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The effects of project-based learning on the academic and linguistic achievement of emergent bilingual learners: A mixed methods approach

Melinda Hardy
The University of Texas Rio Grande Valley

THE EFFECTS OF PROJECT-BASED LEARNING ON THE ACADEMIC AND LINGUISTIC ACHIEVEMENT OF EMERGENT BILINGUAL LEARNERS: A MIXED METHODS APPROACH

A Thesis

by

MELINDA HARDY

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COMMITTEE MEMBERS

Dr. Alma Rodriguez
Chair of Committee

Dr. Sandra Mercuri
Committee Member

Dr. Kip Austin Hinton
Committee Member

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ABSTRACT

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This mixed methods study examined the academic and linguistic impact of teaching emergent bilingual leaners through robotics project-based learning aligned to state standards. Two hundred ten middle school students attending a public charter school in the Rio Grande Valley in Texas participated in the study. Twenty percent of the students were emergent bilingual learners. Qualitative observation notes recorded students' learning process as they completed an adapted Khan Academy robotics project. The students also completed pre- and post-assessments that quantitatively measured academic and linguistic gains. Emergent bilingual learners grew 20.1% points in academic content and 28.6% points in language development ($p \leq 0.001$). Effect sizes for emergent bilingual learners' academic content growth (Cohen's $d = 1.39$) and linguistic growth (Cohen's $d = 1.35$) were greater than those of non-emergent bilingual students (0.89, 0.87). This study demonstrates that project-based learning can lead to significant academic and linguistic gains for emergent bilingual students.

DEDICATION

This research project would not have been possible without the enthusiasm and effort of the robotics teachers, the ingenuity and eagerness of the students, and the encouragement and love of my husband, Mike, and of my family. Thank you.

ACKNOWLEDGEMENTS

Deep gratitude goes to the chair of my committee, Dr. Alma Rodriguez, for her continual support and guidance. Her insights at several key crossroads in the project were invaluable. I left each meeting with her finding she had helped my thinking become clearer and more focused. Thanks also go to the members of my committee, Dr. Sandra Mercuri and Dr. Kip Austin Hinton. Their advice and feedback have elevated the quality of this work.

This research would not have been possible without the robotics designs of Karl Wendt, Khan Academy Projects Creator & Doctoral Fellow. Thanks go to him for the clarity and accessibility of his materials, as well as his insights shared through correspondence along the way. I also express my gratitude to the teachers who participated in the project, as well as my appreciation for their work in the intervening months to continue to refine and hone this robotics project for additional groups of budding engineers.

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INTRODUCTION

Emergent bilingual learners—students learning to speak an additional language, typically English—are the fastest growing subpopulation of public school students in the country (Calderón, Slavin, & Sánchez, 2011). Between 1993-2003, the number of emergent bilingual students doubled in half of US states, with nearly one third of states experiencing a threefold increase (Short & Fitzsimmons, 2007). By 2014, there were approximately 5 million emergent bilingual learners in the country, making up 10% of the student population (Ruiz Soto, Hooker, & Batalova, 2015). This trend is projected to continue. In 2025, up to one quarter of all students nationwide will be emergent bilingual students (National Education Association, 2008). Providing these students with high quality academic and linguistic instruction is among the most pressing challenges facing educators today.

Statement of the Problem

In the last two decades, school reform efforts, most notably the federal 2001 No Child Left Behind Act (NCLB), placed increased focus on closing long-standing achievement gaps for various groups of students, including the growing population of emergent bilingual learners. Despite this positive intention, NCLB's approach of using high-stakes testing in reading and math to incentivize school reform was largely ineffective in closing gaps between emergent bilingual learners and their (often white) monolingual peers (Nieto, 2010; Dillon, 2011; NCLB

Executive Summary, 2004; Education Research Center, 2011). Moreover, recent policy changes reflected in NCLB's successor, the 2015 Every Child Succeeds Act (ESSA), are unlikely to fully address these problems (Mitchell, 2016).

Comparing proficiency levels for English language learners (ELLs) or limited English proficient (LEP) students—two common classifications states use to identify emergent bilinguals—with those of non-ELL students during the NCLB period reveals a persistent disparity in achievement between these groups.[1] Only 4% of eighth grade ELLs nationwide scored at the proficient level on the reading section of the 2005 National Assessment for Educational Progress (NAEP); four years later in 2009, eight years after NCLB passed, that number had fallen to 3%, more than ten times lower than the passing rate of monolingual students (Short & Fitzsimmons, 2007; Education Research Center, 2011). Similarly, NAEP reading and math scores for 12th grade ELLs in 2015 showed growth stagnated over the previous decade (National Assessment of Educational Progress, 2016).

State level data also reflect similar trends: 78% of states did not meet federal NCLB goals for ELLs during the 2007-08 school year (Short & Fitzsimmons, 2007; Education Research Center, 2011). Unsurprisingly, most emergent bilingual leaners fail to achieve the test scores needed to exit the ELL category within six to seven years of US schooling; of those who do, only 20% typically measure at the proficient level in standardized testing, suggesting that academic gaps persist beyond the time period a student formally participates in a dual-language or English as a Second Language program (Short & Fitzsimmons, 2007; Californians Together, 2010).

This trend was also evident in Texas, where the state classifies nearly one in five students as ELLs. According to the 2012-13 Texas State Performance Report, the percentage of ELLs

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[1] See below for a discussion of the history and implications of these various terms. As I will discuss, the terms "ELL", "LEP," and "emergent bilingual learner" are not synonymous; for the sake of exactness in this section, I will use the testing agencies' own classifications for these students.

meeting the state standard fell below the state average by large margins in every tested elementary school subject, with passing rates lower by 21% points in reading, 14% points in writing and in mathematics, and 19% points in science. By high school, the gap between the state's overall passing rate and that of ELLs widened to 42% points in reading, 39% points in writing, 26% points in mathematics, and 30% points in science. At every grade level, ELLs performed lower in reading than special education students, economically disadvantaged students, and all racial or ethnic subpopulations (2012-2013 State Performance Report).

Given that passing state exams is a Texas high school graduation requirement, it is unsurprising that the ELL high school graduation rates also fell far below the state average, with only 59.1% of ELLs graduating within four years of entering high school—a graduation rate 17.8% points below the next lowest student subpopulation and 28.6% points below the state average (2012-2013 State Performance Report). ELLs nationwide were at a similarly high risk of dropping out of high school, and those immigrant language learners that do graduate are much more likely than their non-immigrant peers to struggle to succeed in college (Freeman, Freeman, & Mercuri, 2002; Kanno & Varghese, 2010).

Despite the vast investment of time and money provided by NCLB, emergent bilingual learners' standardized testing performance, high school graduation rates, and college success indicators persist at significantly lower levels than those of monolingual students. Researchers point to several causes for low academic achievement, many of which disproportionately affect emergent bilingual learners. As Gándara and Contreras (2010) point out, sociocultural factors such as living in poor, urban areas or having limited access to basic medical, dental, and vision care, and school factors such as overcrowding, tracking, and inexperienced teachers all directly impact educational attainment (Gándara & Contreras, 2010). The linguistic demands of learning academic content in another language—which emergent bilinguals often need seven to ten years to become fully proficient in—also play a significant role (Richard-Amato & Snow, 2005).

Another cause of low performance may have been NCLB itself. Despite the law's stated intention of closing the achievement gap for underperforming students, it has had unintended consequences as well. One of these is that schools struggling to meet annual yearly progress requirements often alter their curriculum to increase repetitious drilling and frequent benchmark testing (Gottlieb, 2006; Dooley & Assaf, 2009; Nieto, 2010). Reallocating instructional time from non-tested subjects like electives and—in some grades—science and social studies aims at increasing time spent on test-preparation, practice problems, and test-taking skills (Common Core, 2012; Cawelti, 2006; Menken, 2006). Most of the 1,001 public school teachers interviewed by the Common Core (2012) reported "narrowing" curriculum to favor a few subjects and testing strategies, and of the teachers who did so, 93% identified standardized testing as the primary reason for this instructional shift.

Unfortunately, emergent bilingual learners are disproportionately likely to attend underperforming schools using precisely these instructional styles, offering an explanation for why emergent bilinguals' test scores remain persistently low. By narrowing their curriculum in order to increase emergent bilingual students' test scores, the school assumes that *the best way to prepare students to do well on tests is to test more frequently*. This is directly at odds with research-based best-practices that demonstrate that bilingual students learn best from engaging, authentic, and rigorous curriculum (Gándara & Contreras, 2010; Californians Together, 2010; Freeman, Freeman & Mercuri, 2002).

The passage of ESSA in 2015, the largest overhaul of education policy since NCLB's passage, was an opportunity to reverse this test-focused trend in curriculum for emergent bilinguals. If anything, however, the focus on testing increased, with accountability mandates for emergent bilinguals moving from Title III, previously focused on ESL and bilingual programs, to Title I, the main program dealing with accountability for all student groups. Moreover, under ESSA emergent bilingual students' test scores will fully count in school accountability ratings by their third year in the country, despite research indicating emergent bilingual students need several years to become proficient in academic English (Mitchell, 2016). This creates the potential for comparably high, if not higher, stress and focus on preparing emergent bilinguals to pass exams as there was under NCLB. Although the law allocates more funding for ELL and bilingual programs (National Conference of State Legislatures, 2015), simply adding more money, without increasing capacity or improving curriculum, is unlikely to change the trend towards test-focused curricula seen in the NCLB era.

