (inequitable distribution of work, not invited to participate, pace is too fast, and issues of asking for help or helping others).

Coding schemes for student talk. Before I discuss coding schemes, I want to describe how I framed the nature of student talk (see Table 3).

The nature of talk. I want to attend to a trajectory where students move from silence to rigorous scientific discourse. Students do not leap from one terminus of a trajectory to the other; there are steps along the way, particularly for English Learner students. Talk takes on different elements and characteristics, attending to social and academic needs (see Table 3 for examples).

Table 3
Examples of student talk along the nature of talk continuum

Type of talk	Examples of what students said
Silence	• Student does not voluntarily speak • Student responds by gesture or facial expression • Student responds with one word answer
Primarily social talk	• "How was your weekend?" • "I heard you are in the play." • Talk about gaming (Xbox, Wii) • Television, movie, music talk
Simple academic and/or scientific contributions	• Asks yes/no questions • Answers questions with one-three word responses • Science is observational, not explanatory
Novice scientific talk	• "I know blood has salt and the ocean has salt. Does salt have something to do with it?" • How does water get to your home? "The mountains. Rain water." • "Maybe we should come up with a theory and find things to prove the theory"
Rigorous scientific discourse	"There is some controversy with the use of genetically modified organisms. In our story we turn to Dr. Smarty Pants to explain their work with genetically modified marmosets, and follow with an explanation of how the science works. We end with our position in support of I466 using evidence from this report and additional research we conducted."

The five stages of second-language acquisition: What participation might sound like. There is a level of analysis unique to English Learners: attending to the stages of second-language acquisition (Krashen, 1981) (see Table 4). One of the driving forces of problem-based learning is the commitment to, and leverage of, groupwork. In turn, one of the qualities of groupwork is the division and allocation of work. *How* work gets allocated is what I am looking here. It would be difficult to characterize intellectual load along a continuum. Instead, I adapt Krashen's (1981, p.) model to track the interactions of the focal English Learners across five different learning events, examining and comparing interactions between the English Learner and Katharine, the English Learner and their English Fluent peers, and finally, both in comparison to the student's Krashen stage. I do this to identify differences in the character and quality of participation in different contexts, with different participants.

Table 4
The five stages of second-language acquisition

Stage (time range in country)	Typical contributions	What this looked and/or sounded like in science	
		With EF peers	With Katharine or EF peers
Preproduction or silence (0-6 months)	Respond to: show me, circle the…, where is…, who has…	EL does not volunteer to speak; EF does not ask or persist in asking questions	n/a
Early Production (6-12 months)	Respond to: yes/no questions, either/or questions, who… what…, how many…	"Do you want to get some pictures together for the PowerPoint?" "Do you want to do references or the PowerPoint?"	"Is this right?"
Speech Emergence (1-3 years)	Respond to: why…, how…, explain… using phrases and short sentences	"How are we going to divide the work?" "Do you understand this math? Can you explain it to me?"	"Why are some (genetic) tests okay direct to consumer, or why are some states banning it?" "How about… what if you don't want to? (know about the results)?
Intermediate fluency (3-5 years)	Respond to: what would happen if…, why do you think that… providing answers that have more than one sentence	n/a	"What if there's a disease and there's no correction for it?"
Advanced Fluency (5-7 years)	Respond to: decide if…, retell…	n/a	"Decide what kind of change you want to make to reduce your carbon footprint. What are you going to do? How are you going to do it? How are you going to measure it? What do you need to know before you start?"

Adapted from Krashen, 1981

Classroom observations were either transcribed from audio/video files and coded, or coded from scanned field notes. I coded classroom observations in multiple phases throughout the year, as observations were made, analyzed, and used to triangulate data, design new surveys, and track student perception and thinking. During the first round of coding classroom observations, I used themes that emerged from Katharine's interviews, particularly with respect to student perceptions of caring. See previous lists that *caring*, *connectedness*, *belonging*, *voice*, and *representation*.

Another approach to the analysis of classroom observations that I utilized was content analysis (Carley, 1993; Krippendorff, 2012). I used this approach to examine the nature of how students were contributing to classroom talk, as well as the frequency with which they were contributing. For example, for the Socratic Seminars I wanted to examine the differences in the nature and frequency of talk between the English Learner only seminar and the whole class seminar.

When doing the content analysis, I used the following codes based upon the desired types of scientific talk described as signaling proficiency in science in *Taking Science to School* (NRC, 2007 p.), and further articulated in the Next Generation Science Standards. I coded first for participation, then for the nature of that participation, including: *questioning* (e.g., introducing a question that is problematic with or without evidence; questioning someone else's assertion with or without evidence; seeking clarification; driving the conversation), *answering* (e.g., responding to a posed or originated question, with or without clarification, reasoning, or evidence), *reporting* (e.g., restating or retelling information gathered from another source), *building* (e.g., adding a thought or evidence to a claim initiated by someone else), *contradicting* (e.g., making a statement against someone else's statement, with or without evidence), *reasoning* (e.g., transparent/thinking out loud process of making sense of the task at hand, in real time; navigating an argument), *statement* (e.g., a statement made without an implication of veracity), *assertion* (e.g., an absolute statement made, with or without the use of evidence), *evidence* (e.g., the use of evidence to support or refute a claim made by yourself, a peer, or another source), *agreeing* (e.g., agreeing with a peer because you believe they are correct, whether or not they are), *affirming* (e.g., encouraging or supporting contribution from a peer, and *approximating science talk* (e.g., incomplete talk that indicates and effort to use the above elements unsuccessfully, or inaccurately).

Coding schemes for scaffolding. We draw on Van Lier's features of scaffolding for English Learners to examine the implementation and adoption of scaffolding in Katharine's classroom. Specifically: *continuity* (e.g., repeating concepts in multiple contexts, variation of explanation, using different words, connecting concepts to personal experiences in and out of school), *contextual support* (e.g., safe, supportive environment, multiple forms of access), *intersubjectivity* (e.g., mutual engagement and rapport, encouragement to participate, cultivation of community of practice), *contingency* (e.g., adjust tasks when warranted, co-construct speech), *handover/takeover* (e.g., Student assumes control), and *flow* (complexity of challenges increase as students progress).

Coding schemes for artifacts of student work. I coded artifacts of student work in multiple phases throughout the year, as data was collected, analyzed, and used to triangulate hypotheses, design new surveys, and track student perception and thinking. Again drawing from *Taking Science to School* (NRC, 2007), and the Next Generation Science Standards, I coded for: *using scientific language, using evidence to support/refute a claim, using reasoning, argumentation and/or explanation, questioning findings, assumptions, data*, etc. I also examined the degree to which students engaged in these scientific practices accurately or appropriately.

Findings

I collected data[13] at five points over four learning events detailed in the Method section. There were two goals in collecting data during these learning events: 1) to capture student activity at various points in time, with enough time in-between to allow for growth, and 2) to make sure that the work-at-hand would provide students with the opportunity to engage in scientific practices. Students were reunited with the same students from their groups on the first day of school for the group work at the end of the year in order to eliminate as many variables as possible when comparing student collaboration at the beginning of the year and again at the end of the year.

I present my findings according to the three claims that emerged from the data relevant to the ways that English Learner students collaborated with their English Fluent peers. Specifically:

> **Claim #1** In spite of diverse and transparent scaffolding strategies modeled by the teacher, few English Fluent students adopted these strategies when working with their English Learner peers. Furthermore, few English Learners expressed an expectation for how they might be helped by their English Fluent peers when working together.
>
> **Claim #2** Discursive transactions between English Learners and English fluent students were not always uniformly beneficial. There were identifiable characteristics of these exchanges that stopped, redirected, impeded, and/or facilitated English Learner students' contributions to groupwork.
>
> **Claim #3** Though English Learner and English Fluent students saw group work collaboration as an opportunity for "help," the two groups defined help differently, and in ways that were consequential for peer interactions.

Claim #1 Teacher-driven scaffolding strategies were diverse and transparent

Katharine made a practice of modeling a variety of scaffolding strategies (for examples, see Table 5), often naming these moves publicly. From the outset, her strategies for scaffolding

[13] All student quotes maintain the integrity of their original written or spoken feedback. I make not effort to correct vocabulary, spelling, or grammar.

to maintain the rigor and complexity of the work included: adapting readings to simplify the language without simplifying the concepts, offering students the opportunity to read content in their first language prior to reading in English, explaining concepts to students in Spanish, finding reasonable entry points for very novice speakers, having sentence starters ready to get students thinking about the direction of the conversation, etc. Katharine also set out to take advantage of the time that problem-based instruction opened up to make more one-on-one contact with students during class. Katharine also endeavored to connect students to complex scientific ideas and practices by finding out what her students were interested in and knowledgeable about, and then providing opportunities for students to connect the two.

Students wrote of Katharine's ability to help them make sense of topics that were stumping them. Twelve students spoke about questions; that she answers them, to be sure, but also that she *does not* answer their questions but "restates," "probes," "pushes," and "helps" students by asking questions that "help get to the answer."

Students wrote of the ways in which Katharine helps them learn. Though many responses were repeated, there were a variety of responses. Thirteen students wrote of Katharine's efforts to explain the content in a way that would ensure their success, writing that "(she) explains things very well and will provide clarification if it's needed," and "changes sources into easy version," "explaining in Spanish." "She always find(s) the easiest way to explain," wrote several students, and "asks you questions about topics you don't understand and she explains in different ways." "She gives paper with notes to help," acknowledged one student. Students spoke of her instructional materials and instructional practices like her use of "examples," modification of materials for access, "hands-on" activities, "pre-written" or scaffolded notes, "checking for understanding," "helping when (they are) stuck," and "review."

Student adoption of scaffolding strategies. We asked Katharine's student to write about the strategies they use "to support a group member who is learning English" We used Van Lier's features of scaffolding participation as a framework to situate the types of scaffolding strategies cited by students. (see Table 5). Katharine's scaffolding strategies that she modeled for her students align with Van Lier's strategies (see Table 4).

There were 80 English Fluent students present on that day who participated in the survey. Twenty-one additional students were English Learners and had a different question asked of them.

Of the 80 total responses by students not currently receiving ELL support services from the school, there were 74 incidents of instructional support cited by students, 41 of which were simple in nature. Thirteen students described 18 different relational strategies they use when trying to support an English Learner peer.

A majority of the simple instructional moves (16 of 41) listed by students dealt with their efforts to "explain" or "communicate" without any characterization of the explanation or communication. Eight of the 41 referred to slowing down their talk or reading aloud.

Twenty-seven students reported some form of complex instructional strategy used by them to support English Learners in their groups. The complex strategies reported were primarily translation (10 of 30), either by themselves (8 of 30) or finding someone to do it for them (2 of 30). Other popular responses included questioning or checking for understanding (7 of 30), or modification to the language that was used in the initial explanation or material (6 of 30). Four students mentioned the use of some form of tool in the service of explanation or instruction (e.g., illustrations, models, and gestures).

Most students referred to straightforward scaffolding strategies, most often relying on "going slowly," "using drawings or gestures," or "explaining in a different way," to help their peers who were struggling. Twenty-five percent of the English Fluent students, frustrated by the feeling that their English Learner peers are "crazy smart with great ideas," wrote that they wished "they could speak the same language" as their English Learner peers so that they could "communicate better." English Learners, on the other hand, wrote that they wished that they could "speak better English."

When students felt unprepared to help their English Learner peers, their attitudes reflected frustration with the situation, not with the student, and often turned their frustration inward such that they spoke of what *they* could not do, rather than what their English Learner peers could not do.

English Learner students reflected their frustration about the communication gap by commenting that "I wish other student knew we have ideas, but can't discuss it," "I need help when I am not understand," and "I wish other students knew that I can do this." Several English Learner students were apologetic about their difficulty sharing the responsibility for groupwork, writing "I'm sorry that sometimes I can't be helpful."

Table 5

Walqui & Van Lier's features of scaffolding instruction for English Learners (Walqui, 2007 p. 165)

Feature	Examples of Katharine's efforts	What English Fluent students say that they do	Observed examples of student efforts
Continuity • Repeating concepts • Variation of explanation • Using different words	"Concentration, how much stuff of one thing is in a given area… so here we're talking about the concentration of 9 grams of NaCl – sodium chloride…. salt… – in a liter of water. Another way to think of it is who puts on the most perfume or cologne at home? Do they put it on in the bathroom? In the bedroom? Is it a high concentration or low?"	"I speak slowly with simple words." "I try to explain things in more basic words that I think they know." "I try to explain stuff but it's difficult." "Don't use big words."	Many instances of EF students speaking slowly. When asked, EF students repeated what was said; few instances of modification or variation to support understanding.
Contextual support • Safe and supportive environment • Multiple forms of access	"Nice collaboration! *This* is how we help each other…" Beginning of school year: real-time presentation and generation of a "personal story mind map" in front of the class. Students did the same.	"I try to build connections with (English Learners) and talk to them outside of class" "Just make sure they feel comfortable, that basically the goal is to make sure they're comfortable."	Many instances of EF students asking non-science questions of EL peers. Several occasions where EF students ignored EL peers when doing groupwork.
Intersubjectivity • Mutual engagement and rapport • Encouragement to participate • Cultivation of community of practice	Provided students with sentence starters, or sentences to build discursive participation. Guided students through the multi-day process of identifying their collaboration personalities to foster communication and understanding.	"I try to be patient and explain the classwork if they don't understand." "(I) encourage them to learn it and try to communicate with them through English, because the best way to learn is to be immersed." "Try to involve them and be respectful."	Many instances where EF students invited EL students to participate. Complexity of question or task typically low. EF students rarely persisted in seeking EL participation if EL student does not respond to initial efforts.
Contingency • Adjust tasks • Co-construct speech	Consistently modified materials to make reading easier without diluting content.	No examples of this strategy	No examples of this strategy among EF/EL students.
Handover Takeover • Student assumes control	Practice of constant reflection to keep track of which students need more support and which students are ready to be pushed.	No examples of this strategy	No evidence of this strategy
Flow • Increase complexity of challenges as students progress	Preparation of materials that increase in complexity; less translation; asking students to explain in English following conversation in native language.	No examples of this strategy	No evidence of this strategy

Claim #2 Collaborative experiences were not always beneficial

Analysis of the four learning events in Katharine's classroom led to the identification of four types of collaboration among English Learners and their English Fluent peers, namely: stopping participation, redirecting participation, impeding participation, and facilitating participation. Below I present a case of each situation.