A teacher myself, I have seen examples of educators prioritizing this type of narrow, "test-prep" approach to instructing emergent bilingual learners. (Indeed, in a few cases, the examples are unfortunately from my own early teaching, when I was the sole teacher of a group of emergent bilinguals whose test outcomes the school depended on to meet state accountability measures.) It is possible that many educators feel, as I occasionally did, that they can *either* engage emergent bilinguals in engaging, hands-on learning experiences, *or* they can prepare them for the material tested on the state exam—but not both simultaneously. The research discussed above suggests that, in many cases, teachers and school leaders prioritize the latter outcome, and furthermore, that the decision is not paying off in higher achievement for emergent bilingual students.

As I continued teaching and also began my learning as a graduate student in bilingual education, I began to recognize this apparent dichotomy as a false one. I noticed that my students were often the most enthusiastic, hard-working, and successful when the content was interesting and relevant—characteristics not typically shared by the test-preparation material used by so many. At the same time, my graduate studies revealed a consensus among bilingual education researchers—discussed more fully in section two—that effective instruction for emergent bilingual learners differs greatly from the type of test-focused instruction they frequently experience.

In short, I began to see authentic, hands-on learning as instrumental in, not an impediment to, raising academic achievement for emergent bilinguals. One instructional model that follows this approach is project-based learning aligned to state standards (Mitchell, Foulger, Wetzel, & Rathkey, 2009; "Power Hour Shifts Focus," 2013). Project-based learning (PBL) challenges students to complete authentic performance tasks and promotes higher-order thinking and problem solving (*Project based learning,* 2003; The Conference Board, 2006). Significantly, these characteristics of PBL, along with others, are also related to attributes of effective bilingual instruction (Freeman & Freeman, 2007; Rea & Mercuri, 2006; Richard-Amato & Snow, 2005). Yet most studies about PBL focus on its impact on the learning outcomes of monolingual students; little research exists that examines to what extent PBL affects the academic and linguistic success of emergent bilingual learners, and no research that I found directly ties these results to questions assessed on state exams. Given the strong influence high-stakes testing imposes on how teachers and school leaders plan curriculum, this gap in the research is significant.

Purpose of the Study and Research Questions

The purpose of this study, then, is to explore how PBL affects the academic mastery and language development emergent bilingual learners, in this case Latino/a emergent bilingual students at a public charter school in the lower Rio Grande Valley where I worked. As I will describe further in section three, the school already had a growing focus on science, technology, engineering, and math (STEM) instruction. By adapting two middle school robotics projects to focus on the instructional needs of emergent bilingual students and aligning them to specific state standards, I was able to explore the following research questions:

1. What is the effect of robotics-based PBL on Latino/a emergent bilingual leaners' mastery of science and mathematics content objectives aligned to state standards?
2. What is the effect of robotics-based PBL on Latino/a emergent bilingual leaners' mastery of language objectives?
3. How does emergent bilingual students' mastery compare to that of their non-emergent bilingual peers who also engage in PBL?

Definitions of Terms

For the purposes of this study, the following definitions will apply:

1. Academic mastery: State assessments are the tools the state uses to measure students' mastery of academic concepts. At the campus in the proposed study, students also demonstrate mastery of academic objectives by passing with a 70% or higher the formative and interim assessments designed by the school district, campus, or individual teachers.
2. Content objectives: These are learning objectives aligned to state standards of required content knowledge. In Texas, content objectives are based on the state standards, the Texas Essential Knowledge and Skills for Science (2010) and for Mathematics (2012), and student mastery of the TEKS is measured annually by the State of Texas Assessments of Academic Readiness (STAAR) exams.

3. Emergent bilingual learners: Students in the process of gaining proficiency in another language in addition to the language (or languages) they already speak are emergent bilingual learners. As García, Kleifgen, and Felchi (2010) explain, this name recognizes as an asset the linguistic ability students already possess in their first language. My use of this particular term to describe students that the state would classify as ELLs or LEP students (see below) is intentional. My goal is to affirm the growing bilingualism the students are developing, recognizing that their language acquisition in an additional language benefits from and builds on existing proficiency in a first language (Campaign for Educational Equity, 2008). On the other hand, use of this term does not indicate that these students participate in a dual-language bilingual program. The students in this study receive all-English instruction in an ESL setting—which García and Sylvan (2011) still classify as a type of bilingual instruction inasmuch as its aim is to help students become bilingual by developing English proficiency.
4. English language learners (ELLs): According to the Texas Education Agency, an ELL is "a student whose primary language is other than English and whose English language skills are such that the student has difficulty performing ordinary classwork in English. The terms LEP and English language learners…are used interchangeably" (Texas Education Agency, 2012a). Starting in 2013, Texas changed the designation for these students from LEP to ELL on its statewide accountability reports (2012-2013 State Performance Report, 2013). While this more neutral phrasing reduces some of the stigma associated with the LEP label, it still places primary focus and importance on English (Campaign for Educational Equity, 2008). Because of this, I prefer and mainly use the term "emergent bilingual learner." Inasmuch as state testing reports use the term ELL,

however, I follow that naming convention when reporting assessment data or discussing state testing requirements.

In Texas, ELLs are identified through a home language survey given to students and their guardians. When they indicate that a language other than English is spoken at home, schools test the student's oral language and reading abilities. If a student scores below a threshold designated by the state, she is designated as a LEP/ELL student and participates in a bilingual or English as a second language (ESL) program. Her school continues to provide those services—and to count her state assessment data in the ELL subgroup whose progress is required to meet annual yearly progress under NCLB—until she meets the exit criteria designated by the state. For middle school students, including those who participated in this study, these criteria include passing the applicable state assessments in reading and writing (Texas Education Agency, 2012b).

5. Language development: ELL students' language proficiency is measured in the domains of reading, writing, speaking, and listening. The Texas English Language Proficiency Standards (TELPAS) exam involves rating each student in each domain as beginning, intermediate, advanced, or advanced high. Reading and writing are also assessed by STAAR exams.
6. Language objectives: These are linguistic teaching objectives aligned to state standards of required language proficiency skills for ELLs. Texas language objectives are based on the English Language Proficiency Standards (ELPS), and students' mastery of the ELPS is measured yearly by the TELPAS exam.

7. Latino/a: The state of Texas uses the term “Hispanic” as an NCLB/ESSA reporting category. I will use the term Latino/a, however, because it reflects more closely the Latin American roots of the students and teachers who participated in this study.
8. Limited English proficient (LEP): García, Kleifgen, and Felchi (2008) explain in their report for the Teacher’s College Campaign for Educational Equity that educators and policymakers use various terms to describe students who speak two or more languages. They go on to argue that the term “limited English proficient,” used in NCLB and by Texas until 2013 in its official state accountability reports, frames bilingualism as a deficit by using negative phrasing to describe these students (2012-2013 State Performance Report). Under NCLB, each state is required to develop its own definition of LEP students, identify them, and demonstrate that LEP students make yearly progress in academic and linguistic achievement (Campaign for Educational Equity, 2008).
9. Long-term English language learners (LTELLs): ELLs who have attended US schools for seven or more years without meeting the state exit criteria for the ESL or bilingual program are considered long term English language learners (Menken, Kleyn, & Chae, 2012).
10. M1s/M2s: NCLB mandated that states monitor the academic progress of ELLs after they are exited from a bilingual or ESL program. In Texas, these students are designated as “M1” and “M2” students, indicating if they are in their first or second year of monitoring. If M1 or M2 students fail to make academic progress, they may be reclassified as ELLs (Commissioner's Rules Concerning State Plan for Educating English Language Learners, §89.BB). Under ESSA, states can include former ELLs in the ELL testing subgroup for up

to four years, a move that may make it difficult to disaggregate the test results of current and former ELLs (Mitchell, 2016).

11. Non-emergent bilingual (NEB) students: The state of Texas uses no official classification to report test scores for all students who are *not* ELLs. While most students across the state who are not designated as ELLs are indeed monolingual, many non-ELL students participating in this study are in fact *former ELLs* who have exited bilingual or ESL programs (and the two subsequent years of monitoring) because the state now considers them proficient in English. Because of this, I will use the term "non-emergent bilingual" to describe non-ELL students (and "emergent bilinguals" to describe current ELLs).
12. Project-based learning (PBL): A student-centered style of teaching in which students' primary mode of learning is by doing. Generally speaking, PBL engages student learning through an "extended inquiry process structured around authentic questions and carefully designed products and tasks" (*Project based learning,* 2003).

Assumptions and Limitations of the Study

Given that the scope of this study examined the academic experience of Latino/a emergent bilingual students attending a public 6-12 charter school in South Texas, the applicability of the results is naturally most applicable to populations with similar demographics and locations. Furthermore, section three will explain that a handful of the lowest performing students, including a disproportionate share of emergent bilingual learners, were unable to participate in the study, a limitation that must be considered before generalizing results.

As a teacher and curriculum writer at the school in question, my influence on the curriculum and experience of the students is not completely separable from the data that I measured to analyze the effectiveness of the intervention. This participant-observer status has implications for the validity of the data gathered that will be discussed in greater detail in chapters four and five. Attempts to minimize these threats to validity included using objective criteria for measuring student outcomes and external review of the data gathered. Furthermore, because students participated in regular classroom instruction and tutorial programs in addition to PBL, measures to control for multiple treatment interference were needed (Patton, 2009).

Summary

NCLB has failed to achieve significant increases in educational attainment for emergent bilingual students. In some cases, the pressure of high-stakes testing itself has incentivized instructional choices that deprioritize or even omit the type of authentic, engaging learning is critical in increasing achievement for emergent bilinguals. This study focused on how standards-aligned project-based learning impacts the academic and linguistic achievement of emergent bilinguals. The next chapter will explore literature related to how and why PBL is a potentially powerful model for advancing student achievement, particularly for emergent bilinguals.

CHAPTER II

REVIEW OF LITERATURE

As chapter one introduced, the goal of my research study was to examine how participating in PBL affects emergent bilingual learners' mastery of content and language objectives. Understanding to what extent PBL has a positive impact on student learning can help educators better meet the needs of their linguistically diverse students who, as the last chapter outlined, often lag behind their peers in academic achievement. This chapter outlines research supporting the hypothesis that PBL is an effective curricular model for instructing emergent bilinguals, one that leads to academic and linguistic achievement.

Specifically, the following review of related literature provides background from theorists and practitioners regarding the critical elements of effective instruction for emergent bilingual learners. I then compare these criteria with those of PBL to explore the similarities and differences in the two approaches to instruction. The chapter concludes with a review of existing studies examining the academic impact of PBL on students' learning.

Theoretical Approach

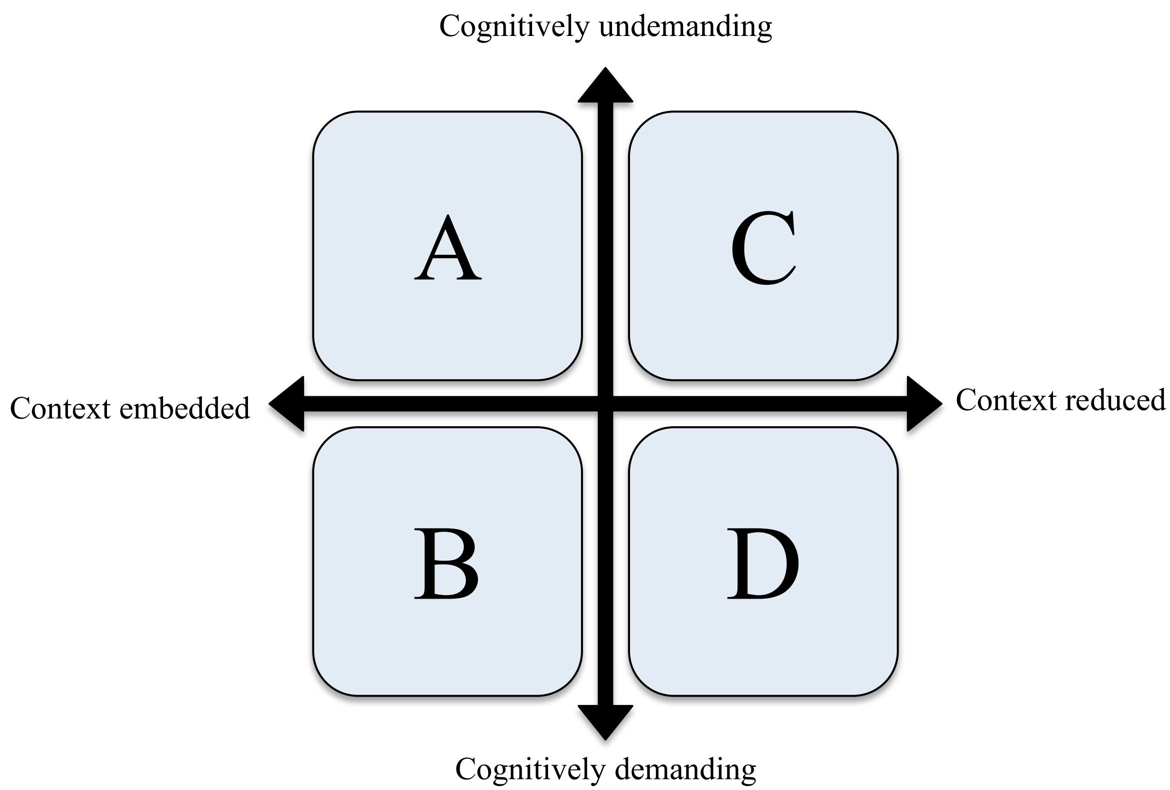
Various theories in language acquisition and content instruction for emergent bilinguals informed my approach in this study, including in particular the overlap between prominent language acquisition theories and the philosophy and pedagogy of PBL.

Characteristics of Effective Instruction for Emergent Bilingual Learners

Emergent bilingual learners need instruction that provides linguistic support and academic rigor (Baker, 2006; Richard-Amato & Snow, 2005). Linguistic support is critical because the grammar, vocabulary, and syntax of academic English are far more demanding than those used in social, informal English (Echevarría, Short, & Powers, 2006). Emergent bilinguals need lessons that provide explicit modeling and instruction in these language skills. At the same time, teachers should not mistake emergent bilingual students' language acquisition errors as an indication that those students are incapable of engaging deeply with rigorous content (Buxton, Salinas, Mahotiere, Lee & Secada, 2015). In fact, language learners do best when their teachers hold high academic expectations and provide linguistic support throughout the learning process.

Cummins (1981) conceptualized this with his four-quadrant framework that categorizes learning experiences based on the cognitive engagement they demand of students and the contextual support those students receive before and throughout the task (see Figure 1, below). Quadrant C represents simple learning tasks that are cognitively undemanding, doing little to push the critical thinking of emergent bilinguals; these result in low academic growth. Rigorous tasks that provide little contextual or linguistic support, categorized in Quadrant D, are also ineffective methods of teaching emergent bilinguals because they fail to provide students with the support they need to access the demanding content. Freeman and Freeman (2011) point out that standardized testing is an important example of this type of high-cognitive-demand/context-reduced activity. This is because such exams feature complex academic language and rigorous problems without providing support for students. Because of this, giving emergent bilingual students a task in Quadrant D may be an effective *assessment* of their learning, but it fails as a *teaching method* because it does not provide students scaffolded support, making it difficult for them to acquire greater content knowledge or language ability. (It is for this reason that curriculum focused on test preparation is often ineffective for emergent bilingual students.)

Figure 1: Cummins' Quadrants (adapted from Freeman & Freeman, 2011).



The best combination for emergent bilingual learners, Cummins argues, is cognitively demanding tasks that are embedded in a context or applicable situation that makes the content and academic language meaningful (Quadrant B). Krashen (1982) adds that the purpose of the learning task itself also plays a key role in student learning. His acquisition-learning and input or comprehension hypotheses posit that emergent bilingual learners best increase their language capability by engaging in relevant, meaningful tasks—rather than through traditional language learning tasks such as memorization, grammar lessons, and staged conversations. Rote tasks such as these do little to engage students in the type of authentic thinking and learning fostered in real-world situations. Accordingly, effective instruction finds ways to embed authentic learning experiences throughout the learning process. Ways to apply these theories include structuring teaching in thematic units to provide students a meaningful, relevant context for learning and designing writing tasks that mirror authentic, real-world situations (Freeman & Freeman, 2011; Duke, Purcell-Gates, Hall & Tower, 2006).

Sheltered Instruction: One Common Approach for Teaching Emergent Bilinguals

Sheltered instruction is a common instructional model used with emergent bilingual learners that combines high rigor with high support (in alignment with Cummins' theory). Its goal is to help emergent bilingual students master grade-level content in math, science, and social studies, and it does so by providing multiple types of linguistic support to help students access the content (Echevarría, Short, & Powers, 2006). Common types of linguist support include strategies such as the use of visuals, hands-on demonstrations, and concrete examples (Rea & Mercuri, 2006; Richard-Amato & Snow, 2005; Lee, 2003). Another type of support is allowing students to use their first language in class as a resource to draw on as they acquire a second language (Shamash, 1990, as cited in Kamwangamalu, 2010).

The Sheltered Instruction Observation Protocol (SIOP) Model is one of the best-known and most-studied sheltered instruction methods. Short, Echevarría, and Richards-Tutor (2011) explain that the SIOP model's approach of making academic content comprehensible by providing linguistic support for ELLs has proven an effective method of increasing emergent bilinguals' academic mastery and language acquisition. One reason for this is that content subjects like math and science are highly cognitively-demanding, and teachers of these subjects may not be aware of the complex linguistic demands associated with the content they teach (Gottlieb & Ernst-Slavit, 2013). If, for example, a science teacher does not provide linguistic support, it is unlikely that her emergent bilingual students will be able to fully access the information conveyed in the abstract, dense, and authoritative language register common to scientific texts (Fang, 2005). Similarly, math teachers need to recognize that successfully solving word problems requires not only the mathematical ability to set up and solve equations, but also the linguistic ability to understand long, complex sentences, to recognize shifting subject referrals, and to identify when the same pronoun is used to refer to different subjects (Gottlieb & Ernst-Slavit, 2013). One of the benefits of SIOP, then, is that it trains teachers in specific strategies that will empower them to support their emergent bilingual students.

Strategies for vocabulary instruction are particularly important in math and science. One way of providing this linguistic support is to introduce key academic terms in an authentic context and then give students opportunities to apply the terms (Gottlieb & Ernst-Slavit, 2013). It is particularly useful if that application includes hands-on, authentic opportunities for students to engage in the scientific process, allowing them to hear and use vocabulary terms in the same context in which they are used outside the classroom (Ellis, 2007, as cited in Echevarría, Richards-Tutor, Canges & Francis, 2011). This is an example of the type of high-rigor, high-support approach recommended by Cummins; in addition, by engaging learners in authentic scientific inquiry, it also provides the relevance Krashen recommends for effective learning activities.