Collaborative experience that stops participation - Lanh

Lanh was a Vietnamese Advanced level English Learner in his third year at Cielo Vista at the beginning of the 2013-2014 school year. His written academic English was clear and articulate. Lanh was one of the 20 students I observed for two years, beginning with the 2012-2013 school year. Over the two years I heard him verbally participate only rarely, and with directed support and encouragement from Katharine or Abe Mills, his Bio-Chem I teacher. I observed him interact with his English Learner peers during the English Learner Only Socratic Seminar, during which time he was social and, while not at ease, visibly more comfortable than I had ever seen him in the previous eighteen months.

Over the course of the year, Lanh encountered numerous instances where his participation was stopped through a series of shielding actions taken up by his English Fluent peers. I use the term shielding here to indicate any time that an English Fluent student made a move that prevented an English Learner from contributing to the intellectual and conceptual work of the group as a form of "protection," preventing the English Learner from feeling awkward, uncomfortable, or "bad about not being able to help."

NASA Activity. During the NASA Activity, Lanh completed the worksheet working alone like the rest of his group members. His completed worksheet included rankings of supplies and brief, two-four written word rationales for his ranking decisions. During the group conversation, however, Lanh did not volunteer at all. When his group members attempted to draw him into the conversation, Lanh stared only at his paper, never making eye contact. His group members did not ask any for any further input, nor did they attempt to gather information from his completed worksheet. Two group members made comments to me about not wanting to make him uncomfortable, or feel bad about participating.

CO_2 Presentation. Lanh's group members were different for this project. During the group's preparation of the presentation, Lanh did not volunteer any input other than to agree to keep track of the length of his showers for two weeks (one baseline week, one intervention week). Lanh did not respond to group members' requests for information or data from him. Group members did not ask Lanh if he understood the problem, the task, or the proposed presentation. Nor did they work one-on-one with him to practice CO_2 usage calculations. During the presentation, everyone else in the group had data, analysis, and discussion to present for their unique sets of data. When I asked him why he had not completed the task he quietly said "Lazy."

Socratic Seminars. Lanh looked visibly uncomfortable and did not contribute at all during the whole class Socratic Seminar, in spite of Katharine's provision of a sentence starter, initially, as well as a complete question towards the end of the session. During the English Learner Only Socratic Seminar, Katharine prompted his contribution by first pointing out that it appeared that he had something to say, and then waiting for him to say it.

Katharine:	So what happened? You saw the video…
Kun:	Yeah.
Katharine:	(Pause)
	Lanh is saying something over there, he's just not saying it out loud.
	(The kids encourage/cheer him on)
Lanh:	Maybe the baby has shot and better protection, so that can happen?
Tai:	Cool.

Genetically Modified Organism Activity. Lanh was reunited with the same group members he was with for the NASA Activity. Although this particular foursome has not worked together since the beginning of the year, Lanh had been in groups with these students one at a time throughout the academic year. Lanh did not volunteer or contribute in any significant way when the group brainstorms, divides the work, assembles the advertisement, or presents the final product. The members of the group assigned him the task of finding images to "dress up" the advertisement. One of the group members turned to me and said quietly, "I'm just looking out for him. Don't want him to feel uncomfortable." A second group member also took on the responsibility for finding appropriate images. None of Lanh's group members asked him if he understood the assignment or the group's plan of action. I saw no record of images collected by Lanh, or presented to the group.

Lanh is not a unique case of shielding. Throughout the year I observed numerous times in which English Fluent students would take on more responsibility in order to make sure that their English Fluent group members would not "feel bad." One morning in September, I noticed that one of Katharine's students seemed overwhelmed. When I asked her how she was doing, she said "There's just so much to do, I don't know how I'm going to get it all done." "On the project," I asked? She nodded. "Why are you doing all of the work?" "No. I mean. Katie is doing some of the work, but Marcella…she can't really and I don't want her to feel bad that she can't so I'm trying to do it all."

This phenomenon was not unique to English Fluent students. There were moments when more advanced English Learners, no longer receiving ELL Support services, would take on the work of their English Learner peers. During a January observation of groupwork on the CO_2 project, I heard Denali say "I got this. Can you just do the calculations? I can do the slides if you do the calculations. Less writing for you. I think that's easy for you and this is easy for me, ok?"

Mei and Rudy, both Intermediate English Learners, are shielded from participation during the CO_2 Activity preparations and presentation. The remaining three group members divide the time among the presenters. I draw the readers attention to the fact that the other three group members are English Learners either receiving services at Cielo Vista, or formerly receiving services. Mei and Rudy make eye contact with group members, nod in affirmation of group decisionmaking, and offer verbal contributions infrequently. Their group members do not persist in asking questions, nor do they check to make sure that the two understand the task at hand.

Collaborative experience that redirects participation – Belle

At the beginning of the 2013-2014 school year, Belle was in her third year at Cielo Vista. She was classified as an Advanced English Learner whose first language is Mandarin. She spoke highly of her academic experiences at Cielo Vista, once offering a comparison of Cielo Vista and her school in Japan. "The teachers here, when you say that you do not understand, they try to find a way to make you understand. In Japan, all of my teachers would yell at me to learn better."

Belle worried that Katharine gave her too much credit for doing well in her class. “I wish Ms. Bryant knew sometimes it is not because I'm smart, but I learned before.”

At the beginning of the year, Belle was relegated to creating detailed illustrations in support of the group’s work. Belle is a gifted artist with a tremendous capacity to innovate her drawings in order to illustrate not only scientific conceptual understanding, but the evolution – or step-by-step unfolding of scientific conceptual understanding. During these early assignments, Belle drew and held the group’s posters, a trend that did not change even when her group members did.

Whole Class Socratic Seminar. Belle was partnered with Lizzie, an English Fluent student, for the Whole Class Socratic Seminar. One of the roles meant to be played by an individual’s partner was that of a coach. The coach sat behind the participating member during their half of the seminar session and offered advice, feedback, and suggestions to make contributing and participating more manageable. To begin, Katharine posed a question to the group: “What does all of this (genetic testing) have to do with DNA to RNA to protein? Lizzie appeared confused, and looked to the people to her left and right. Belle offered her a note on which was written: “Proteins would be different if dna → rna aren’t regular.” This input, as well as a second note were both ignored by Lizzie. (Note: Belle did not participate in the English Learner Only Socratic Seminar).

Genetically Modified Organism Activity. Reunited with her original group members from the NASA Activity, Belle was again assigned the task of creating a series of illustrations for their political advertisement. I observed the group discussing their plans for writing, creating, and editing the advertisement. While still drawing, Belle interjected a suggestion to do a voice-over that they could layer on top of her illustrations. “That sounds really hard,” replied Ellie. “I don’t know how to do that. At all. No way. Do you (to Margaux, an English Fluent girl)?” “Not me. Let’s think of something else. But still use your drawings.”

Collaborative experience that impedes participation – Hei

Hei is a South Korean girl who had been in the US for two years at the beginning of the 2013-2014 school year. Hei was classified as an Intermediate English Learner. She was one of Katharine’s students who was a part of the ELL Support Class. When Katharine first started attending the ELL Support class, Hei appeared reluctant to engage – looking away from Katharine, responding to Katharine’s questions passively with a shrug or one-word answer. Within a month, however, Hei had questions and tasks ready for Katharine upon her arrival.

During the NASA Activity, Hei did not initiate conversation, and her group members, after two attempts, stopped inviting Hei to contribute. Afterwards, one of Hei’s group members I had known from the previous year, Biming, said that she was worried about making Hei feel bad because she seemed very “fragile.”

Over the course of the year while offering whole class presentations, Hei had shown that she was capable of reading information and explaining it. For example, in January, working with two other English Learner students, Hei read an article about ocean acidification and provided information from the article to the rest of the class.

During the final project of the year, Hei was partnered with the same two girls that were in her group at the beginning of the year. While working on the Genetically Modified Organism

Activity, Hei's group members did not have to persist in order to get her to join in the planning and implementation of their advertisement.

The following is a clip from that advertisement, representing about two minutes of a four minute ad. I draw the reader's attention to the various types of *scientific content* contributions made by each of the three girls.

Hei:	So, Doctor, what about this monkey is so great?
Biming:	Well, really, the best thing about the marmoset is how human-like they are. Since monkeys and humans are such similar species, having the marmosets gives us an almost exact genetic look at how genetic modification will affect humans.
Hei:	Then why will we want to test on animals? What good does it do?
Biming:	Well, right now we are trying to figure out how to cure diseases such as cancer and Alzheimers, through genetic modification. By testing marmosets we can figure out how to plant the desired gene into their DNA and have it go so deeply embedded in their DNA that they pass it on to their offspring.
Hei:	How does it genetic modification?
Lena:	First we collect some plasmid from a bacteria (illustrating the process on a whiteboard while speaking). Then a restriction enzyme cuts a desired gene from the plasmid and separates the two. The same restriction enzyme cuts the (missed) plasmid to insert the desired gene by using ligase enzyme to glue them back together. Then the new plasmid is put into bacteria, and the organism is given the bacteria by (missed) transfer DNA.
Hei:	Doesn't that change and hurt the monkey?
Biming:	Why no! The marmosets have no pain during this process. The marmosets are very happy in captivity and very easy to work with. They are small so they can be handled more easily. And they are calm. The monkeys are much more fertile. And we have much more information to go on.
Hei:	Thank you Dr. Smarty-Pants. Any last words?
Biming:	Yes! Genetic modification is a very important part of disease research and I466 wants to end that. For the sake of the afflicted, vote no on I466.

Hei directs the conversation, and asks questions that anchor what the two other group members have to offer, but the character of Hei's talk is talk *about* science, while the character of the group member's talk is talk that *explains* science. In fact, during preparation of the presentation, Biming and Lena did most of the research and decisionmaking, relying on Hei for planning and performing.

Collaborative experience that facilitated participation – Si

During the CO_2 preparation and presentation, Si and his group members made decisions collectively. Si agreed to collect data on the length and temperature of his showers over a two week period (one week, baseline and one week, intervention).

During collaboration in preparation, Si group members, two English Fluent boys, support Si by a) making sure that Si knew the steps for figuring out how to measure CO_2 use, and b) establishing an expectation that Si would produce his own part of the presentation.

Si recorded his findings and calculated the amount of CO_2 emissions that were reduced due to his intervention (taking shorter showers). He prepared his own PowerPoint slides for the class presentation. The slides read[14]:

Slide 1	CO_2 dota grape & table	
Slide 2	Part 1. Because Si want to save CO_2. So Si collect the information about CO_2 we use at one week and count to one year.	
Slide 3	data, shower length, temperature (seven points of data)	
Slide 4	Intervention:	Baseline
	time used 36.65	time used = 5.79 for day
	for a week 36.65= 1.007875	40.53 min for a week = 1.114575
Slide 5	Used a years	
	52 tims	52 time
	1.007875 = 52.407284	1.114575 = 57.9574
Slide 6	CO_2 we save	
	We save almost 5.55 CO_2 a years. So if we use short time every day CO_2 will be save. If everybody do that, world will been save. Thanks for watch!	

During the presentation Derek, an English Fluent group member, speaks for the entire group, including the other English Fluent group member.

[14] All student work represents the vocabulary, grammar, and style of the original author.

Claim #3 Defining help; it makes a difference

To get students to unveil their thinking about the intricacies of collaboration and groupwork, I designed a series of questions that provided them the opportunity to reflect on the best parts of groupwork, what makes them – as individuals – a good group member, and what makes others a good group member. I also asked questions that gave students the opportunity to write about what frustrated them about the process, and what they thought they would need to do in order to be a better group member. Finally, I asked students to write about their best day in science class, as well as their proudest moment.

English Fluent student responses. The 79 English Fluent students surveyed devoted the most attention to variants of work (see Table 6). They wrote about the value of hard work – by self and others – and dedication to the activity or problem. Students wrote about their delight in sharing or dividing the work, and the pain of being left to do all of the work. In aggregate, English Fluent students mention work 126 times, group member contribution 26 times, and group member participation another 10 times. Ten percent of English Fluent students (eight each response) wrote about the benefits of sharing ideas, and being effective communicators. Five percent of this group of students also wrote about the importance of help – being helped, and helping others – within the group.

English Learner student responses. The most common response among English Learners on the other hand, was an uncharacteristic blank or null answer (e.g., I don’t know) 25% of the time (see Table 6). When English Learner students elaborated, their characterizations were different than those of the English Fluent students. For example: English Learners mention work only 14 times, using descriptors like "does work," "less work," and "teamwork" when they did. Participation is mentioned only three times – once as a negative – and contribution is mentioned not at all. Hardworking/hard worker is mentioned only three times. English Learners categorize help into two groups: helping each other (mentioned 9 times), and getting help (mentioned 5 times). The opportunity to share ideas (mentioned 8 times) is mostly framed as a positive, with one English Learner pointing out his frustration that "some ideas can't be executed."

Table 6

The varied ways that English Learners and English Fluent students characterize collaborative groupwork

Characteristic	English Fluent students (n=79[15])		English Learner students (n=20)	
Work	126	159%	14	70%
Group member contributions	26	33%	0	0
Group member participation	10	13%	3	15%
Sharing ideas	8	10%	8	40%
Effective communicator	8	10%	0	0
Being helped	4	5%	5	25%
Helping others	3	4%	0	0
Helping each other	0	0	9	45%
Blank/Null	3	4%	15	25%

English Learners were the only students to report feelings of guilt or remorse in reference to their membership and participation within a group. "I couldn't do it. Felt guilty." English Learners were also alone in their reporting of being on the receiving end of negative feedback from their group members. "I was yelled at," and my English Fluent group members "didn't listen to (me)."

Discussion

Over the course of the year I observed more than 200 of Katharine's classes. For 20 of her students, the 2013-2014 academic year represented my second year with them. The

[15] One student asked that their data not be included.

longitudinal nature of this study affords a particular insight that would not have been possible had I been present for a single lesson or unit. These moments of observation and interaction with Katharine and her students are rare opportunities that offer a unique level of analysis. Persistence in the classroom made it possible to see things that would not have been readily apparent over shorter time frames.

In this section, I organize my discussion according to the claims and anchored to a second version of my conceptual framework.

In spite of diverse and transparent examples, students did not adopt scaffolding strategies

Katharine intended for her instructional approach to be transparent and supportive so that students would see her efforts and recognize them as contributory to their social and academic success in science. For Katharine, her actions are meant to integrate the instructional and relational – communicating with students and families in Spanish, making herself available at school during the day and well after the end of the school day, holding students accountable to high standards while remaining flexible, etc. The transparency of her scaffolding – saying, for example: "Maybe it'll make better sense if I put it another way… when I say metabolism, I'm talking about how quickly your body can change stored sugar into actual work." … "So, the question is, would he sweat more in the hot tub? Let's break it down: what's happening to his body in the hot tub? … "What happens when you get hot?" … "Where does the water that makes up sweat come from? Inside or outside of the body?"

When thinking about student uptake of scaffolding strategies, we considered two possibilities: 1) students did not notice, or were not conscious of, Katharine's scaffolding strategies, or 2) students did notice her strategies and did not take them up. This meant that prior to understanding why students did not take up these practices, we needed to determine whether or not students recognized them to begin with.

Students wrote of Katharine's efforts to help them make sense of topics by restating, probing, pushing, and asking questions that "help get to the answer." They also wrote that "(she) explains things very well and will provide clarification if it's needed," and "changes sources into easy version," "explaining in Spanish." "She always find(s) the easiest way to explain," wrote several students, and "asks you questions about topics you don't understand and she explains in different ways." "She gives paper with notes to help," acknowledged one student. Students spoke of her instructional materials and instructional practices like her use of "examples," modification of materials for access, "pre-written" or scaffolded notes, "checking for understanding," "helping when (they are) stuck," and "review." All of these strategies, aligned with Van Lier's features of scaffolding, are moves that Katharine planned and implemented with intention. The data clearly showed that students recognized Katharine's instructional actions. It is safe to say then that students noticed.

This left us then to consider the implications of what it meant that students noticed her scaffolding strategies but did not adopt them. About this we have two thoughts discussed below: 1) students did not adopt Katharine's scaffolding strategies because she was not explicit enough about student's uptake, and 2) students did not adopt Katharine's scaffolding strategies because they did not know how to translate Katharine actions into a personal strategy.

Modeling is not explicit enough

Teaching and learning are social endeavors that occur in contexts with a unique sociocultural habits and practices (Lave & Wenger, 1991). Beyond that, Hmelo-Silver (2008) emphasizes the socially situated nature of problem-based instruction, instruction and learning that require skilled facilitation (Chin & Osborne, 2010). When students enter this space they bring experience and understanding of different sociocultural habits and practices. This is especially true for English Learners new to the country; these students will need explicit support as they navigate new practices, while being encouraged to share their own.

Students need to be taught how to learn, explicitly (Walqui, 2006, p. 169). Students are not meant to attempt all of the scaffolding strategies that Katharine modeled for them. Nor do students have a deep understanding of Van Lier's features of scaffolding instruction. For example, teachers know that one of the principles of scaffolding is maintaining complexity of the material. Students have an intuitive sense about what English Learners need – linguistic support – but they are missing fidelity to complexity. Students do not know this absent implicit instruction. As such, it is unrealistic to expect the unproblematic uptake and implementation of what is modeled by Katharine.

Issues of transfer impact ability to support

English Fluent students in a science class are second language learners as well, except in this case they are English speakers who are learning the language of science. The data show us that our English Fluent students found it challenging to support their peers with effective scaffolding strategies. We believe that this is in part due to the fact that English Fluent students are learning the language of science while simultaneously developing their conceptual understanding of new material. We believe that it is also in part due to the fact that English Fluent students did not know how to take what they saw Katharine doing and make it a part of their own collaborative practice. English Fluent students were successful drawing upon strategies that were largely intuitive – slowing down, defining vocabulary, repeating, using gestures in the course of explanation –efforts that attempted to address the immediate needs of English Learners.

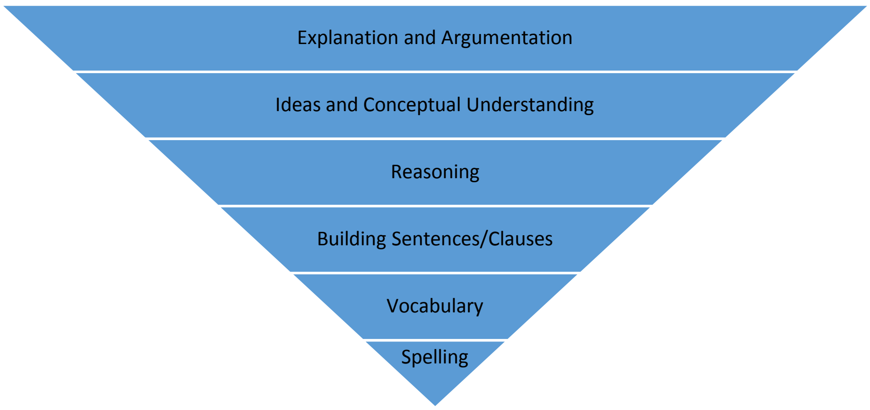


Figure 2 Hierarchy of feedback priorities in problem-based science classrooms (Adapted from Walqui & Van Lier, 2010 p. 74)

By that same measure, English Learners reported that they expected this kind of support from their peers, perhaps because they, too, instinctively think to address the most pressing issue – linguistic comprehension before conceptual understanding.

Katharine was looking for higher-order scientific thinking from her English Learners, representing conceptual understanding. It is possible that English Fluent students are so occupied with their own conceptual understanding that they miss the scaffolds Katharine used to support it. Katharine knew what she was looking for, in terms of conceptual understanding, and believed that she was explicit.

Claim #2 Not all collaborative experiences were beneficial

A majority of English Learner scientific discourse happened in the intimate spaces of one-on-one scaffolding cultivated by Katharine, a finding consistent with the work of Swanson, Branchini & Lee (2013). In looking at English Learner scientific contributions in the course of groupwork we discovered that small group interactions had identifiable characteristics that paralleled the different ways that English Learners participated. When Lanh and other English Learners were shielded from participating by their English Fluent peers, they rarely insisted their way into fuller or more rigorous participation. “To be successful, scaffolding requires enticing the (student) to take as much initiative as possible,” (Walqui & Van Lier, 2010 p. 19). This leaves us with questions about nurturing agency among English Learners and their peers.

In fact, throughout all of the cases, English Learners did not push back on the constraints or the facilitation offered by their English Fluent peers. Belle, though fully capable of more ambitious scientific practice, appeared resigned to serve as the group’s artist. In spite of her growth over the course of the year, Hei did not insist on adding to the group’s representation of their conceptual understanding.

In contrast, Si’s group members implemented a few of Katharine’s scaffolding strategies – holding high expectations, checking for understanding, breaking down critical tasks into manageable pieces – which were evident in their group interactions. Derek’s appropriate support in carrying the verbal component of the presentation freed Si to concentrate on the elements of the presentation – planning, data collection, analysis, and explanation – rather than become overwhelmed by the actual presentation. The group, in preserving Si’s slides and leaving them just as he made them, maintained his voice for the rest of the class.

These small moves made it possible for Si to participate fully with his group as well as with the whole class. In each of the less successful examples, there are equally small moves that group members could have made that may have resulted in a significant shift in participation and representation of English Learner voice. For example: Lizzie might have shared Belle’s idea with the class, and Belle's group members could have invited her to explain her idea and possible strategies for successful completion. Hei's group members could have taken her through the process of explanation in order to include her scientific voice as well as her academic voice.

Lanh, Belle, and Hei are not without agency in Katharine's classroom, even if they did not fully assume it. Which begs the question: how do we better prepare English Learners to advocate for equitable representation in the work of their groups? All three student in the above cases were fully capable of advocating for taking on more responsibility within their respective groups. These cases illustrate significant missed opportunities for equitable science participation.

Differing definitions of help constrain collaboration

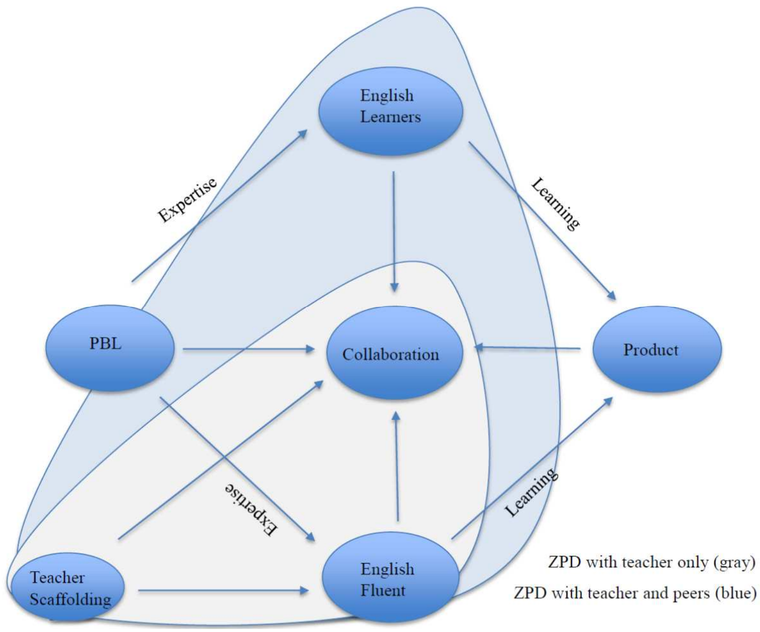
One of the most fascinating implications to come out of this work are the findings about how English Learners and English Fluent students characterize positive elements of group work. English Fluent students were twice as likely to talk about work as a function of the group, whereas English Learners were more likely to characterize group work as a place where students helped each other, shared ideas, and got help.

The implications of how one defines help – as something one does or as something one has done for them – are significant. It is not difficult to understand the frustration felt by a student when a collaborator is not – for whatever valid reason – doing the work that is expected of them. Neither is it difficult to imagine the frustration of an English Learner who wants to do the work, but does not feel capable or adequately supported to do the work. Identifying these differences may be the first step in assisting multilingual groups in their collaborative efforts. Which is not to say that English Learners and English Fluent students should alter their expectations; it is reasonable for English Fluent students to expect group members to do work, as much as it is reasonable for English Fluent students to expect substantive help from their peers. Rather, both groups should have clearer expectations, and strategies to get there. Navigating this terrain is

Implications for scaffolding

Teachers, Katharine certainly, guide students through social activity where learning is co-constructed through a series of scaffolded interactions. These interactions take place in what Vygotsky referred to as the Zone of Proximal Development (ZPD). Defined as “the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers,” Vygotsky explains the ZPD as elastic – expanding in the presence of scaffolding, shrinking in the absence of it (Vygotsky, 1978 p. 86). “Students develop higher-order functions as they engage in activity that requires them to use language,” development that is not reserved to scaffolding events that are guided by teachers alone (Walqui & Van Lier, 2010 p. 7).

Vygotsky proposed that transactions between peers could result in learning, a proposition supported since by the research of Donato (1994), Gibbons (2002), and Rogoff (1995). With that in mind, I propose a conceptual framework (see Figure 3) that represents the relationships between emerging expertise, collaboration, learning through collaboration that is reflected in the product, and finally, the imagined impact upon a students' ZPD if and when peers can scaffold instruction, in addition to teachers. Without scaffolding, the ZPD has no opportunity to expand. English Learners may benefit from having English Fluent peers who are better prepared to scaffold instruction for them; the ZPD expanding more robustly than if each English Learner was instead forced to wait only for Katharine. In a problem-based context however, there is an implicit pressure for these instructional moves to happen by students, for students, long before it gets to the teacher.



Problem-based instruction drives student collaboration. English Learners and their English Fluent peers collaborate in a variety of ways, developing expertise and learning, that have implications for English Learner participation within the group. Teacher scaffolding supports English Learners and the expansion of their Zone of Proximal Development (ZPD). Peer scaffolding for English Learners from English Fluent students could further support English Learners, likewise influencing the expansion of the English Learner students' ZPD.

Figure 3 Theoretical framework to examine the role of teacher and peer scaffolding as it impacts English Learner – English Fluent collaboration

Limitations

There are, of course, limitations to the findings in this paper. My qualitative analysis, though grounded in the literature and carefully considered, is not flawless. I tried to be true to the spirit of what was said, without being overly generous or overly critical. Moving forward, I hope to recruit some assistance from colleagues to engage in a process of interrater reliability testing.

When surveys are used, there exists the possibility of bias in the writing of the tool, as well as in the self-reporting. While I have no reason to believe that any student engaged in satisficing, it remains a possibility. Moving forward, I could be more critical of my survey instruments so that an increased number of questions verify each other. Furthermore, it is difficult to determine what a student is thinking and feeling internally beyond superficial analysis of facial cues and body language. It is also difficult to assume that the decisions made by English Fluent students to scaffold or not scaffold come from a position of power or assumed deficit stance (Valenzuela, 1999; Yoon, 2008), or from a benevolent deficit stance.

The sample size, one teacher and her 120 students represented a robust case study but is too small to generate any generalizable trends.

Finally, my role as a highly invested, long-term community member and participant observer open up the possibility that I influenced data and/or impacted outcomes. I tried to be clear about those moments where it was possible that my input might have played a role.

Conclusion

It is a widely held belief that collaborative groupwork is an instructional tool that fosters learning and substantive conversation, and has shown promise as a tool for equitable teaching (Oakes & Lipton, 1990). As we saw here, not all collaboration is successful, and not all discourse is productive (Baron, 2003; Krajcik, 1998). Teachers, until recently, have borne the bulk of the responsibility for instruction, including scaffolding. In a problem-based classroom, students take up a fair portion of instruction. This has left me to wonder about whether or not English Fluent students are expected, or even prepared, to scaffold instruction for their English Learner peers, and if English Learners are prepared to advocate for their voices to be heard and represented in the work of the group. I am also troubled by the possibility that we are expecting too much from students with too little support, even if it is in the honorable name of equitable science teaching.

If, in fact, we decide that it is fair to expect students to scaffold instruction for one another, then I for one shall shout from the mountaintop: we need to make sure that students, all students, are prepared and supported to do this important work. This begins with training teachers to be facile with their own repertoire of scaffolding skills. From there we can encourage teachers to be explicit with their students, facilitating the cultivation of their own repertoire of scaffolding skills. That sounds like the beginning of an equitable practice.

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Appendix A – CSI Problem-Based Unit Documents (partial)

Seattle/King County
Washington

King County
Medical Examiner's Office

Case No	13 -25422

Medical Examiner's Record Page 1 of 1

Reported	Arrived at Scene	Returned to Office
0535hrs	0717hrs	0842hrs

Decedent

Unidentified?	ID Not Confirmed?	Last Name	First Name	Middle Name	HMC Doe Name
		Rodriquez	Luz	A	

Sex	Death Date/Time	Estimate	Race	Hispanic?	Age	Date of Birth	Social Security Number	Marital Status
Female	07/15/13 0100hrs	Est.	White	Yes	24	07/02/89	552-99-2021	Single

Residence Street Address	City	County	State	Zip Code	Country
12019 SE 40th Ave #302	Seattle	King	WA	98111	

Birth Place	Occupation	Type of Business	Retired?	Unemployed?	Military Branch
	UPS Package Handler	Shipping			

Surviving Spouse	Father's Name	Mother's Maiden Name
N/A	UNK	UNK

Informant	Relationship	Street Address	City	State	Zip Code
Hilary Jimenez	Co-worker	10222 Rainier Ave S. #771	Seattle	WA	

Place of Death

Place of Death Unknown?	Place of Death Name (If Institution)	Place of Death Address	County	City	State	Zip Code
	UPS Processing Center	22322 S. Eastlake	King	Seattle	WA	

In City Limits?	Census Zone	Death Day of Week	SceneVisit?	Scene Visit Type
Yes		Monday	Yes	

Incident

Incident Street Address	City	County	State	Zip Code	Country	Census Zone
UPS Processing Center 22322 S. Eastlake	Seattle	King	WA		United States	

In City Limits?	Type of Location	Incident Date/Time	Estimate	Law Enforcement Involved Death?	Possible Homeless?
✓	Warehouse	07/15/13 0100hrs	Estimated		

Police Department	Police Case Number	Police Officers
SPD	13-056222	Officer Snagmore Badge 666

Found unresponsive by co-worker in package handling facility (UPS) with sharp-force injury.