Project-Based Learning: A Related Approach

Many of the above characteristics of effective instruction for emergent bilinguals are similar to those of PBL. For example, students learning through PBL engage in projects that address authentic, real-world problems that, if developed taking into consideration students' backgrounds, can provide them opportunities to draw on valuable funds of knowledge that exist in their households and communities (Moll, Amanti, Neff, & González, 1992). The students also do most of the thinking and learning, and collaboration is an essential part of that process (*Project based learning,* 2003). This provides them authentic opportunities to acquire language in realistic contexts, and their learning by nature will be context-embedded and rigorous (Bunch, Shaw & Geaney, 2010). The most effective PBL will combine this type of rigorous, hands-on learning with culturally sensitive content explicitly connected to students' prior knowledge, another key for engaging emergent bilinguals (Lee, 2003).

Because of these similarities, PBL is a potentially useful approach to instructing emergent bilingual students. It is important, however, to note and adjust for one aspect of PBL that presents a potential pitfall when used to instruct emergent bilingual students. The area of caution relates to the teacher's role during learning. Efstratia (2014) points out that effective PBL teachers often guide students by shifting much of the learning and thinking onto the students; after teacher provides the project and materials, she asks thought-provoking questions and allows students freedom to communicate and work collaboratively as they grapple with a challenging problem. While this approach can push students to engage in highly rigorous thinking, emergent bilingual learners may fail to thrive in this environment if they do not have enough initial support to be able to access key content and language material. As section three will outline, this distinction played a role in the development of the curriculum for this research study.

Empirical Studies

Because PBL somewhat aligns with the theoretical framework of effective instruction for emergent bilingual learners, it is next important to determine how PBL impacts the learning of emergent bilingual students. Little existing research addresses this question.

Whittier and Robinson (2007) are unique in the literature in investigating how PBL aligned to state standards impacted the learning of emergent bilingual students. In their study, 29 middle school emergent bilingual students in a SIOP-based science class learned about evolution by participating in a Lego robotics project. The specific evolution concepts were linked to state standards. During the project, students received explicit instruction in vocabulary, and they engaged in class discussion, peer discussion, supplemental reading, writing, and hands-on building. Overall, 23 of the 25 students who completed both the pre- and post- assessment improved, with an average gain of 15.4% points (from a mean score of 26.9% to 42.3%). The researchers also reported qualitatively that students gained greater comfort in and ability to use content-specific terms like “adaptation” and “niche specialization” during the course of the project.

While this was the only study I encountered that specifically linked emergent bilinguals’ learning during PBL with state standards, other studies addressed related topics. Campbell (2012) used a mixed methods approach to study a high school PBL unit for emergent bilingual and monolingual students. One impediment to student success was limited teacher ability to manage behavior expectations during the project. The researcher also identified a need to integrate direct content and language instruction within the project to support learners; the learners did, however, benefit from extended opportunities to engage in authentic conversations related to the project.

A study by Dresden and Lee (2007) also demonstrating the effectiveness of PBL aligned to state standards, although the students in the study were not emergent bilinguals. The researchers report that a first grade science PBL unit covered more state standards than a similar unit led by a teacher delivering traditional instruction. Additionally, the students in the PBL unit experienced important opportunities to use academic language in meaningful contexts. This study supports the premise that PBL can be an effective vehicle for delivering academic content, and suggests that language development—specifically vocabulary—can also fit in a PBL approach.

With regards to robotics specifically, existing studies show that robotics-based PBL engages students in authentic, meaningful tasks, which is an important characteristic of effective instruction for emergent bilinguals (Barak & Zadoc, 2009). Another study indicated that teaching through this type of curriculum provides emergent bilinguals with important opportunities for language development, while still another explained how PBL with robotics builds student investment (Mills, Chandra & Park, 2013; Pendergraft, Daugherty, & Rossetti, 2008). Altogether, this existing body of research, while limited, suggests that emergent bilinguals can effectively learn state standard-aligned content, including academic vocabulary, through PBL.

Summary of the Literature Review

Project-based learning is a compelling instructional model for emergent bilinguals because it overlaps with research-based practices recommended to help those students increase language and content mastery. This happens in part because PBL allows student to take the primary role in solving challenging, open-ended problems; existing studies indicate that students are highly engaged in and have increased academic mastery by participating in this type of learning. Empirical studies also indicate that linguistic support can be embedded successfully within this rigorous instructional model.

My study similarly examined emergent bilingual students' content mastery in PBL. It also addressed gaps in the research by measuring language development in addition to content mastery, and by exploring how the learning of emergent bilingual students in PBL compares to that of their peers who are not emergent bilinguals. Having now described the theory and empirical studies informing my approach to the project, in the next chapter I explain the planning, preparation, and scope and sequence of the research project itself.

CHAPTER III

DESIGN AND PROCEDURES OF THE STUDY

The purpose of this study was to analyze how robotics-based PBL for middle school emergent bilingual learners impacts their mastery of content and language objectives, and to compare this to the learning of non-emergent bilingual students. This section explains the study's methodology, including how I designed the study and how I functioned in my role as the researcher. It also explains the school context, the participants, and the creation of the project. I will also explain aspects of the methodology that impact the reliability of the findings.

Mixed Methods Study Design

My original plan for the study was to use an experimental design process to study the causal comparative impact of PBL on the quantitative learning growth of emergent bilingual students who participated in PBL and compare that to the growth of a control group of students. The school, however, only had enough instructors available to teach half of the students at one time. Because of this constraint, the second group of students could not study the same academic and linguistic content as the students participating in PBL, eliminating the possibility of a true control group that learned the same content via a method other than PBL. In addition, I realized that the study provided a strong opportunity to gather qualitative data in the form of observation notes. I began to see increasing value in using this information to inform my understanding of the research questions.

For these reasons, I revised my study to adopt a mixed methods approach. As Creswell (2015) explains, this approach allows for gathering both qualitative and quantitative data in order to analyze how each set of data connects to and informs the interpretation of the other. In my case, I gathered quantitative data through administering a pre- and post-test of academic and language mastery to the students who participated in PBL. This helped me answer the research questions regarding the impact of PBL on emergent bilingual and NEB students' content and language learning. This quantitative data carried importance in my study because it gives me the clearest objective measure of student learning. I also collected qualitative data throughout the project by recording observation notes during the robotics project. This data was equally important because it served a critical role in helping me see if the daily actions and conversations of students and teachers revealed important trends, reasons, or context to explain the results of the quantitative data. By gathering both at the same time, I was able to compare my results at the end of the study to determine how the two sets of data complement and provide context for the other.

More formally speaking, I used a convergent parallel design for the study, in which I gathered quantitative and qualitative data simultaneously throughout the project, analyzed the data, and then compared the results in order to examine convergence or divergence in the results. This model is represented below in Figure 2. The "+" indicates that the quantitative and qualitative data were gathered simultaneously, and the uppercase letters indicate that the quantitative data and qualitative data were equally weighted in the project (Creswell, 2015). Ideally, the advantage of having these two sources of data is that one can compensate for weakness or lack of nuance in the other (Creswell, 2015).

Figure 2: Mixed Methods Design

QUAN + QUAL

School Context

The students and teachers who participated in this study attended and worked at a public charter school in the Rio Grande Valley serving students in grades 6-12 during the 2013-14 academic school year; I also worked at the school as the academic interventionist. This area of South Texas has two of the country's poorest and least educated cities, and 89% of the students at this school that year were economically disadvantaged (Li, 2013; Dill, 2014; 2011-2012 Campus Performance Report). Additionally, 97% of the students at the school were Latino/a. As a school of choice, the charter school enrolled students based on a free lottery of applications submitted by parents and guardians. This creates selection bias and raises the possibility that the results of the study may not be generalizable to students enrolled in traditional school districts (Ni, 2012).

The school's practices around bilingualism had both drawbacks and benefits for emergent bilingual learners. Students identified as ELLs participated in an English as a second language (ESL) program. They attended the same all-English classes as non-emergent bilingual students. In theory, the teachers provided sheltered instruction strategies to help emergent bilinguals access content and language material; in practice, some teachers modified little to none of their instruction for emergent bilinguals. At the same time, many teachers and campus leaders were bilingual, and it was not uncommon to hear teachers and students mixing Spanish and English or conversing solely in Spanish, although this mainly happened outside of instructional time.

During partner work time in class, many teachers on the campus would allow their students to speak in Spanish or English according to their preference.

Because of the size of the student population, the school employed one teacher in each subject per grade level: for 6^{th} grade, there was one math teacher, one science teacher, one language arts teacher, and one humanities teacher. During the school day, students attended each of the four content classes, elective classes, and an academic intervention class. The intervention class ran simultaneously for all students in the grade so that the content teachers, special education and elective teachers, and the interventionist could dynamically group students by academic need and ability level in order to provide remediation and enrichment.