Decedent was a 24 year old discovered by co-worker at approximately 0500 hrs after co-worker began her shift. Co-worker clocked in and proceeded to the semi-tractor trailer which was in the process of being unloaded, where she discovered the decedent who had failed to clock out from her previous shift. The decedent was found mostly prone, apparently collapsed over boxes she had been removing. A box cutter was present near the decedent and dried bloody material was present on the knife blade, a box which was partially under her, and the hand and fingers of her left hand. Closer examination revealed the source of the blood appeared to be sharp force injuries sustained to her 3rd-5th fingers of her left hand. Initial examination revealed no other apparent injuries.

An unopened can of "Ripped Force" energy drink and an empty container of "Pure Protein" were present on the loading dock adjacent to the truck which was identified as likely belonging to the decedent. Interview with a co-worker who had "lunch" with the decedent earlier in her shift stated she had consumed said protein powder, then returned her lunch box to her locker and was observed to rub a cream onto her inner arms which she stated were because of injury. Interview with a second co-worker stated that the decedent had one noticeable quirk—always consuming the exact same lunch of grilled chicken, steamed vegetables, and quinoa.

Aside from the usual noise associated with the warehouse, no one interviewed related any unusual noises, or activities associated with the decedent during her shift. Examination of the scene revealed no mechanical or electrical equipment in use near by.
The containers found near by, box cutter and locker contents were documented photographically and collected as evidence. The body was transported to KCMEO for examination.

King County Medical Examiner

AUTOPSY REPORT

Ian M. HEIGH
KCME 13-025421
Page 1

PATHOLOGICAL DIAGNOSES:

1. Asphyxia due to fresh water drowning
    a. Found floating face down in hot tub
    b. Watery gastric content present
2. Acute combined ethanol and fentanyl intoxication.
3. Hypertensive cardiovascular disease
    a. Cardiomegaly with symmetric left ventricular hypertrophy
4. Blunt force injury of extremities
    a. Superficial abrasions of knees and elbows
5. Blunt force injury of head
    a. Laceration to occipital scalp, underlying skull and brain intact
6. Remote blunt force injury of left ankle, status post surgical repair
7. Body in a state of early decomposition.

OPINION:

The decedent was found floating in a private hot tub without owners' knowledge or permission. The decedent's clothing was near by. Scene investigation revealed no suspicious circumstances. At examination, blunt force injury was present over scalp, knees and elbows. Several findings consistent with drowning were present. Toxicology reveals combined intoxication. This 22-year-old male died as a result of asphyxia due to fresh water drowning. A factor contributing to death is acute combined ethanol and fentanyl intoxication. Subsequent investigation by law enforcement revealed no suspicious circumstances. The decedent has no history of suicide attempts or mental illness. The manner of death is therefore best classified as accident.

____
Aldo J. Fusaro, DO
Associate Medical Examiner

____
Date Signed
AJF:wl

DATE AND TIME OF EXAMINATION:
8/21/2013 at 0800 hours.

EXTERNAL EXAMINATION:

IDENTIFICATION:

Identification is accomplished by name tags accompanying the body. In addition, photographs are taken under my direction for identification purposes. A morgue identification tag is present around the right ankle. Length, weight, and case note are printed on the right side of the body in black marker. All forms of identification correspond.

CLOTHING AND PERSONAL PROPERTY:

The body is received unclothed, covered with a white sheet. The following clothing items accompany the body:

1. One black T-shirt.
2. One pair of blue jeans with a black belt
3. One pair of white socks.
4. One pair of white sneakers
5. One pair of white briefs

The underwear appears water-soaked

GENERAL DESCRIPTION:

The body is that of a normally developed, thin adult white male measuring 5 foot 10 inches in length, weighing 167 pounds and appearing between the ages of 20 and 30 years.

The body is cold to touch after refrigeration. Postmortem lividity is nearly fixed and present posteriorly. Rigor mortis is loose to absent. The body is in a state of early decomposition.

The scalp hair is short, brown and straight. The hair extends up to 2 inches from the scalp surface. The eyes are closed. The irides are blue. The conjunctivae are congested. Early decomposition changes are present over the face as manifested by skin slippage of the upper eyelids. The skeleton of the nose, the maxilla, and the mandible are intact to palpation. The lips and frenula are intact. The upper jaw is edentulous. The lower teeth are natural. The neck is freely moveable. The ears appear normally formed and set. The left earlobe is pierced once. The anterior neck skin is without evidence of injury.

The chest, abdomen, back, and buttocks are symmetrically formed and without injury. Focal skin slippage is present over the left lateral chest. The genitalia are that of a circumcised adult male. Both testes are palpated in the scrotum. The pubic hair has been recently shaved. The anus is without external evidence of injury.

The upper extremities are symmetrically formed and are without injury. Focal skin slippage is present over both wrists. Over both posterior shoulders is residual adhesive for two possible rectangle shaped medication patches. No patches are submitted with the body.

The fingernails are present at the level of the nail beds and are clean. Wrinkling of the palmar skin is present consistent with prolonged exposure to a moist environment. The fingertips of the right thumb and forefinger contain fingerprint ink.

The lower extremities are symmetrically formed and without injury. The toenails extend up to 0.1 inches from the nail beds. The soles of the feet are thickened and are wrinkled, consistent with prolonged exposure to a moist environment.

IDENTIFYING MARKS, SCARS, AND TATTOOS:

1. Circumferentially around the right upper arm is a monochromatic tattoo depicting barbed wire.
2. Over the lateral left shoulder is a monochromatic tattoo depicting the name "Heigh" in gothic lettering.
3. Within the lateral left lower leg from knee to ankle is a vertical well healed scar. A visible fracture-malunion is present along the left ankle.

MEDICAL THERAPY:

1. Within the right antecubital fossa is a vascular catheter.
2. Exiting the right shin is an intraosseous catheter.

EVIDENCE OF INJURY:

1. Over both anterior knees are superficial abrasions.
2. Over the lateral aspects of the elbows are faint superficial abrasions.
3. Within the right occipital scalp is a laceration extending to the periosteum of the occipital bone measuring 3 cm in length; a corresponding subgaleal hemorrhage is present, the underlying skull and brain are intact.

INTERNAL EXAMINATION:

HEAD AND CENTRAL NERVOUS SYSTEM:

The scalp is unremarkable and the skull is intact. There is no epidural, subdural, or subarachnoid hemorrhage. The brain weighs 1223 grams and has normally configured gyri and sulci. The leptomeninges are thin and transparent. The cerebral vessels are unremarkable. The cortical gray ribbon is intact and the ventricular system is appropriate size. The deep cerebral nuclei and hippocampi are unremarkable. The brainstem and cerebellum are unremarkable. The skull base has the expected anatomic features. The proximal spinal cord, when viewed through the foramen magnum, is unremarkable.

NECK ORGANS:

Examination of the anterior soft tissues, cartilaginous and bony structures of the neck reveals no abnormalities. The usual anatomical relationships are preserved and the upper airway is not obstructed. Edema froth is present within the upper airway to the level of the vocal cords. All cartilaginous and bony structures are intact. Cut surfaces through the tongue reveal no intramuscular hemorrhage.

BODY CAVITIES:

The organs are normally situated and no unusual fluid accumulations or fibrous adhesions are present.

CARDIOVASCULAR SYSTEM:

The heart weighs 412 grams. The epicardium is unremarkable. The chambers demonstrate their usual shape and configuration. The coronary arteries are right dominant and have only scattered atherosclerotic streaks throughout the course of all vessels. No old or recent myocardial injuries are present. The left ventricle measures 1.5 cm and symmetric. The valves and atria are unremarkable. The aorta follows its usual course and the origins of the major vessels are normally disposed and unremarkable. The great vessels of venous return are in their usual positions and are unremarkable.

RESPIRATORY SYSTEM:

The larynx and trachea contain edema froth from the cords to the lung parenchyma. The right lung weighs 543 grams and the left lung weighs 522 grams. The pleural surfaces are glistening and contain anthracotic pigment deposition. The parenchyma appears hyper-inflated and pink. Edema froth exudes from cut parenchymal surfaces. There is no consolidation, hemorrhage, mass or cavitary lesion. The bronchi and vasculature are normally distributed.

HEPATOBILIARY SYSTEM:

The liver weighs 2081 grams. The capsular surface is smooth. Cut surfaces are firm, mottled red-brown, and yellow. No masses are present. The extrahepatic biliary system is unremarkable. The gallbladder contains 10 ml of viscous green bile without calculi.

LYMPHORETICULAR SYSTEM:

The spleen weighs 170 grams and has a smooth, glistening capsule and an unremarkable parenchyma with the usual anatomical features. A 33 gram thymus is present and contains red-tan lobulated external and cut surfaces. The lymph nodes, where appreciated, are unremarkable.

URINARY SYSTEM:

The right kidney weighs 168 grams and the left kidney weighs 189 grams.
The cortical surfaces are smooth and the cortical architecture is normal. There is good cortico-medullary differentiation. The pelves have the usual anatomical relationships and are continuous into normal ureters which insert into an unremarkable bladder containing 280 milliliters of light clear yellow urine.

INTERNAL GENITALIA:

The prostate and testes are normal in size and configuration. No hemorrhage or mass is identified.

GASTROINTESTINAL SYSTEM:

The upper esophagus is intact. The stomach is intact and contains approximately 400 milliliters of turbid watery material. The gastric mucosa is unremarkable. No small or large intestinal hemorrhage is present. The small and large intestines contain unremarkable external surfaces. The appendix is present and without gross inflammation.

ENDOCRINE SYSTEM:

The pancreas, pituitary, thyroid, and adrenal glands are unremarkable.

MUSCULOSKELETAL SYSTEM:

The vertebrae, clavicles, sternum, ribs, and pelvis are without fracture. The musculature is normally distributed. The periumbilical fat pad thickness measures 3 centimeters. Radiographs of the left lower leg are obtained which reveal old evidence of injury and medical therapy in the form of a fracture malunion of the distal left tibia, talus and fibula. A plate and screws extends from the ankle joint to the mid tibia. Additional screws maintain the relationship of the talus to fibula and tibia

MICROSCOPIC:

HEART:	Occasional hypertrophic myocyte nuclei
CORONARY ARTERY:	Widely patent
LUNG:	Congestion
LIVER:	Mild mixed micro and macrovesicular steatosis, no bridging fibrosis present
KIDNEY:	Autolysis
BRAIN (Cerebellum):	No pathologic diagnosis

EVIDENCE, RADIOGRAPHS, AND ANCILLARY PROCEDURES:

1. Samples are collected for toxicologic analysis; a separate report will be issued.
2. Tissue sections are taken for histology and entered into stock.
3. Radiographs of the left lower leg are obtained and reveal a fracture-malunion of the distal tibia/fibula with plates and screws extending to the mid tibia.

CSI project – final product Rubric **DUE FRIDAY, SEPTEMBER 27TH**

Remember to include:

_______ Proposed cause of death – explain in detail

_______ Physiological sketch (what was happening inside the body that caused the death?)

_______ Causes you ruled out and explanation for each one

_______ Source list: websites, texts, etc.

	1	2	3	4
Cause of death description – using evidence to support a claim	Cause of death is very general – for example, "He bled to death" or "She got hit on the head."	Cause is more specific, but leaves out important ideas.	The cause of death is described clearly and logically, explaining how a condition would have led to a death.	Everything from #3, plus a description of what the victim or paramedics could have done to prevent death.
Sketch of what's happening inside the body – interactions between different organs/systems	No sketch is included, or the sketch does not relate to the explanation.	A basic sketch is included, but without much detail.	Sketches are clear and show how all relevant parts are connected.	Everything from #3, plus a sketch of the effects of possible intervention(s) – see category above.
Causes ruled out – using evidence to support a claim	0-1 alternative causes are listed. No or very little explanation of why they were ruled out.	2-3 alternative causes are listed; some explanation of why they were ruled out, but explanations are not complete.	3-4 alternative causes are listed. Each one has a clear reason for why it was ruled out as a cause of death.	3-4 alternative causes are listed. Each one has a clear reason for why it was ruled out as a cause of death, *and* specific evidence or scientific reasoning is cited.
Use and cite sources appropriately	0-1 sources listed. Source list leaves out important information and is not formatted correctly.	2-3 sources listed. One or two of the sources are formatted correctly. Sources may have questionable reliability.	3 or more sources listed. All sources are reliable, but there are a few mistakes in formatting.	3 or more sources listed. All sources are reliable and formatted correctly.

Comments:

Standard	Met Standard Level 1	Level 2	Level 3	Level 4	Level 5
A. Give an example of how two or more body systems interact; explain the interaction and its effects.	○	○	○	○	○
B. Explain homeostasis and its role in maintaining body health. Give a specific example to illustrate.	○	○	○	○	○
C. Identify examples of positive and negative feedback and explain your answers.	○	○	○	○	○
D. Make a claim and explain it clearly, using specific evidence to support your ideas.	○	○	○	○	○
E. Appropriately use and cite resources (printed and online).	○	○	○	○	○
F. Critique a claim; use specific evidence to support your critique.	○	○	○	○	○

CSI – Human Body Unit Standards Name:______________________________

Scale: 5 = Consistently Exceeding Standard, 4 = Exceeding Standard, 3 = Meeting Standard, 2 = Approaching Standard, 1 = Getting Started

- The written description of each standard = level 3 (meeting standard).
- To earn a 4 on standards A-C, you will need to apply your knowledge to a new scenario in addition to providing/explaining an example.
- Standards D-F: see specific rubric on opposite side.

	Group	**Group**	**Individual**
Assessments for this challenge	CSI cause of death report (due Sep 27)	CSI peer critique (in class Sep 25-26)	Written quiz (in class Sep 27)

Critique a Claim: You are the state medical examiner. Did the local authorities do their work correctly?

______ **Review** the group's explanation and **examine** their evidence.

______ Look up <u>at least two</u> of the sources the group used; verify whether the sources are **reliable** and whether the group **used the information correctly**.

______ Based on your findings, **rank** each section of your partner group's report on the final product rubric.

______ **Explain** your rankings. Use specific evidence from their report to back up your conclusions.

	1	2	3	4
Critique a claim; use specific evidence to support your ideas	No explanation included, or just a vague statement.	General statements; no specific evidence used.	Rankings generally explained. Specific evidence backs up the claim.	Each ranking is explained separately with evidence for each.
Appropriately verify and cite sources	0-1 sources listed. No information about sources being verified.	1-2 sources listed; some information about verifying reliability.	2 or more sources listed. Clear explanation of whether sources are reliable and whether the information was used correctly.	

Appendix B – NASA Activity

Name ______________________ Per _____

NASA Exercise: Survival on the Moon

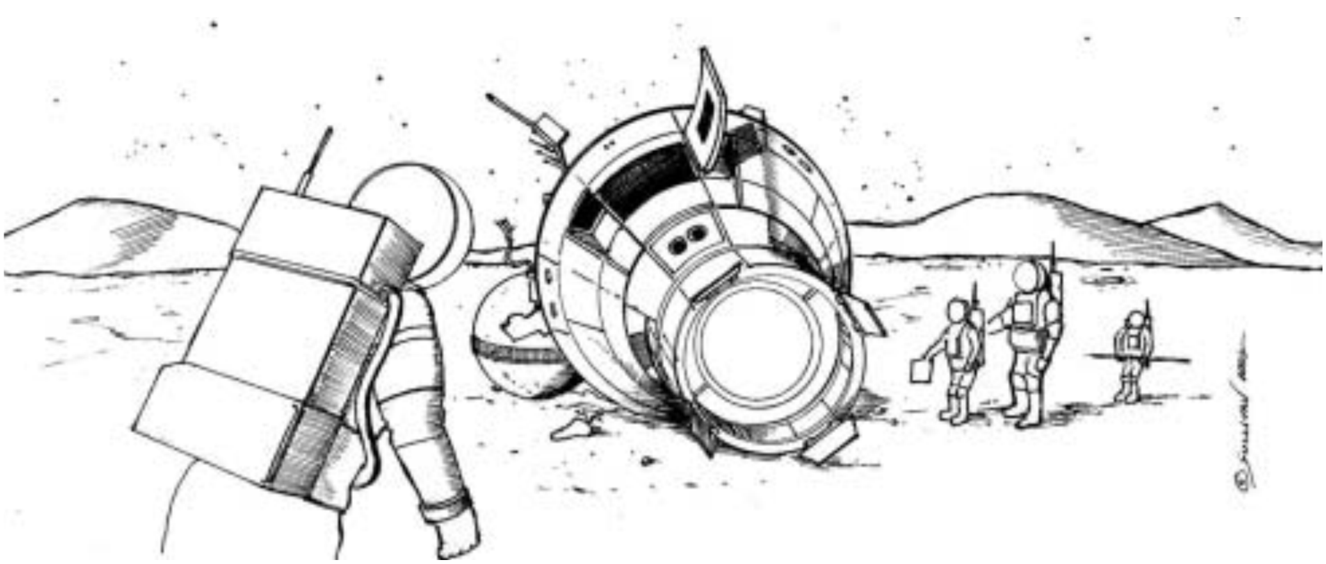
Scenario:

You are a member of a space crew originally scheduled to rendezvous with a mother ship on the lighted surface of the moon. However, due to mechanical difficulties, your ship was forced to land at a spot some 320 kilometers from the rendezvous point. During reentry and landing, much of the equipment aboard was damaged. Since survival depends on reaching the mother ship, the most critical items available must be chosen for the 320 kilometer trip.

Your task is to *rank order them in terms of their importance* for your crew in allowing them to reach the rendezvous point. Place the number 1 by the most important item, 2 by the second most important, and so on through number 15 for the least important.

Take 5-10 minutes and rank order the items by yourself. Then work with your team for 20 minutes to *come to consensus* about your team rankings. Every member of your group must share ideas and reasoning as you come to consensus.

Some details about the items are intentionally left out; think critically about the **potential benefits and limitations** of each item.



Adapted from *The Space Age Activity Guide,* © 1992 QED Communications Inc., and several earlier NASA sources; Suzanne Chippindale.

My Ranking	Survival Items	Reason I ranked this item with this value	My Group's Final Ranking	The key reason(s) my group came to this consensus	NASA Ranking	Net Score
	Box of matches					
	Food concentrate					
	15 meters of nylon rope					
	Parachute silk					
	Portable heating unit					
	Two .45 caliber pistols					
	One case dehydrated milk					
	Two 46 kg tanks of oxygen					
	Stellar map					
	Self-inflating life raft					
	Magnetic compass					
	19 L of water					
	Signal flares					
	First aid kit, with injection needle					
	Solar-power FM receiver-transmitter					

matches

parachute silk

dehydrated milk

self-inflating life raft

food concentrate

portable heater

oxygen tanks

magnetic compass

nylon rope

two pistols

stellar map

water

signal flares

first aid kit

solar-powered FM
receiver/transmitter

Appendix C – CO2 Carbon Footprint Problem

Name: ____________________ Period: __________ Date: ______________________________

CO_2 Challenge 2014

<u>My CO_2 reducing intervention will be:</u>

I plan on ***measuring*** a change in CO_2 emissions by first measuring ____ for a week to gather "baseline data."
In the second week I will ***measure*** whether there is a difference in how much ___________________________________ I use compared to the first week.

<u>The Hypothesis:</u>
I believe if I do ____ then ____ will occur. (use as much space as needed)

Basic data collection table (feel free to modify based upon your experiment)

	Numerical data (odometer reading, electric meter reading, gas meter reading, water meter reading, other?)	Units (therms, BTU, gallons, liters, other?)
Day 1 (initial measurement—no intervention)		
Day 7 (final measurement—no intervention)		
Day 7 (initial measurement—with intervention—should be same as the day 7 measurement above)		
Day 14 (final measurement—with intervention)		

My other group members' interventions are:
I think __________________________________ (name of member) will have the largest reduction in CO_2. I think this because…
<u>Journal</u>: Write here an **"*exceptional circumstances*"** that occur during your experiment. If you are measuring a change in water usage, but you realize on day 12 that your little brother or sister *left the faucet running* in the bathroom overnight, you would definitely want to note that here. If you are measuring how much driving you do, and you had to do some crazy, unplanned family trip that makes it look like you use more gasoline than "average," you would need to account for that.
Add additional pages as needed—this is an experiment—take lots of notes and document everything—additionally, try to have only one **manipulated variable** (keeping everything else **constant**)!

CO2 Challenge 2014

What we know: CO_2 emissions have an impact on our atmosphere and our oceans—in short, our environment and ecosystems are being harmed by humans burning large quantities of fossil fuels.

The two major carbon problems we have learned about are *Global Climate Change* and *Ocean Acidification*.

The solution (backed by the vast majority of scientists today) to both of these problems is reducing CO_2 emissions.

Your task: Design an intervention or series of interventions that will result in an overall reduction in **YOUR** Carbon Footprint.

- The average American **personally** contributes 20.0 metric tons of CO_2 annually. You must identify interventions that would reduce American's **personal** CO_2 output by 8-10% annually over the next ~40 years. This means a decrease in CO_2 emissions of 1.6 metric tons per person over the first year.
- According to www.shrinkthatfootprint.com , personal CO_2 emissions stem from "the combined emissions from personal spending on housing, travel, food, products and services." Thankfully that means we don't have to calculate the emissions from businesses or government—these are simply the choices that we make daily which directly impact the burning (or lack thereof) of fossil fuels.

PART ONE: decide upon one personal intervention that you can collect data on in the next few weeks.

- Week 1: Collect baseline data (example: calculate how much electricity your home uses in a week by monitoring your electric meter).
- Week 2: Implement your intervention and collect a second set of data (example: As an intervention I replace all incandescent lights in my house with LED lights; I would then evaluate how much electricity my home uses with the LED light bulbs when compared to the initial data). ****Choose your intervention wisely. This has to be something you can ACTUALLY do for a week!****
- Determine your CO_2 savings (or offset) for this one personal intervention.

PART TWO: Add the CO_2 offsets of each of your group members together. If one individual did *all* of your group's interventions what would their total CO_2 savings be?

PART THREE: (If you did not reach the 1.6 metric ton reduction) research other ways to offset your CO_2 emissions. (If your group targeted interventions that produced large CO_2 savings, you may require fewer or no additional interventions.) ***Remember you must reduce individual CO_2 emissions by 1.6 metric tons in year one!

- Talk to other groups—what are they doing to reduce their CO_2 emissions? Is this something you or your family might consider doing?

- Research on the internet—if you typically dry your clothes in an electric or gas clothes dryer, could you air dry your clothing instead? How much CO_2 could the average person save by doing this intervention?

PART FOUR: present your findings in a PowerPoint to a panel of interested students and adults. Your PowerPoint must follow the Formal Lab Report Format (next page) with *at least one slide for each of the 8 main sections (Title → Literature Cited)*. In the "results" section all calculations must be shown for each step with units clearly labeled.
Grading: The % grade calculated using the Formal Lab Report Rubric will be translated to a Standards Based grade.

Formal Lab Report Rubric—100 points total

		Student Self-Assessment /	**Teacher Assessment**
Title	• Concisely explains the purpose of the investigation (example: the effect of additional nitrogen fertilizer on the growth rate of corn)	_____ / 3 pts	_____ / 3 pts
Abstract	• A summary of the lab investigation • Fewer than 100 words (Like the abstracts for articles in scientific journals)	_____ / 3 pts	_____ / 3 pts
Introduction	• Background information • Purpose of the investigation; how the investigation answers a specific question; curricular context (What have we just studied? What are we currently studying?) • Hypothesis(es) "if…then"	_____ / 5 pts _____ / 5 pts _____ / 5 pts	_____ / 5 pts _____ / 5 pts _____ / 5 pts
Materials and Procedures	• Materials / supplies listed • Procedures clearly stated	_____ / 5 pts _____ / 5 pts	_____ / 5 pts _____ / 5 pts
Results/ Data Collection/ Analysis	• Data recorded in tables (tables titled, calculations completed) • Graphs present • Graphs titled • Axes labeled correctly • Analysis of numerical data collection (What do the results tell us?)	_____ / 10 pts _____ / 10 pts _____ / 2 pts _____ / 3 pts _____ / 5 pts	_____ / 10 pts _____ / 10 pts _____ / 2 pts _____ / 3 pts _____ / 5 pts
Conclusions and Discussion	• Results summarized • Errors identified • Results compared to hypothesis and reason for competing the lab • Conclusions stated/results interpreted • Suggestions for improvement (the lab in general, your results, etc. **Do NOT leave this blank or say "we did a pretty good job!"**)	_____ / 2 pts _____ / 2 pts _____ / 2 pts _____ / 10 pts _____ / 4 pts	_____ / 2 pts _____ / 2 pts _____ / 2 pts _____ / 10 pts _____ / 4 pts
Questions	• What are questions for further investigation? What new questions arise from the results of the investigation?	_____ / 12 pts	_____ / 12 pts
Literature Cited	• Outside sources used for writing the formal laboratory report are cited within the write-up. • Citation information is accurate (no URLs! Correct MLA format)	_____ / 2 pts _____ / 2 pts	_____ / 2 pts _____ / 2 pts
Correct Use of Language	• Grammar • Punctuation • Spelling	_____ / 1 pt _____ / 1 pt _____ / 1 ps	_____ / 1 pt _____ / 1 pt _____ / 1 pt

Group: What did the students do well in their presentation? What could the students work on for their next presentation? Do you think the students' results are reliable? What would make you more confident in their data? What did you learn from this group that you didn't already know? **Please use the back for any additional comments	Please rate each of your group members using the following scale (more than one person can have the same score):

CO$_2$ Challenge 2014—Data analysis and Calculations

PERSONAL CO$_2$ EMISSIONS

1. During the last two weeks, what aspect of your life did you target to reduce CO$_2$ emissions?
2. a) How long did you collect baseline data? b) How long did you collect intervention data?
3. Calculate how much CO$_2$ are you responsible for releasing into the atmosphere for your ONE targeted intervention during the "baseline" data collection time period (2a).
4. Calculate how much CO$_2$ are you responsible for releasing into the atmosphere for your ONE targeted intervention during the "experimental" data collection time period (2b).
5. How much CO$_2$ would you have released in ONE YEAR if you continued about your normal daily life (use the data from question 2a and 3)?
6. How much CO$_2$ would you have released in ONE YEAR if you continued about your normal daily life (use the data from question 2b and 4)?
7. How much CO$_2$ would you have SAVED/OFFSET if you implemented your "new lifestyle" in a one year period? (refer to questions 5 & 6)
8. Did you reach your target of reducing your CO$_2$ footprint by 1.6 Metric Tons (1 metric ton is 1000 kg)? If not, how much are you off by?

GROUP CO$_2$ EMISSIONS

9. If you combine every group members' actions/lifestyle changes, what would be the total CO$_2$ savings/offset?
10. As a group, if each of you did EVERY intervention represented in your group, could you reach the 1.6 Metric Ton target?

CHOOSE ONE!

Uh-oh! We still didn't meet our target! Proceed to the next step

Yay! We rock! We met our 1.6 Metric Ton Goal You are done with calculations—start working on your PowerPoint Presentation

PART THREE: (If you did not reach the 1.6 metric ton reduction) research other ways to offset your CO$_2$ emissions. (If your group targeted interventions that produced large CO$_2$ savings, you may require fewer or no additional interventions.) ***Remember you must reduce CO$_2$ emissions by 1.6 metric tons in year one!

- Talk to other groups—what are they doing to reduce their CO$_2$ emissions? Is this something you or your family might consider doing?

- Research on the internet—if you typically dry your clothes in an electric or gas clothes dryer, could you air dry your clothing instead? How much CO_2 could the average person save by doing this intervention?

Here are the OTHER ways we could reduce CO_2 to meet our target of 1.6 Metric Ton CO_2 savings (you may need an additional sheet of paper to document your calculations).