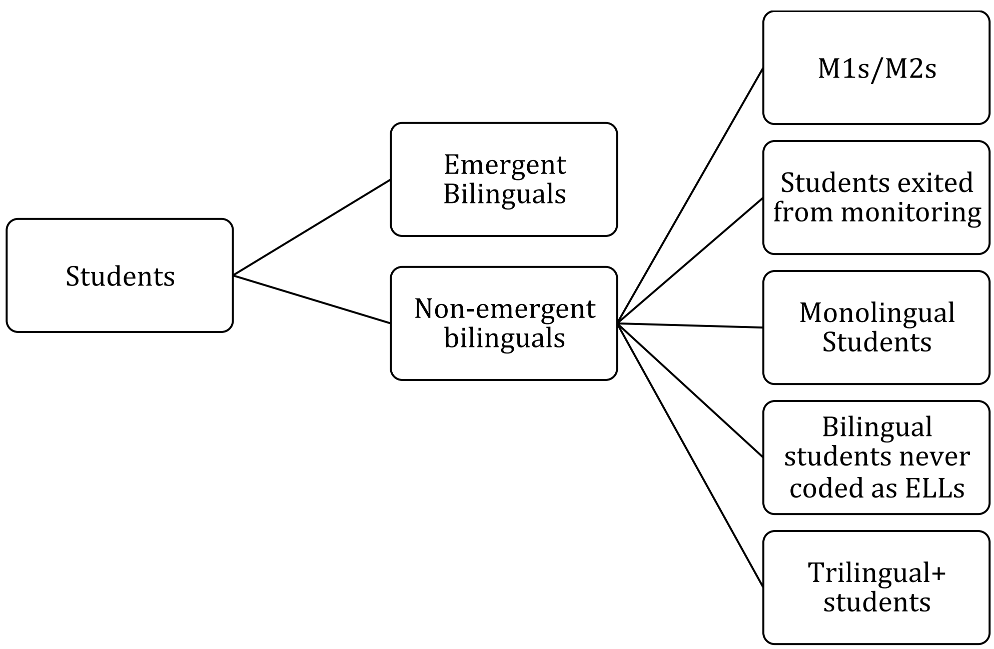
During the 2013-14 school year, the school was in the process of piloting a project-based learning program. Teachers led the projects, many of them STEM focused, during the academic intervention period. Part of the intention of the projects was to engage students in authentic, meaningful learning. Most students alternated between PBL and online adaptive learning software during the intervention period; a small number of students (roughly 10% of the student body), however, spent the academic intervention period in small group remediation with their teachers, and thus did not participate in PBL.

Participants

I faced several decisions as I selected participants for the project, the first of which was deciding which project to focus on. Because Latinos/as are underrepresented in STEM professions in this country—16% of the US population in 2010 was Hispanic, but only 8% of STEM degrees were awarded to Hispanics (White House initiative for educational excellence for Hispanics, n.d.)—I was particularly interested in investigating how robotics PBL impacted the learning of Latino/a emergent bilingual students. As the academic interventionist in charge of the project-based learning initiative, I knew that the initial project plan approved by the school included a LEGO robotics project for 6th graders during the first semester, and a Khan Academy robotics project for 8th graders during the second semester of the year. I selected the Khan Academy project as the more suited of the two robotics projects to study, due to the time that it fell during the school year and to the flexible nature of its design process.

I then identified the emergent bilingual and non-emergent bilingual students in 8th grade. As Figure 3 shows below, while the former category is quite clear, the latter category is actually comprised of many types of students. Students in their first and second year of monitoring after meeting the exit criteria for an ESL or bilingual program (M1s and M2s) were considered non-emergent bilinguals at the time of this study[2], as were former M1s/M2s.

Figure 3: Subtypes of Non-Emergent Bilingual Students



[2] ESSA now allows states to report scores from M1s and M2s as part of the emergent bilingual category.

The non-emergent bilingual group also combines students who have fully exited their ESL or bilingual programs by completing the two monitoring years—who could be considered potential "success stories" for ESL and bilingual programs[3]—with monolingual (and trilingual) students. This lack of clarity makes it difficult to fully disaggregate student results in the study, which is a limitation of this approach (one that I could remedy in future research by gathering additional demographic data through surveys).

After sorting through the complexity of the categorization, I found that there were too few 8th grade emergent bilinguals to provide a sufficient sample size for the study (Creswell, 2015). Accordingly, I considered which additional students I could invite to participate in order to increase the sample size. I selected the 6th grade students because they and their teachers had petitioned to complete another robotics project due to their positive experience first semester with the LEGO robotics project; that grade also had the highest number of emergent bilingual students on the campus.

Thus, the participants were convenience samples selected in order to coordinate this study with the existing school PBL plan (in the case of the 8th graders) and to provide a sufficient sample size (by adding the 6th grade students). The fact that the 6th grade teachers and students all had previous experience earlier in the year with LEGO robotics PBL also differentiates them from the 8th grade students. While these factors were constraints based on the school population and systems, they introduced an additional variable into the study, necessitating separate data analysis for each group in addition to combined analysis (Creswell, 2015). In contrast, although the grades selected were purposely identified, almost all 6th and 8th grade students enrolled at the school were invited to participate in the study, the only exceptions being 15 students in 6th grade

[3] On the other hand, these students may not be truly bilingual due to limited schooling to develop literacy in their first language. Likewise, the tests used to measure ESL and bilingual exit criteria may favor students who are successful test takers or may under-measure students' ability in speaking and listening.

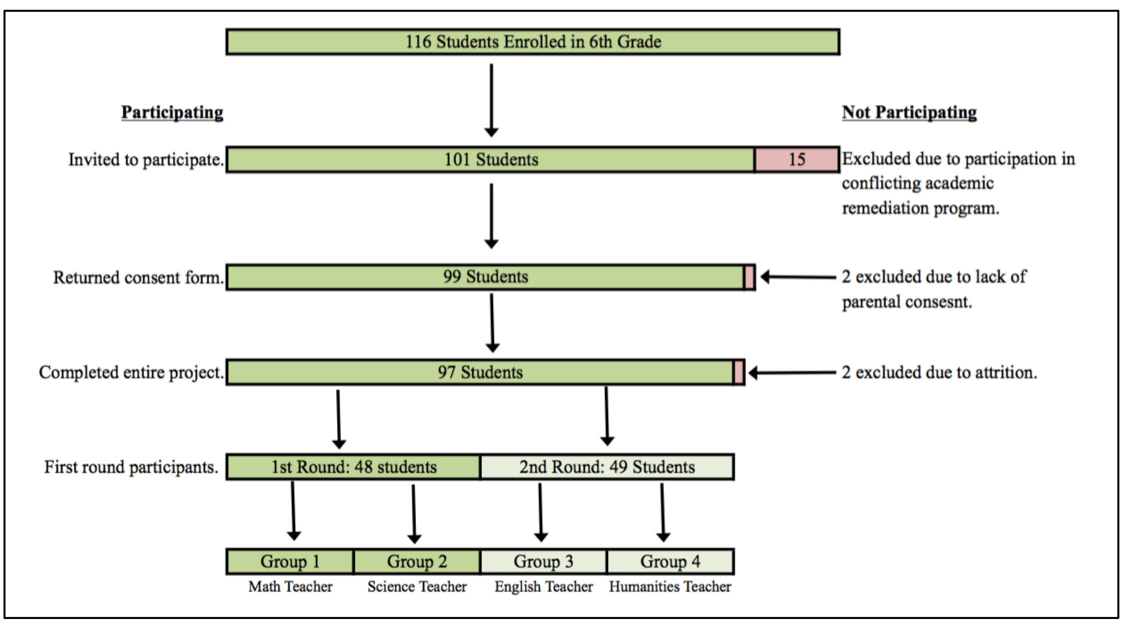
that attended the academic remediation classes offered only during the intervention block. (Campus leaders and teachers considered the remedial classes a higher priority than participating in PBL, and so those students did not participate in any PBL throughout the year.)

All other students in grades 6 and 8 received an explanation of the research study from me or from their math or science teacher, along with copies of the applicable IRB-approved informed assent and consent forms. Students who returned completed forms with parent or guardian permission were enrolled in the study. I also explained the purpose and implications of the study to each of the four teachers—two math teachers and two science teachers, one for each grade—who participated when giving them their informed consent form.

6th Grade Subjects

As depicted in Figure 4 below, 97 of 116 6th graders enrolled at the school (84%) participated in either the first or second round of the robotics project (rounds are explained more fully below).

Figure 4: Participation of 6th Grade Students in the Study



Of the 97 participating students, almost one third were emergent bilingual students, and an additional 15% were M1s/M2s. The remaining 54% were monolingual English speakers or now-bilingual students who had exited their schools' bilingual programs by the end of 4th grade. (Existing student data did not provide a way to differentiate between these two types of students.) Only two students were excluded from the sample due to parent refusal of permission or for non-return of the consent form. An additional two students were excluded from the study due to attrition, in this case failure to complete either the pre- or post-test (due to absences). In all, 3.4% of the potential sample was excluded for these reasons, suggesting that selection bias for these reasons is low.