Potentially useful websites, conversion factors, etc.
http://shrinkthatfootprint.com/carbon-calculator (carbon footprint calculator used in class)
http://shrinkthatfootprint.com/the-shrink-guide (recommendations for shrinking carbon footprint)
http://www.epa.gov/cleanenergy/energy-resources/refs.html (other, less common conversion factors)

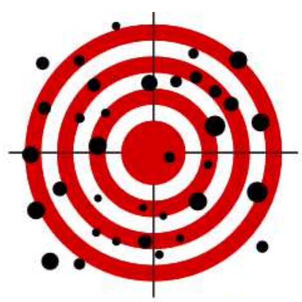
(Electricity) 7.0555×10^{-4} metric tons CO_2 / kWh
(Natural gas) 0.005306 metric tons CO_2/therm
(Household water use) 0.011 kg CO_2/ gallon
Example to calculate a car's CO_2 output (if you travel 11,493 miles per year and get 21.5 mpg)

8.92×10^{-3} metric tons CO_2/gallon gasoline × 11,493 VMT $_{\text{car/truck average}}$ × 1/21.5 miles per gallon $_{\text{car/truck average}}$ × 1 CO_2, CH_4, and N_2O/0.985 CO_2 = **4.8 metric tons CO_2E /vehicle/year**

CO2 Challenge 2014—Debrief

1) What was your original intervention?
2) How does your intervention work to reduce CO_2 going into the atmosphere/ocean?
3) How much were you able to reduce CO_2 by over one calendar year?
4) Did you think you were going to reduce CO_2 more or less?
5) What kinds of interventions were better at reducing CO_2? Why?
6) Why is there no "quick fix" to reducing CO_2?
7) How can we REQUIRE American citizens to reduce CO_2?
8) According to the Seattle Times, in 2010 only 7% of Americans knew about ocean acidification (*Sea Change*, 1/23/14), communicate your understanding of the harmful effects of CO_2 in the environment and how as individuals we can make small changes to reduce our CO_2 footprint. Write your take-away statement for this unit (going back to watching An Inconvenient Truth)—What do you want those 93% of Americans to know?
9) If you were to do this experiment over again, what would you want to investigate further (choose something completely new or something related to your original intervention)?
10) Are you CONFIDENT that your calculations are correct? How could you increase confidence in your results?
11) What could you do increase the validity and/or reliability of your data?

Unreliable & Unvalid



Unreliable, But Valid

Reliable, Not Valid

Both Reliable & Valid

Appendix D – Socratic Seminars

(This page intentionally left blank. Materials follow below)

Name ______________________ Date __________ Period ________

6 Categorizing Genetic Tests

Based on Burke, W., Pinsky, L., and Press, N. (2001). "Categorizing genetic tests to identify their ethical, legal, and social implications." *American Journal of Medical Genetics*, 106:233-240. Adapted with permission.

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1 What if you could go to the doctor and present a card that contained all your genetic information? Your doctor could scan the card and see whether you were more likely to have an allergic reaction to a particular drug, or whether you were at increased risk for a disease or disorder. Every year, scientists come closer to making this scenario a reality. More than 1,500 genetic tests are currently available[1], and the number of tests available has more than doubled in the past eight years. Genetic testing companies are making it increasingly possible for consumers to have portions of their DNA sequenced, and to receive some information about what the results might mean. The growth of these "direct-to-consumer" testing companies has resulted in the ability of individuals to learn unprecedented amounts of information about their own genes.

2 There are a variety of genetic tests available. For example, some tests are performed on early embryos formed by ***in vitro fertilization*** (in which egg cells are fertilized by sperm outside the body) to determine whether they are disease-free and should be implanted in a woman (**Pre-implantation Genetic Diagnosis, or PGD**). **Prenatal** genetic tests test cells from a developing fetus before birth. Newborn screening tests are provided to children immediately upon birth. **Diagnostic tests** are used to identify (or rule out) a particular genetic condition and **carrier tests** are used to identify whether an individual who may not show any condition him/herself carries a particular gene.

3 Genetic tests have tremendous value in helping doctors diagnose and treat diseases. They can also predict who may develop a disease in the future, helping patients take a proactive role in their health care. Knowing an individual's genetic makeup may also help doctors identify the best treatments, as some drugs might be more effective for patients with particular genetic variations. They can also provide information to individuals that may affect their choices about having children in the future.

4 However, genetic tests also raise some challenging issues. For example, patients might encounter discrimination in various forms, or might experience stress as a result of knowing the outcome of a test. While the federal Genetic Information Non-Discrimination Act (GINA) of 2008 sets a baseline for patient protection with regard to insurance and employment, there are areas it does not cover (for example, companies with fewer than fifteen employees are exempt). GINA also does not prohibit health insurers from obtaining and using genetic test results to determine who should receive health insurance payments. Another concern is that the results of genetic tests impact not only the individual taking the test but entire families, who often share much of the same genetic information. Even a test that shows that a person does not have a genetic disorder might cause stress in the form of "survivor guilt" if other family members are affected by the disorder.

5 Genetic tests can be characterized according to their **clinical validity** and the availability of effective treatments. The term "clinical validity" means how accurately a test predicts a certain clinical outcome (such as getting a particular disease or symptom). Different types of tests raise different ethical issues and require different types of genetic counseling.

High Clinical Validity – Lack of Effective Treatment

6 Traditionally, genetic counselors have been guided by the view that recommendations should be "non-directive;" in other words, people should be provided with information and then allowed to make their own choices. This view acknowledges that many decisions regarding health care are currently driven

by personal preference. For example, the decision of whether to terminate a pregnancy because of a genetic disorder is viewed as a private matter. Non-directive approaches also apply to some genetic testing situations that do not involve reproductive choices. For example, an individual whose parent had **Huntington's disease (HD)** might want to find out if he or she carries the mutation that results in the disease. Because HD has a high penetrance (in other words, an individual with the mutation has a large chance of developing the disease), an individual who tests positive receives information that might be helpful in planning for his or her life. However, there are currently no effective treatments to delay or prevent the disease, so an individual who tests positive for the HD mutation cannot use this information to make decisions about medical treatments that might help them.

7 In addition, there is the possibility that a person with a positive test may face discrimination or harmful psychological effects (including the stress of knowing that they have the mutation). A counselor might explain the different concerns and issues related to taking the genetic test, but the decision to test is ultimately left to the patient. Ethical issues often focus on making sure that people consider the kind of information the test will provide and the lack of treatment options.

High Clinical Validity – Effective Treatment

8 Newborn screening tests, by contrast, are required by all states. Newborns are screened for a variety of disorders. In some states, parents may choose not to have their children screened (for example, for religious reasons). A classic example of a newborn screening test is the test for a disease called **Phenylketonuria (PKU)**. If a child who has the PKU mutation is diagnosed early in life, a modified diet can be given and mental retardation prevented. There is broad agreement that testing for PKU is extremely beneficial because a highly successful treatment—a modified diet—exists. Ethical concerns related to such genetic tests often focus on making sure that eligible people have access to the tests and treatment.

9 These examples show that the availability of an effective treatment makes a big difference in thinking about the implications of a genetic test, whether the use of that test is justified, and how health care providers should counsel families. In fact, health care providers have a duty (supported by court cases) to clearly tell patients if there are tests available in cases where successful treatments exist and non-treatment can lead to serious harm. If there are no effective treatments, non-directive counseling provides an appropriate framework for talking to patients about the possibility of testing.

Low Clinical Validity – Lack of Effective Treatment

10 Clinical validity is affected not only by the penetrance of the mutation, but also by how good a test is at predicting whether someone will eventually get the disease. In other words, if a patient receives a positive test, how high is the likelihood that they will eventually become ill with that disease? In some cases, such as testing for the ApoE4 genotype (which may result in an increased risk for **Alzheimer's disease**), a positive result may show an increased risk, but the actual lifetime risk for the disease is uncertain. People with two ApoE4 alleles are ten times more likely to have Alzheimer's disease than those with other versions of the gene, but because Alzheimer's can occur late in life, someone might have two ApoE4 alleles and die of something else before Alzheimer's sets in. No treatment is available to reduce the risk.

11 As with testing for HD, the main risks are related to psychological effects on those who are tested, as well as discrimination. However, the HD test provides a highly accurate prediction about future risk. The risk associated with the ApoE4 test is less certain. Many experts recommend not testing for ApoE4, based on the ethical obligations for health care providers to avoid harm. Many genes that contribute to human disease have been identified. However, since the corresponding genetic tests may not be clinically valid, the real impacts of a positive test may be difficult to interpret, and few treatments may be available. Many direct-to-consumer tests fall into this category; they provide information related to disease risk that is difficult to evaluate due to uncertainty about the validity of the test as well as a lack of effective treatment.

Low Clinical Validity – Effective Treatment

12 So far, the examples presented have been ones that either predict diseases well (HD and PKU), but differ as to the treatments available, or that do not predict the disease well and also do not have an effective treatment (Alzheimer's – ApoE4). A fourth case is when there is an effective treatment, but the test is not clinically valid. For example, mutations in the HFE gene can lead to susceptibility to a disease called **hemochromatosis**. This disease causes iron overload and has potentially life-threatening consequences. However, only a small proportion of individuals with mutations in both copies of their HFE gene actually show symptoms of disease (low penetrance); therefore, the clinical validity of the test is low. Periodic blood draws, however, can help prevent dangerous complications such as liver cancer. So, in the case of HFE, the clinical validity of the test is low, but the treatment is minimal and beneficial. The benefit to the patient in terms of health outcomes may outweigh the potential psychological effects of testing or the potential social stigma of being labeled a carrier of a genetic disease. Ethical discussions about these types of tests, therefore, tend to be framed in terms of balancing potential harms and benefits. Tests that do not predict outcomes very well might be acceptable when the "label" associated with the disease has little social stigma (for example, hypertension).

*shame or humiliation

13 *BRCA1* and *BRCA2* are interesting to analyze using this framework. There is uncertainty about how penetrant the *BRCA1* and *BRCA2* mutations are. The lifetime risk of breast cancer associated with *BRCA1* or *BRCA2* mutations ranges from 36%-85%, with a wide variation in how the cancer manifests itself (as breast cancer, ovarian cancer, or both). The penetrance is probably determined by the exact type of mutation (many *BRCA1* and *BRCA2* mutations are known) as well as environmental and other genetic factors. In a "high risk" family (four or more relatives affected by breast/ovarian cancer before age 60), females with mutations in *BRCA1* or *BRCA2* are estimated to have a lifetime risk of 85% for breast cancer. The effectiveness of the different treatments offered to carriers of *BRCA1* or *BRCA2* mutations is also subject to debate. The options include early mammograms, ovarian cancer screening, and surgery before any cancer appears. Most women with *BRCA1* or *BRCA2* mutations do not opt for such preventative surgery, especially if they do not have other risk factors in their history. However, those in a "high risk" family might consider the test to be highly predictive and the treatment effective.

* mastectomy and/or hysterectomy

14 A genetic test, therefore, should be evaluated based on both the test's clinical validity and the treatments available for those individuals with positive results. It may take many years for researchers to gauge how accurate a test is at predicting a disease outcome. The development of treatments and tests of their effectiveness in patients also requires time. This framework can help guide researchers in making decisions about which kinds of information to seek about tests, and can help patients think about the characteristics of the tests they are considering. It also explains why some tests have become widely accepted while others have not. As more genetic tests with limited clinical validity and predictive value become available, and more direct-to-consumer tests are marketed to the general public, it will be increasingly important to consider carefully how those tests are used.

* patients order tests themselves without a a doctor note or prescription

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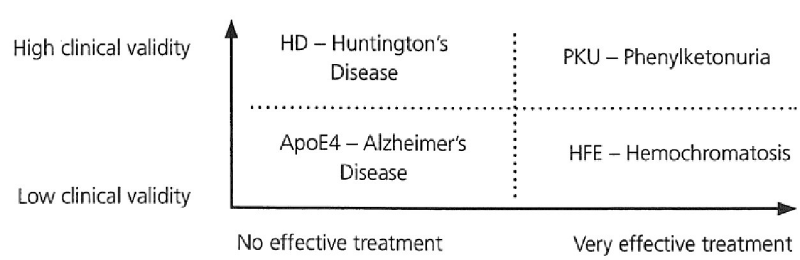
Genetic Test Categories



Genetic Conditions Glossary

Alzheimer's disease: A brain disease that causes problems with memory (such as difficulty remembering people and events), thinking, and behavior. It is most common in people over 65, but up to five percent of people with the disease have early-onset Alzheimer's (also known as younger-onset), which can appear in the patient's 40s or 50s. Alzheimer's worsens over time, and there is no cure, though some treatment options are available that appear to reduce the speed with which the condition worsens.

Carrier test: A genetic test to determine whether an individual carries a particular gene but may not show any conditions themselves. For example, a carrier test may be used to determine whether two parents both carry a copy of a recessive trait, which may be passed on to their child(ren).

Clinical validity: How accurately a test predicts whether a person will get a particular disease or symptom (known as the "clinical outcome"). This is often related to the penetrance of the gene involved, and whether or not the condition is polygenic.

Diagnostic test: A genetic test used to identify (or rule out) a particular genetic condition. For example, diagnostic genetic testing is used to determine whether a baby has Phenylketonuria (PKU).

Effective treatment availability: Whether or not there are treatment options available for a particular disease or condition. This is sometimes thought of as a "cure" although most genetic conditions are "treated" rather than "cured."

Hemochromatosis: An autosomal recessive genetic disease that results in the body absorbing too much iron from food. This extra iron is stored in the body, including in organs like the liver and pancreas. The extra iron results in pain, organ damage, cancer, heart problems, and in some cases, death. Symptoms usually begin around age 30 to 40, but may begin in childhood. There is no cure, but the condition can be controlled with a specific diet, removal of blood (to remove the extra iron), and medication.

Huntington's disease (HD): An autosomal dominant genetic disease causing nerve cells to waste away gradually, resulting in uncontrolled movements, severe problems with balance, clumsiness, emotional distress, problems swallowing, and loss of mental function. The condition usually begins when a person is in their 40s, and gets worse with age. The condition is ultimately fatal, and there is no cure.

***In vitro* fertilization:** A process in which egg cells are fertilized by sperm outside the body. This is often used to help couples who have difficulty getting pregnant.

Penetrance: The frequency that individuals with a specific genotype will express a specific phenotype. For example, as seen in *Lesson Three*, approximately 85% of women with particular *BRCA1* mutations will develop breast or ovarian cancer. *BRCA1* is said to have "high penetrance" because an individual with a cancer-causing mutation in *BRCA1* has a large chance of developing breast cancer.

Phenylketonuria (PKU): A rare autosomal recessive genetic disease in which the body does not make an enzyme necessary to convert the amino acid phenylalanine to the amino acid tyrosine, causing phenylalanine to build up in the body to unsafe levels. This can cause mental retardation, brain damage, and seizures during infancy and early childhood. While a modified diet, including special protein supplements, can reduce the severity of PKU's symptoms, new research suggests that diet alone is not enough to prevent symptoms.

Pre-implantation Genetic Diagnosis (PGD): Performing a genetic test on an embryo created by *in vitro* fertilization before placing it in the mother.