As mentioned above, 15 of the 6th grade students were also excluded from the sample because of their prioritized need to attend academic remediation during the time allocated for PBL. The fact that 9 of 15 (60%) of these 15 students were ELLs—compared to 30% in the study sample—indicates that language learners were disproportionately likely to be identified as Tier 3 students. This disparity aligns with the statistics in chapter I regarding the gaps in performance between ELLs and non-ELL students. Nevertheless, the fact that the most struggling 23% of ELLs in 6th grade (9 of 39 students) were excluded from the sample must be taken into account before generalizing any results from the study.[4]

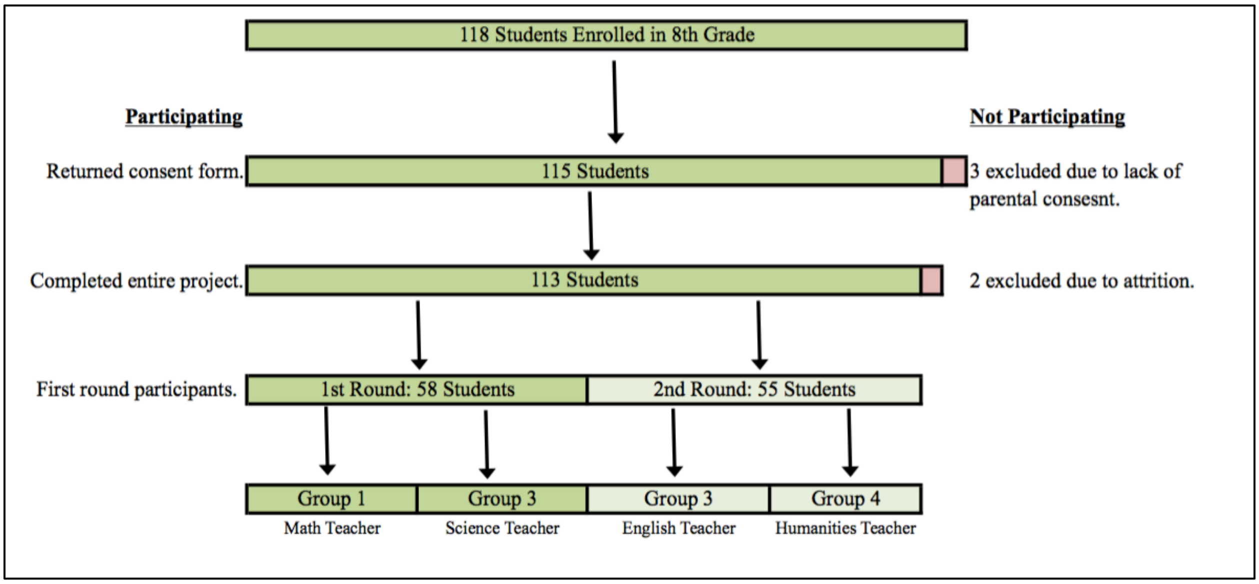
8th Grade Subjects

As shown in Figure 5 below, 96% of the 8th grade students participated in the study. Unlike the 6th grade, the 8th grade had no students scheduled to attend academic remediation at the same time of day as the robotics project (although this was largely due to an absence of additional teachers to help the 8th grade during their scheduled intervention time rather than a lack of struggling students in the grade). Only 4% of students were excluded from the sample for

[4] The 15 students in academic remediation also had a higher proportion of SPED students than the rest of the 6th grade cohort.

any reason, suggesting any effects of selection bias within the pool of potential student subjects is small. Overall, 30% of 6th graders and 10% of the 8th graders participating in the study were emergent bilingual learners[5]. Both the 6th and 8th grade emergent bilinguals had completed, on average, seven years of schooling in the United States.

Figure 5: Participation of 8th Grade Students in the Study



Teacher Subjects

The math teacher and science teacher from 6th grade and from 8th grade—four teachers in total—participated in the project (See Table 1 below). The two 6th grade teachers were

[5] The difference in percentage of emergent bilingual students in each grade appears to be due to more than the 8th graders having the benefit of two additional years of school. Comparing the number of ELLs in each cohort when they were in 6th grade reveals strong differences: the 2013-14 6th graders had 39 ELLs, and the 2011-12 6th graders (who became the 2013-14 8th graders) included only 16 ELLs.

Although this difference could be due to a variety of factors, from differences in elementary schools' application of exit criteria to demographic shifts in students applying to the charter school over time, one other potential cause is worth noting: The 2013-14 cohort of students had to pass the STAAR exam in grades 4 and 5 to exit a bilingual or ELL program, while the 2011-12 cohort took the less-rigorous TAKS (Texas Assessment of Knowledge and Skills) as 4th and 5th graders. The difference in the difficulty of the exams could account for the larger percentage of ELLs in the 2011-12 cohort being exited from language programs before arriving in 6th grade. Confirming this hypothesis is outside the scope of this study; however, exploring potential causes for the differences in the quantity of ELLs in the two grades of students is a reminder of how external mandates may affect the educational experiences of language learners for several years.

bilingual natives of the Rio Grande Valley who had several years of teaching experience, as well as one semester teaching a LEGO PBL unit earlier during the academic year. The two 8th grade teachers were monolingual English speakers from outside of Texas who entered teaching through an alternate certification program (via Teach for America). Both were in their first two years of teaching. They had also taught PBL the previous semester, though their projects focused on non-robotic engineering problems. While all four teachers were purposely selected because they were the only math and science teachers for these grades (these subjects being the most related to the content objectives of the PBL curriculum), I was also interested in examining differences in teaching style that may be related to the background of each teacher.

Table 1: Demographics of Teachers Participating in the Research Study

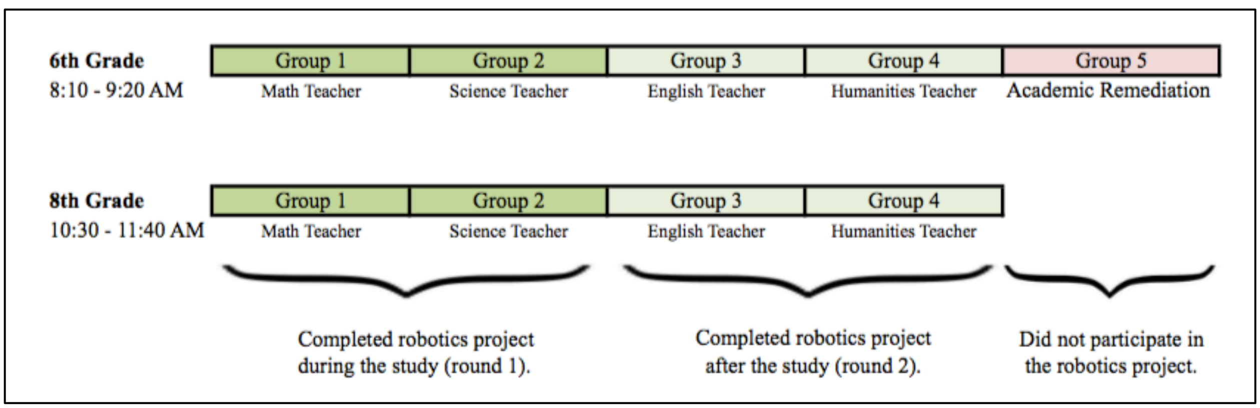
Grade/Subject	Years of Experience	Teacher Training	Ethnicity	Language
6th Math	4	University Degree	Latina	English/Spanish
6th Science	4	University Degree	Latina	English/Spanish
8th Math	1	TFA/Alternate Certification	Not Latina	English monolingual
8th Science	2	TFA/Alternate Certification	Not Latina	English monolingual

Having teachers with a wider range of experiences can provide more specific insights into elements of effective instruction and implementation. This was one of the primary reasons for including two grade levels of students and teachers in the study. The other major reason was the differences in numbers of ELL students in each grade; by adding one more grade level, I sought to increase the sample size to obtain more reliable outcomes. Comparing and contrasting the experiences of students in the two grades could also yield more nuanced conclusions.

Sorting Participating Students Into Groups

The math and the science teacher in each grade were capable of leading the robotics project. Because half of the students would be with the English and humanities teachers, however, only 50% of the participating students could complete the robotics project at a time (see figure 6, below). Because of this, I sorted students into "Round 1" and "Round 2" groups. Students in Round 1 completed the robotics project during the time frame of this study; during the academic intervention block, the Round 2 students worked on content-specific work with their English and humanities teachers. After the study was completed, the student groups switched, with the Round 2 students completing the robotics project (although their experiences and results are not included in this study due to the time constraints of the project). Each group met in their teacher's regular classroom. The 6th grade students met at 8:10 AM each morning—their regular intervention period—and the 8th grade students met during their intervention period at 10:30 AM.

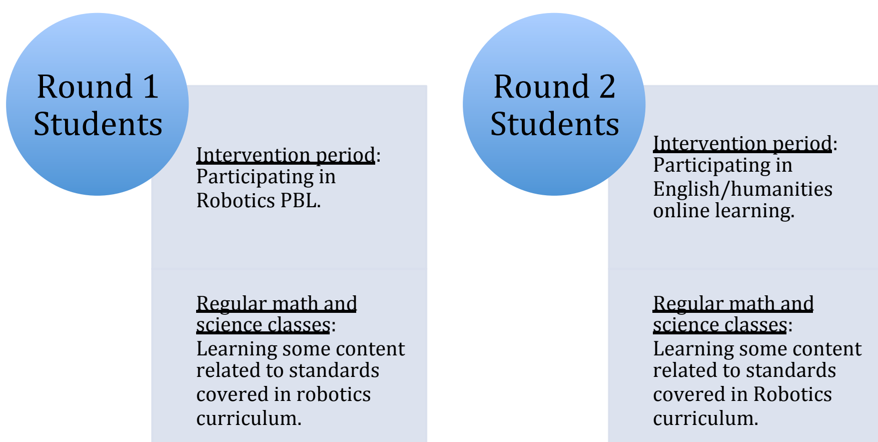
Figure 6: Student Groupings During the Project



To control for bias in students' group assignments, I stratified the participants into emergent bilinguals, M1s/M2s, and non-emergent bilingual students. I then used student ID numbers to blindly sort the students such that Groups 1-4 each had the same proportion of students at each linguistic level. I then showed the lists of names to the teachers for review. Based on their knowledge of students' behavior, the teachers swapped a few students from group 1 to group 2 (or group 3 to 4), making sure that the exchange left the overall proportions the same. The benefits of improving student behavior outweighed ensuring fully random assignment of groups, particularly in light of research showing that classroom management is a key factor impacting the success of project-based learning (Campbell, 2012).

Finally, although Round 2 students did not complete the robotics project until after the study concluded, they did participate in the study in one specific way. Specifically, they took the pre- and post-test assessments along with the Round 1 students so that I could compare the results of both groups. This served two purposes: first, by comparing the scores of the two student groups on the pre-assessment, I had an additional measure that the Round 1 and Round 2 groups had been sorted randomly at the beginning of the project. More importantly, however, the scores of the Round 2 group provided a comparison baseline to isolate growth from participating in PBL from growth that occurred due to attending regular math and science classes. This was particularly important because the math and science teachers were teaching some of the PBL objectives in their regular classes to both Round 1 and Round 2 students during the duration of the project, as Figure 7 depicts.

Figure 7: Curriculum for Round 1 and Round 2 Students



The Role of the Researcher

My own identity and experiences prior to the project influenced my approach to this study. Unlike the four teachers who participated in the study—who were either native Spanish speakers or monolingual English speakers—I am a native English speaker who learned Spanish in high school and college. I also taught in another school district in the Rio Grande Valley teaching high school recent immigrants and LTELLs in a sheltered English classroom, an ESL model not utilized at the school where I conducted my study. My time teaching those students, as well as my participation in the Master's in Bilingual Education program, provided me qualitatively different opportunities than the other instructors had.

During the study itself, I played several roles. When the study began, the students at the school knew me as a teacher who occasionally taught them in small-group instruction or academic intervention period. As the lead campus interventionist, the teachers saw me as both a colleague and a trainer who designed curriculum and offered support in academic intervention. While I did not directly evaluate teachers or grade students, I had established close relationships with the future participants in the study before it began.

As the study began, my role was to acquire and adjust the curriculum of the project, procure materials, and train the teachers. I also acted as a co-evaluator of student work during the pre- and post- assessments. During the robotics project itself, I was a participant observer: At some times I mainly recorded observation notes, and at other times I stepped in as a participant in the learning process, sharing my knowledge with individual students or, on certain occasions, the whole class as a second teacher in the room (Creswell, 2015). On two occasions, I filled in as the main instructor when the main teacher had to miss class.

This participant observer role had both benefits and drawbacks. Our interactions before the project began meant I had personal relationships with the teachers and some of the students. I also had background knowledge of the teaching style and ability of the teachers, which allowed me to better plan the curriculum and professional development for the teachers. My knowledge of the students' academic and linguistic abilities helped me to better plan the project itself. The drawbacks are also important to note. One drawback is that my role as a participant observer could affect the outcome of the study (Creswell, 2015). For example, because I gathered data during the study (by evaluating pre-assessment data and by gathering qualitative notes), my knowledge of this could have affected my interactions with students, thus biasing the results. Additionally, my relationships and influence with the participants before the study could have had implications on the power dynamics and roles we assumed during the project (Creswell, 2015). These factors are potential limitations of the study.

Sources of Data

The mixed methods approach of this research study led me to collect both quantitative and qualitative data.

Quantitative Data

The quantitative data I gathered helped answer my research questions about how PBL affects emergent bilingual students' academic and linguistic achievement. All student participants in the study completed a pretest and posttest to measure their academic and language mastery related to the content of the robotics project.

I designed the test to measure student mastery of academic content objectives with multiple choice and short answer questions aligned to math and science objectives for 6th and 8th grade (see Tables 2 and 3, below). I selected the state standards to include in the assessment by reviewing the TEKS for math and science for 6^{th} and 8^{th} grade. I then selected those standards that most naturally fit with the concepts in the robotics unit[6] and found existing test questions from publically available released state standardized tests for grades 5-11 in Texas, California,

Table 2: State Standards-Aligned Questions
on the Pre- and Post-Assessment for 6th Grade

Learning Domain	Objective	# of Questions	Question Type
Language	Academic Vocabulary	10	Matching
	Writing - Transitions and cohesive devices	1	Essay
Science & Math Content	Electricity and Circuits (gr. 5-11)	5	Multiple Choice
		2	Short answer
	Transformation of Energy (grade 8)	5	Multiple Choice
		1	Short answer
	Angles (grade 6)	5	Multiple Choice
		1	Open-ended
	Circumference and Area (grade 6)	5	Multiple Choice
		1	Open-ended

Table 3: State Standards-Aligned Questions
on the Pre- and Post-Assessment for 8th Grade

Learning Domain	Objective	# of Questions	Question Type
Language	Academic Vocabulary	10	Matching
	Writing - Transitions and cohesive devices	1	Essay
Science & Math Content	Electricity and Circuits (gr. 5-11)	5	Multiple Choice
		2	Short answer
	Transformation of Energy (grade 8)	5	Multiple Choice
		1	Short answer
	Motion (grade 8)	5	Multiple Choice
		1	Open-ended
	Graphing (grade 8)	5	Multiple Choice
		1	Open-ended

[6] One challenge was that some highly relevant concepts were not included in the state standards for middle school. For example, electricity is a basic component of the robotics project, but after 5th grade, this concept was not returned to until high school physics (typically taught in 10th or 11th grade). This relates to a larger pedagogical question of whether to teach science and mathematics objectives in an integrated manner or as discrete topics, and falls outside the scope of this study. It was one of many roadblocks that helped me understand why PBL presents instructional challenges for teachers (see chapters 4 and 5 for more discussion).

and New York (all large states with high populations of emergent bilingual students). Selecting existing questions from published state exams yielded questions of higher reliability than if I had written the questions. Because of some of the state standards for 6th and 8th grade aligned separately to the robotics project, some objectives covered on the two assessments were different.

Each set of multiple-choice questions for a content objective had a scaffolded order of questions. For example, the first two circuits and electricity questions are from 5th grade, and the last three are from high school physics exams. There were no questions from 6th-8th released tests because states standards do not cover those objectives during those years. I wrote the open-ended questions to test parts of student learning that would not be tested by the multiple choice questions, and created rubrics for grading them to enable multiple graders to evaluate responses consistently.

Because academic language is a key challenge for emergent bilinguals, the assessment measured students' mastery of key academic terms. These terms included what Marzano & Simms (as cited in Marzano Research Laboratory, 2013) call Tier 2 and Tier 3 terms. I selected ten Tier 2 words—general academic terms used in various subject areas—from their list that aligned well with the robotics project (including terms like "diagnose", "modify," and "orient"). Students were assessed with questions asking students to match words and definitions. There were also opportunities for students to write about Tier 3 terms—content-specific terms like "insulated wire," "resistor", and "soldering iron"—in open-ended questions. The writing questions' rubrics included specific strands of the Texas TELPAS proficiency level descriptors and the 7th grade STAAR Expository writing rubrics.

After I created the initial drafts of the assessments, the 6th and 8th grade teachers then gave feedback on the materials, leading to a few small changes. The final stage of testing the instruments consisted of administering the entire exam for a small group of 7th graders. This allowed a trial of the clarity of the instructions. The student responses were also used to norm the grading of the free responses among all raters.

Qualitative Data

While the quantitative data has primary weight in this mixed methods study, the qualitative data provides an important counterweight. Standardized assessments do not easily explain causes for why students do or do not master material. By gathering observation notes throughout the project, I hoped to glean information that would help me interpret the quantitative data. If the data converged, I would have a stronger result, and if the data diverged, I would have information to examine to understand why that occurred.

Process for Analyzing the Data

Table 4 displays the types of data gathered in this study as well as the method for analyzing each one. I used Stata's statistical software package to analyze the quantitative data, and I manually coded and analyzed the qualitative data in a Word document (StataCorp, 2014).

Table 4: Methods of Data Analysis

<table>
<tr><th>Type of Data</th><th>Method of Analysis</th></tr>
<tr><td colspan="2">Quantitative</td></tr>
<tr><td>Math/science content (multiple choice questions)</td><td rowspan="2">1. I created summed scores of each student's correct answers on questions assessing language or academic content for each the pre- and post-test (Creswell, 2015).
2. I generated descriptive statistics to identify differences in mean scores for different subgroups of students.
3. I then used a paired t-test to analyze the null hypothesis that there was no difference in pre- and post-test scores for students who participated in the study. The significance level was set to p = 0.01 (Creswell, 2015).
4. I also calculated effect size using Cohen's d to measure the practical significance of the results (Creswell, 2015).</td></tr>
<tr><td>Academic vocabulary (matching questions)</td></tr>
</table>

Qualitative	
Observation notes recorded during the robotics project.	1. I recorded typed observation notes as I observed the project. 2. After the project was completed, I conducted a preliminary exploratory analysis by rereading all the notes (Creswell, 2015). 3. As I read the text twice more, I created 11 codes. By continued re-reading and honing in on the codes that most related to my research questions, I arrived at five themes (Creswell, 2015).

Preparing the Project

After creating the instruments to measure student learning, I acquired, adjusted, and added to the curriculum. This section describes that process in greater detail.