Prenatal: Before birth. For example, some genetic tests are performed on a developing fetus while s/he is still in the mother's womb.

Name ______________________ Date __________ Period ________

6 Weighing the Risks and Benefits of Direct-to-Consumer Genetic Testing: Who Should Decide?

Concerns about Direct-to-Consumer Genetic Testing

1 Direct-to-consumer (DTC) genetic testing has offered personal genetic data to consumers since 2006, without the need for—or potential benefit of—medical doctors or genetic counselors. However, medical providers and those in government have been concerned that the risks of DTC genetic testing may outweigh the benefits.

2 What if the estimates for how likely someone is to develop a disease prove to be incorrect, either overestimating or underestimating a person's risk? If someone found out that their risk for a disease like Alzheimer's was well above average, would they become depressed? Would they alter their behavior for better, for worse, or perhaps not at all?

3 These concerns have led some states – including New York and California – to either ban DTC genetic testing, or strictly limit it. According to a report by the Genetics and Public Policy Center in June 2007, only about half the states in America permitted DTC genetic testing with no restrictions.[1]

4 The US Food and Drug Administration (FDA) does not currently provide oversight of the DTC genetic testing industry. In March 2011, the Molecular and Clinical Genetics Panel, an advisory committee to the FDA, suggested more oversight. They expressed concern that consumers may misunderstand genetic results without medical counseling, or that the disease risk estimates provided in those results may be incorrect, as there is currently no standard about the level of evidence needed by DTC genetic test manufacturers to make claims about their genetic tests. The FDA panel noted that, while DTC genetic tests seem similar to other at-home medical tests like those for blood sugar or pregnancy, "many DTC clinical genetic tests often carry a disclaimer stating that they are intended for 'educational and informational' purposes, and that the individual receiving the test results may wish to take them to their clinician for follow-up."[2] (warning) (doctor)

5 A member of the FDA panel noted that companies have a right to sell their products to the public, but the FDA has an obligation to compare the risks and benefits of these products, set product standards, and make sure information is understandable by the public. (responsability)

Response from a DTC Company: 23andMe

6 23andMe is a DTC company. According to the creators of the company, "23andMe was founded on the belief that individuals have a right to access their own genetic information, and this conviction is still as firmly held as ever," but 23andMe is assured that the FDA will take a "reasoned approach to integrating the feedback it received from the panel."[3] However, they hope that feedback will come from all involved parties, as 23andMe notes that the FDA panel had a panel member who represented the consumer and the patient, but they did not "hear directly from consumers and others who have first-hand experience with the information provided by direct-access genetic testing services."[3] 23andMe encourages consumers to make their voices heard about their experiences with DTC genetic testing. (belief)

7 In addition, DTC genetic testing companies like 23andMe use the genetic information of their customers to further our understanding of human genetics, if customers consent. In a study published in the scientific journal PLoS Genetics, 23andMe used customer data and web-based surveys to evaluate genetic variation in a number of common human genetic traits, such as hair color, eye color, and freckling.[4] This may not seem like a giant scientific breakthrough, but it makes an important contribution to our understanding of ***how*** we can conduct genetic research. Genetic studies often require a great deal of time and money to recruit study participants, perform genotyping, document phenotypes, and perform genetic analyses. The 23andMe approach offers a potentially powerful new way to conduct these types of studies with willing DTC genetic testing customers, using less time and at lower cost. (increase) (allow)

Challenges to Understanding Genetic Test Results

8 According to the American Medical Association (AMA), "[t]he results of genetic tests (whether DTC or ordered by a physician) can be challenging to interpret. A positive result does not necessarily indicate a clinical diagnosis. Often, a positive result indicates an increased risk for developing a disease or condition."[5] The AMA goes on to say that the same mutation in different people can mean different things, based on penetrance, environment, and other factors. "Also, since only a fraction of testable mutations are identified for genetically based diseases, a genetic test with a negative result is not indicative of the absence of disease risk." The AMA recommends that any patient undergoing genetic testing (DTC or otherwise), do so "under the guidance of a qualified health care provider."[5]

·understand

9 The American Society for Human Genetics (ASHG) noted in a report released in September 2007 that the federal government currently has limited oversight of the "analytic validity" of genetic tests (the ability of the test to correctly detect a particular genetic variant), and no oversight of the "clinical validity" of genetic tests (the ability of the test to correctly predict whether someone will develop a particular disease).[6] The ASHG recommends that all DTC genetic testing companies provide consumers with information about genetic testing accuracy, including the strength of the scientific evidence about genetic test results, and that the federal government improve regulation of DTC genetic testing companies, to ensure the accuracy of the information provided to consumers.

10 However, some are concerned that, without direct government oversight, the DTC genetic testing industry may not do a good job regulating themselves. The Government Accountability Office (GAO) testified in 2010 before the US House of Representatives about their 2006 investigation of DTC genetic testing companies. They obtained 10 genetic tests from four DTC genetic testing companies, using DNA from two donors, and compared the results.[7] According to the GAO report, "GAO's fictitious consumers received test results that are misleading and of little or no practical use." One fictitious donor received contradictory results from each of the companies: below average, average, and above-average risks of developing hypertension and prostate cancer. Many of the estimates of genetic disease risks are based on scientific studies, but often these studies contain too few African American or Asian participants to make meaningful conclusions about these groups. In addition, "follow-up consultations offered by three of the companies failed to provide the expert advice that the companies promised."7 There were also examples of deceptive marketing, in which two companies claimed that donor genetic information could be used to create personalized supplements to "repair damaged DNA" or cure disease, or predict which sports donors' children would do well in. Experts say these claims lack scientific evidence, and the GAO has referred all four of the companies "for appropriate action" to the FDA and the Federal Trade Commission (which regulates marketing of products).[7]

·"vitamins"

What Do Consumers Think about DTC Genetic Testing?

11 But is all of this concern really necessary? If these tests are truly for "educational and informational purposes only," do we really need government agencies to regulate them as they would regulate genetic tests in a doctor's office? What do patients think? Has anyone asked them? Two studies provide insights about what DTC genetic testing consumers think about these products.

12 A paper published in the *New England Journal of Medicine* in February 2011 describes preliminary results from the Scripps Genomic Health Initiative, which measures the psychological and behavioral effects of DTC genetic testing on subjects recruited from health and technology companies.[8] Study subjects purchased genetic tests using the Navigenics Health Compass (Navigenics is a DTC genetic testing provider) at a discounted price—$225 instead of $400 to $2,000. Researchers then followed the subjects for three months using web-based surveys to measure anxiety level, diet, exercise, whether the DTC genetic tests caused subjects any distress, and whether subjects used more medical screening tests after receiving their genetic test results.

·anxiety

13 What did these researchers find? About half of the study subjects said that they intended to use more medical screening tests after receiving their DTC genetic test results, and about half did not. There was no clear increase in anxiety level, dietary fat intake, and exercise behavior among these subjects—who were all in general good health at the beginning of the study. About 10% of the subjects said they discussed their test results with the Navigenics board-certified genetic counselor, and about 26% said they discussed their results with their doctor. In fact, most of the study subjects did not do anything different after obtaining their study results: they did not talk to their doctor, they did not change their diet or exercise, and they did not seem to be upset by any of their test results.

14 In another report published in *Health Economics* in 2010, researchers studied how much, if anything, people would be willing to pay for DTC genetic tests that predicted their risk of future diseases.9 The study included 1,463 people randomly chosen to participate through web-based surveys. They were asked about their willingness to pay for testing for Alzheimer's disease, arthritis, breast cancer, or prostate cancer, using tests that were "perfect" or "not perfectly accurate." Between 70-88% of study participants said they would pay for these genetic tests, with rates lower for Alzheimer's or "not perfectly accurate tests" and higher for prostate cancer or "perfect" tests, even if there were no direct impact on the person's medical treatment options.

15 The costs of DNA sequencing and analysis technologies continue to go down, making genetic testing available to more people at lower costs. Consumers, DTC genetic testing companies, and the US government will have to decide how best to move forward – balancing the rights of companies to sell their products, the rights of individuals to have access to their own genetic information through accurate and scientifically valid genetic testing, and the obligations of the federal government to protect its citizens.

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Appendix E – Initiative I466 – Pro/Con Genetically Modified Organism Political Advertisement

I-466 RUBRIC	Does Not Meet Standard—1/50%	Approaching Standard—2/70%	Meets Standard—3/85%	Exceeds Standard—4/95%	Well Exceeds Standard—5/100%
Participation (as determined by group members)—Individual grade	Group member participation is well below the group's expectations of the individual. There is little to no evidence that the group member contributed to the final product.	Group member participation is below what group expected of the individual. There is not clear evidence that the group member contributed consistently to the final product.	Group member participation is consistent with group expectations. Student's "voice" is present in the project, whether that be through artwork/visuals, script-writing, or audio/voice.	Group member is beyond the group's expectations. This group member participated in many facets of the production of the final product and consistently contributed to the final product—ENHANCING the final product.	Group member went well beyond the group's initial expectations. This group member's participation significantly added quality to the final product, HOWEVER, this group member was a team-player and did not push others out of their assigned roles.
Scientific Description—Group grade	Students do not adequately describe any part of the modification process. Scientific description is superficial and there is no evidence of knowledge of process of genetic modification. ***see sample video	Students brush the surface of how an organism is modified at the DNA level and how that change impacts the organism. Details are lacking. ***see example video	Students use evidence to show how an organism is modified at the DNA level and how that change impacts the final protein production of the genetically-engineered species. ***see example video	Same as level 3, but group includes a deeper explanation of the mechanism of change. ***description goes beyond that of the level 3 exemplar video	Group goes above and beyond in thoroughly explaining the process of modification. ***description goes well beyond that of the level 3 exemplar video
Evidence Provided to Support Pro/Con Statement	Evidence is not factual or is biased.	Slight deviations from factual evidence may be included, but none stray far from the truth. A source may contain some slight bias.	Evidence is factual/valid and can be traced back to an original source (at least 3 citations provided). Students evaluate the benefits, risks, costs, and alternatives of genetic engineering.	At least 4 sources of factual and reliable evidence are included to help support the claims of the commercial. In addition to level three, the group presents information specific to allergenicity, outcrossing, or gene transfer.*	Same source requirements as level four. The group presents information specific to TWO of the three - allergenicity, outcrossing, or gene transfer.*
Visuals—Group Grade	Visuals are lacking or are totally unrelated to the GMO assigned.	Models, diagrams and visuals are not specific to the GMO assigned. Visuals may be unclear or may not add to the overall project. Visuals may be superfluous and/or redundant.	Models, diagrams and other visuals chosen are appropriate to the SPECIFIC GMO assigned, visuals are clear, and easily read, visuals ADD to the overall project and are not superfluous.	Same as level 3, but visuals are specifically designed for this project—not simply taken off the internet and cut/pasted. Visuals show a level of planning and effort consistent with going beyond simple clip-art.	Same as level 4—amazing visuals, really clear, connections to the scientific concepts and is beyond the "typical" sophomore work. Your 1st semester selves would be shocked to see the amazing work you've done.
Production Quality and Communication—Group grade	Commercial is lacking many of the features consistent with level 3 work.	Commercial may be dull, difficult to hear, unprofessional in editing or quality. Final product is well-below the quality of video seen in a political campaign commercial.	Commercial is communicated in a way that is intriguing to the viewers and pleasing to watch. Voices are easily heard and understood, the final copy is professional with appropriate editing, and work is consistent with a political campaign commercial.	Same as level 3, but could include features such as subtitles, sound effects, other graphic/special effects to enhance and make the video more professional appearing (these added features should not be gimmicks)	Same as level 4—puts professional production to shame! Totally an achievable feat given our awesome video production classes here at school ☺

* See the World Health Organization's article on GMOs for more information on allergenicity, outcrossing, and gene transfer.

GMO Unit Challenge—Design and Produce a political campaign Infomercial either for or against the use of Genetically Modified Organisms in Washington State.
Length of Infomercial: 3-5 minutes, edited
Options for submission: 1) A PowerPoint Presentation with Embedded Voice Recording
2) A filmed video
All group members must participate in the creation of the final product. Necessary components include a definitive PRO/CON statement, visuals to explain concepts, and recording of student voices.

Initiative GMO (I-466)
This measure would require all enterprises manufacturing and using genetically engineered species to stop using them for all commercial and educational purposes within Washington State beginning in July 2015. This requirement would apply to all species of genetically-modified organisms including agricultural commodities, processed foods, seeds and seed stock, and all genetically engineered organisms used for educational purposes. The measure would authorize state enforcement and civil penalties, and allow private enforcement actions.
A YES vote for I-466 means that genetically-modified organisms will not be allowed within Washington State. A NO vote for I-466 means that genetically-modified organisms will continue to be allowed within Washington State.

Name: ___________________________________ Per: __________ Date: _________________

What is a genetically-modified organism (GMO)?

1) Why would you want to genetically engineer a crop like soybeans, for example? What kinds of traits could you give a crop that would be helpful in raising it? Where would these new traits come from?

2) How do you genetically engineer an organism?

3) Would you or your family members go out of your way to avoid buying and eating Genetically Modified (GM) foods at the grocery store? Why or why not?

4) Brainstorm a list of ideas as to why you think someone would be opposed to GMOs.

5) Brainstorm a list of ideas as to why you think someone would be for GMOs.

6) Is GM labeling currently required in the food industry?

7) How long have GM crops been around, do you imagine? How new/old is this technology?

Using the information from all three articles together, **draw** and **explain** how the GM salmon were produced. (You may discuss as a group, but each person must do this individually!) Be sure to include:

- The original salmon
- The GM salmon
- The genes used in the change
- How you think the genes were moved between organisms

Name: ____ Per:_________ Date: ____
Use the following animations and simulations to better understand the process of genetic engineering. Remember this is basically the same process for genetically engineering a crop or those AquAdvantage Salmon.
http://www.abpischools.org.uk/res/coResourceImport/modules/hormones/en-flash/geneticeng.cfm

1. What process is the animation above trying to model?
2. Why would it be helpful for bacteria to produce the medicine above?
3. What cuts the plasmid? Remind yourself in a few short sentences what those "things" do…
4. What creature did the new gene come from?
5. The plasmid is cultured (allowed to grow)—what is the result of growing those new bacteria that have been modified with a plasmid?

When watching the following animation, be sure that you can hear the descriptions! If you cannot hear the descriptions, the descriptions are written out at the bottom of the screen. The pause and reset animation features are very helpful!
http://www.instruction.greenriver.edu/mcvay/es204/es%20docs/animations/transgenic_plants.sw

1. What type of organism will receive the new trait?
2. What types of organisms can donate the new trait?
3. What is a plasmid?
4. Where are cuts made in order to insert the new trait into the plasmid?
5. Once the genetically modified plasmid is made, where must it first go?
6. How can you get the genetic information from the bacteria into a plant cell (2 ways)?
7. What do you think is special about *agrobacterium*? Why is it used to transfer the new genetic information?
8. "The transgenic cells are cultured to form plantlets." What do you think transgenic means?

http://www.pbs.org/wgbh/harvest/engineer/transgen.html

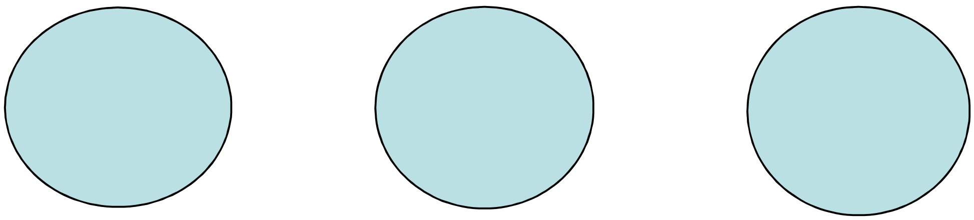
1. What is Bt? Why would it be useful in a commercially-grown crop?
2. What is a vector?
3. What is the 2nd gene included on the vector?
4. Why was *agrobacterium* chosen this time? Do you need to modify your answer in the section above?
5. Which grown medium did you choose, why? What do you imagine is different in the different types of growth medium?
6. Why do you spray herbicide on the plant cuttings?
7. When this is done in a lab, what form is the herbicide in?
8. How will you know that the gene was transferred?

Your mom or dad finds out that you are studying genetically-modified organisms at school. They tell you that they didn't vote for the recent initiative requiring labeling of genetically-modified foods because they didn't understand the science behind GMOs. Write your mom or dad a note below, explaining to them how a scientist might genetically modify a wheat plant so that it can produce its own form of pesticide.

pGLO Lab Handout Name:________________________

Data Collection – Day 1

- Make a drawing of the bacterial plates.
- Label whether any colonies glow green or not.



-pGlo, -AMP -pGlo, +AMP +pGlo, +AMP

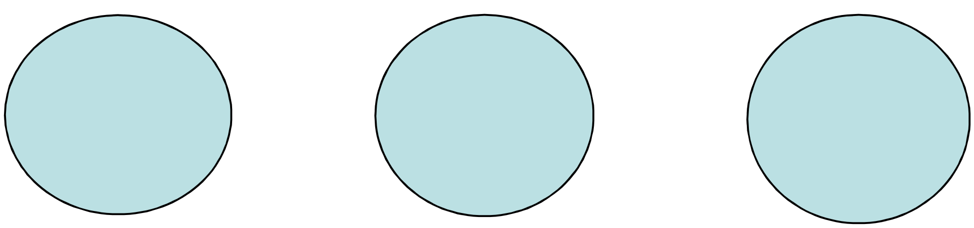
- Use the terms **nothing, colonies (spots), lawn (large covered area).**
- If possible, count the number of colonies on each plate.

Analysis questions

1. Which of the plates has bacteria most like the original non-transformed *E. coli* colonies that you started with? ***Explain your answer.***
2. Which plates should be compared to determine if any genetic transformation has occurred? Why?
3. We did not add the plasmid to half of the bacteria (-pGlo). How do you know that these bacteria are not resistant to ampicillin (antibiotics)?
4. We added plasmids to the other half (+pGlo). How do you know that these bacteria ***are*** *resistant to ampicillin?*

pGlo Lab Day 2

- Make a drawing of the bacterial plates.
- Label whether any colonies glow green or not.



-pGlo, -AMP -pGlo, +AMP +pGlo, +AMP

- Use the terms **nothing, colonies (spots), lawn (large covered area).**
- If possible, count the number of colonies on each plate.

Analysis questions

1. What changes do you see in your plates from day 1? (Be specific!)

   –pGlo, -AMP:

   –pGlo, +AMP:

   +pGlo, +AMP:

2. What *evidence* do you have that arabinose is required for green fluorescent protein (GFP) to fully function?

3. Overall, do you feel your transformation procedure was successful? Why or why not?

Bacterial transformation lab conclusion statements:
For each statement, explain what thinking allowed you to come to this conclusion. Cite evidence from the lab that supports this idea.

Statement 1: The antibiotic ampicillin kills most normal E. coli bacteria.

Statement 2: Only a small percentage of bacteria exposed to plasmid DNA take in the DNA during the heat shock procedure.

Statement 3: An organism's DNA influences the proteins it makes.

Statement 4: An organism's environment influences which proteins it makes.

Statement 5: One way organisms respond to their environment is by changing whether a protein is made or not. In other words, they respond to their environment by sometimes turning genes "on" and sometimes turning them "off."

How you think the genes were moved between organisms

Appendix F - Tool for tracking student participation

Student name	Student Contribution		Solicited or Unsolicited	Nature of the contribution		
	• EL student said/wrote • EL student did (action/gesture)	• EF student invite/include • EF student cover		Scientific Practice	Academic Practice	Personal
Notes						

Appendix G – Full set of surveys used for this dissertation

February 28, 2014							
	Ugh	**So-So**	**Ok**	**Good**	**Great**	**Super**	**Love**
The School							
Do you like school?							
Do you feel welcome here (in school)?							
Do you feel valued here (in school)?							
Do you want to do well in school?							
Do you expect to do well in school?							
Do your parents expect you to do well?							
What do you think it means to do well in school?							
The Class	**Not at all**	**Rarely**	**Some of the time**	**Yes**	**More or less**	**Almost always**	**Totally**
What is your favorite thing about this class?							
Do you like this class?							
Do you feel welcome here (in class)?							
Do you feel valued here (in class)?							
Do you expect to do well in this class?							
Do your parents expect you to do well?							
The Work							
Do you like science?							
Think back to the first day of school and the NASA activity:							
Who was in your group?							
Who had really good science ideas?							
Who contributes a lot during class?							
Do you ask for help when you're confused?	**Yup!** Who helps you out when you're confused with the work?				**Not really…** If not, why not?		

Working with others	**Not interest ed.**	**Check out my new phone…**	**What's going on?**	**I'm alright working with others**	**I hope I like this or this isn't going to be fun**	**Let's get to work!**	**Everyone wants to work with me!**
Do you like working with others?							
What makes **someone** a good group member?							
What makes **you** a good group member?							

What would **help** you to be a better group member?							
Working with Ms. Miller	**Not at all**	**Not really**	**A little**	**Yes**	**More or less**	**Almost always**	**Totally**
Do you think that Ms. Miller cares about you as a person?							
Do you think that Ms. Miller cares about you as a student/learner?							
What has Ms. Miller done to show you that she cares about you?							
Tell me one thing that Ms. Miller does that **helps you learn**?							
Tell me one thing that you would **change** about this class.							
What is your **favorite** thing about Ms. Miller?							
Have you seen Ms. Miller outside of Science class for help?	**Yes!**		**I've thought about going…**		**No.**		
How did it help?							
You							
Tell me about the best day you've had in science class this year: • What were you doing? • Who were you working with? • What kind of assignment was it? • Why was it awesome?							
Do you feel like you have something to contribute to this class?	**Yes!**		**I think so…**		**No.**		
Do you speak up when you have a question or idea?	**Yes!**		**Sometimes…**		**No.**		
Do you share your questions and ideas with **friends** one-on-one instead of with the whole class?	**Yes!**		**Sometimes…**		**No.**		
Do you share your questions and ideas with **small groups** instead of the whole class?							

March Survey about Ms. Bryant's use of Spanish in the classroom

Who are you? /¿Quién es? ____

Have you talked to Ms. Miller about science outside of class? About stuff other than science?

How do you feel about Ms. Miller speaking Spanish in class?

Do you talk to your classmates in a language other than English? ______________

How does that help you?

March 31, 2014 – English Learner Survey

	Never	Rarely	Sometimes	Often	Always
I am confident that I will do well on science tests.					
I am sure that I can do well on science tests.					
I am confident that I will do well on science labs & projects.					
I believe I can master science knowledge & skills.					
I believe I can earn an A in science.					
I am sure I can understand science.					

I wish Ms. Miller knew…

I wish other students knew…

I wish my group members would…

	Never	Rarely	Sometimes	Often	Always
Whether the science content is difficult or easy, I am sure that I can understand it.					
I am not confident about understanding difficult science concepts.					
I would put in more effort if I felt like Ms. Miller cared about me.					
When science activities are too difficult, I give up or just do the easy parts.					
During science activities, I prefer to ask other people for the answer rather than do the work for myself.					

Is it easier to work with other students who are learning English? Yes No Sometimes

Do you prefer to work with other students who are learning English? Yes No Sometimes

	Never	Rarely	Sometimes	Often	Always
When the science content is difficult, I don't try to learn it.					
When I find the science content difficult, I ask for help because I know that Ms. Miller will help me.					
No matter how much effort I put in, I can't learn science.					
I was comfortable preparing for the Socratic seminar					

Now that you have done the Socratic seminar, would you prepare differently for the next one?

Did you listen to the audiofile that Ms. Miller put on Edmodo? Yes No

My English-fluent classmates could help me by…

Question	Never	Rarely	Sometimes	Often	Always
Does Ms. Miller give you opportunities for cooperative learning?					
When have you learned something working with your classmates?					

This year's science class compared to previous science classes: Circle one

Far better **Better** **The same** **Worse** **Far worse**

Reason(s) why it:

Might be better… Circle all that apply!	Wasn't different…	Might be worse… Circle all that apply!
I like the course content more		I like the course content less
I come to tutorial		I should come to tutorial but I don't
I like the problems we have to solve		I don't like the problems we have to solve
I have a good relationship with Ms. Miller		I don't have a good relationship with Ms. Miller
My grades are more important to me this year		My grades aren't as important to me this year
I'm older and wiser		
I ask for help when I need it		I used to ask for help when I need it, but now I don't

March 31, 2014 – English Fluent Survey	Never	Rarely	Sometimes	Often	Always
I am confident that I will do well on science tests.					
I am sure that I can do well on science tests.					
I am confident that I will do well on science labs & projects.					
I believe I can master science knowledge & skills.					
I believe I can earn an A in science.					
I am sure I can understand science.					

I wish Ms. Miller knew…

I wish other students knew…

	Never	Rarely	Sometimes	Often	Always
Whether the science content is difficult or easy, I am sure that I can understand it.					
I am not confident about understanding difficult science concepts.					
I would put in more effort if I felt like Ms. Miller cared about me.					
When science activities are too difficult, I give up or just do the easy parts.					
During science activities, I prefer to ask other people for the answer rather than do the work for myself.					

How do you help classmates when they are confused?

	Never	Rarely	Sometimes	Often	Always
When I find the science content difficult, I do not try to learn it.					
When I find the science content difficult, I ask for help because I know that Ms. Miller will help me.					
No matter how much effort I put in, I can't learn science.					
I was comfortable preparing for the Socratic seminar					

Did you listen to the audiofile that Ms. Miller put on Edmodo? Yes No

How do you help classmates who are learning English?

When I have someone in my group who is learning English, I wish…

Question	Never	Rarely	Sometimes	Often	Always
Does Ms. Miller give you opportunities for cooperative learning?					
When have you learned something working with your classmates?					

This year's science class compared to previous science classes: Circle one

Far better **Better** **The same** **Worse** **Far worse**

Reason(s) why it:

Might be better… Circle all that apply!	It's not different	Might be worse… Circle all that apply!
I like the course content more		I like the course content less
I come to tutorial		I should come to tutorial but I don't
I like the problems we have to solve		I don't like the problems we have to solve
I have a good relationship with Ms. Miller		I don't have a good relationship with Ms. Miller
My grades are more important to me this year		My grades aren't as important to me this year
I'm older and wiser		I used to ask for help when I need it, but now I don't
I ask for help when I need it		

Final Survey – June 12, 2014

Some of these questions are new; some are repeats of earlier questions.

I think Ms. Miller cares about me as a person	Not at all	Not really	A little	Yes	More or less	Almost always	Totally
I think Ms. Miller cares about me as a student	Not at all	Not really	A little	Yes	More or less	Almost always	Totally
How does Ms. Miller show you that she cares about you?							
If you think that Ms. Miller doesn't care about you, does that bother you? What could/should she do differently in the future?							
What does Ms. Miller do to help you learn?							
What is your favorite thing about this class?							

Which unit has been your MOST favorite this year?
CSI Oral Rehydration Therapy Carbon Footprint Independent Research Project I466 Commercial Bacteria in the Water Project
I loved working on the…
Because…

On this project:

I was in control	Not at all	Not really	A little	Yes	More or less	Almost always	Totally
I felt it was important to me	Not at all	Not really	A little	Yes	More or less	Almost always	Totally
I felt it was important to science	Not at all	Not really	A little	Yes	More or less	Almost always	Totally
I learned a lot	Not at all	Not really	A little	Yes	More or less	Almost always	Totally
Anything to add?							

Which unit has been your LEAST favorite this year?
CSI Oral Rehydration Therapy Carbon Footprint Independent Research Project I466 Commercial Bacteria in the Water Project
I didn't like working on the…
Because…

On this project:

I was in control	Not at all	Not really	A little	Yes	More or less	Almost always	Totally
I felt it was important to me	Not at all	Not really	A little	Yes	More or less	Almost always	Totally
I felt it was important to science	Not at all	Not really	A little	Yes	More or less	Almost always	Totally
I learned a lot	Not at all	Not really	A little	Yes	More or less	Almost always	Totally
Anything to add?							

I wish Ms. Miller knew…	
I wish other students knew…	
Problem-based learning is…	
The best thing about working in a group is…	
The worst thing about working in a group is…	
My proudest moment in this class was when…	
I do my best work when…	

Thank you, thank you, thank you! Your input and feedback has been genuine and interesting and really important for helping us understand how kids are doing in class. You are awesome!

VITA

Known to her friends as Biz, Elizabeth went to thirteen schools in six different states before graduating from high school. She spent ten years working and traveling prior to attending college at Northern State University in Aberdeen, South Dakota. After earning her B.A. in Biology, she spent a year working for The El Paso Coalition for the Homeless as an AmeriCorps volunteer. She has volunteered for health clinics in Washington, D.C., Pierre, S.D., and El Paso, TX, and was the Health Services Director for a Head Start program in Massachusetts. Biz works hard at cultivating and maintaining her relationships with friends, family, and former students, and loves the Red Sox almost as much as she loves the people in her life, and considers herself lucky to have been at Fenway for Dave Roberts' stolen base. Biz is at home in the classroom working with students and teachers and looks forward to returning to the classroom as a teacher for Rainier Scholars during the summer of 2015 before embarking on the next – unknown – chapter.