Preparing the Project Materials

My school principal had previously contacted Karl C. Wendt, the designer of the online, free instructions from Khan Academy for the Spout Bot robotics project (Robots, 2013). Based on his recommendation, I explored the material online, built the robot myself, and studied the 6th and 8th grade math and science TEKS to determine the suitability of the project. Mr. Wendt, an ED.L.D. candidate at the Harvard Graduate School of Education, provided feedback on my plans for adapting the curriculum to meet the needs of students' at my school (2014).

The online curriculum consisted of a few lists of parts and several demonstration videos showing how to build the robot. My work in adapting the curriculum was extensive, and the process was informed by the constraints and goals. One constraint was that the teachers and I decided it would be difficult for all the students in the same room at the same time to individually watch the videos and construct the robots due to the noise level this would create. Also, there were sometimes internet-connectivity problems at the school that could hinder this approach's efficacy. The videos themselves were also long, and we estimated that the project would take longer if we used video frequently. Instead, I created a student manual of the steps to build the robot. I used pictures I took, labels, and text to more concisely convey the information.

I integrated multiple instances of the academic vocabulary and transition words students studied in the unit so that they could see these academic terms in context, with key terms color coded to help students notice them.

I also created handouts for teachers to use during the project. Each day began with a few minutes of supportive learning activities like building investment in the project, outlining the projects' goals, pre-teaching or practicing vocabulary, supplemental reading, solving problems, and writing. The remainder of each day was designated for hands-on building of the robot.

I designed the project for students to work in groups of four. Each student in the group had a specific role, and students collaboratively set roles in their group on the first day working on the robotics project. The roles were:

- Language leader: This student was responsible for knowing all the academic vocabulary terms and quizzing other students in the group on the terms. They also could encourage group members to use the terms in context as they were working on the project.
- Communication coach: This student was responsible for editing and giving peer feedback on the use of transitions during writing assignments.
- Science specialist: This student gave assistance and feedback when students worked on the science content objectives of the project.
- Technical teacher: This student mastered the use of all the tools for building the robot, including the soldering iron.

Following this work, I also designed the challenge projects that students completed at the end of each robotics project.

Other Preparation

Additional pre-work activities included creating the informed consent forms for students, parents, and teachers and applying for IRB approval. School district approval for the project was also granted. Teachers explained and distributed the consent forms, and together we followed up until there was a response rate of 99% for 6th grade and 98% for 8th grade. I purchased supplies with campus funding, assembled the kits and tools, and created the student groups by blindly sorting students into the first or second robotics groups by student ID number. (The teachers then gave feedback on the ability of students in the groups to work well together, resulting in one or two students being moved from one classroom to the other classroom.) The teachers and I then met to build the robot together. This hands-on learning took a few hours as teachers learned the methods of soldering the wires and constructing the robot and served as a primary method of training the teachers in the curriculum.

Scope and Sequence of the Project

The curriculum was designed to extend to 4 class periods a week for four weeks, a total of 16 days of instruction. Adding two days each for pre-assessment and for post-assessment brings the total to 20 days overall. The basic curriculum outline was as follows:

- Days 1-2: Pre-assessment.
- Day 3: Investment, goal setting, review of how students will be assessed, moving to work in groups to learn vocabulary and science concepts collaboratively, hands-on exploration of the robotics materials.
- Day 4: Soldering safety video, writing project, and hands-on practice.
- Days 5-6: Continuation of soldering safety practice, open-ended exploration of how to use the robotics materials to meet several small challenges (e.g., light up an LED).
- Days 6-14:

- First 10-15 minutes of class – explanation and practice of content information, vocabulary terms (mixture of whole class instruction and group members teaching each other). This practice is aligned to the post-assessment.
- Remainder of class: begin using the robotics manual to build the robot in partners. Students practice using academic language in context as they talk and build their robot.
- One extended writing assignment explaining the transformation of energy as it flows through the circuit. Students peer edit and revise their writing. This assessment is aligned to the post-assessment.

- Days 15-18: Flex days to complete robot and robotics challenges aligned to objectives for angles, area, and circumference (6^{th} grade) and motion and graphing (8^{th} grade). Awards given for best robots, teamwork, creativity, and problem solving.
- Days 19-20: Post-assessment.

Summary

Overall, this project involved extensive planning, preparation, and adjustment during the execution phase. This section outlined anticipated and unanticipated challenges that arose, and also discussed several factors that curtail the generalizability or imputation of causality of the findings. The next stage of the project was to score and tabulate the results, and to integrate those answers with the qualitative data. The next section will present these results.

CHAPTER IV

RESULTS OF THE STUDY

This chapter discusses the results of the study. I will address the first two research questions—how PBL affects emergent bilinguals' mastery of content and language objectives—in order, sharing the quantitative and qualitative data supporting each answer. As I do so, I will also discuss the third research question by noting any differences between the performance of emergent bilinguals and non-emergent bilinguals. I will explain cases when the quantitative and qualitative data converge or diverge, and the implications of this. I will then close the chapter by explaining challenges and unanticipated findings I encountered during the project.

Summary of the Execution of the Project

The study began with students taking the pre-assessment during the academic intervention class the week prior to starting the robotics project. Teachers administered it over two days: one for multiple-choice and one for open-ended responses. I scored the multiple-choice questions and recorded them in a spreadsheet. To prepare to rate the open-ended questions, the teachers and I together rated several open-ended response questions from the 7th grade pilot of the assessment in order to norm our grading. For the actual scoring of 6th and 8th grade open-ended questions, I graded each answer, as did one of the math or science teachers. Because of the amount of time to grade the open-ended responses, teachers graded them over the next weeks as the project was carried out. These scores were stored in a spreadsheet on a password-protected computer.

Students spent the majority of the time in the project actually building the robot, following the process outlined in detail in the manual I created. The steps led students to assemble a working robot from off-the-shelf parts such as insulated copper wire, motors, resistors, batteries, hot glue, paper clips, switches, and LEDs. The students learned to use hand tools like nipper pliers and wire strippers, as well as a glue gun and a soldering iron. When students correctly wired and soldered the circuitry, the robot moved forward when switched on and in reverse when it hit a barrier. After completing the robot "challenges" at the end of the project, students were allowed to take their robots home. They finished the project by taking the post-assessment, and I followed the same process for grading and recording scores.

Research Question 1: Mastery of Content Objectives

My first research question was "What is the effect of robotics-based PBL on Latino/a emergent bilingual leaners' mastery of science and mathematics content objectives aligned to state standards?" I collected quantitative data to answer this question from pre- and post-test scores as well as qualitative data collected while observing the project.

Quantitative Data

Table 5 below shows the results of analyzing the quantitative data collected from the pre- and post-tests given to 6^{th} grade students. The emergent bilingual students' average score on the pre-test was 36.6%, and by the post-test their score increased to 55.0%, a difference of 18.4% points. A paired t-test showed that this difference is significant at the .001 level. M1s/M2s grew 21.2%, and non-emergent bilingual students increased by 15.4% points. Round 2 students, on the other hand, increased by 5.7% points, a difference not statistically different from their pre-assessment score, suggesting that the gains for students in PBL can be attributed to their participation in the robotics project.

Table 5: Average Scores and Growth on Content Objectives for 6th Graders

	Content Objectives: Math and Science		Difference
	Pre-test	Post-test	Post - Pre
Emergent Bilinguals N = 15	36.6% (13.3)	55.0% (17.0)	18.4%**
M1s/M2s N = 8	49.4% (15.5)	70.6% (15.5)	21.2%**
Non-Emergent Bilinguals N = 25	43.0% (14.2)	58.4% (19.2)	15.4%**
Round 2 students N = 49	*43.2% (15.2)*	*48.9 (18.2)*	*5.7%*

** $p \leq 0.001$

8th grade emergent bilingual students also grew from the pre- to post-test, as shown below in Table 6: the initial average score was 33.3% (actually lower than the 6th grade students' scores), and they grew to 57.8%, a difference of 24.5% points ($p \leq 0.01$). In terms of academic mastery, both populations of emergent bilingual learners made statistically significant gains, with 8th graders making slightly more growth than 6th graders.

Table 6: Average Scores and Growth on Content Objectives for 8th Graders

	Content Objectives: Math and Science		Difference
	Pre-test	Post-test	Post - Pre
Emergent Bilinguals N = 6	33.3% (4.6)	57.8% (12.0)	24.5%*
Non-Emergent Bilinguals N = 52	48.0% (14.3)	62.0% (18.0)	14.0%**
Round 2 students N = 55	*46.2% (16.9)*	*45.9% (17.0)*	*-0.3%*

* *$p \leq 0.01$*
** $p \leq 0.001$

Table 7 shows the combined outcomes for students in both grades. While emergent bilingual students, M1s/M2s, and non-emergent bilingual students all showed statistically significant growth, the Round 2 students did not, supporting the hypothesis that participation in PBL increased students' academic mastery. The effect sizes for emergent bilingual students

(1.39) and M1s and M2s (1.38) were large; while the effect size for non-emergent bilinguals (0.89) was lower, it still indicated nearly one standard deviation of growth (Creswell, 2015).

Table 7: Average Scores and Growth on Content Objectives for 6^{th} and 8^{th} Students

	Content Objectives: Math and Science		Difference	Effect Size: Cohen's d
	Pre-test	Post-test	Post - Pre	Post - Pre
Emergent Bilinguals N = 21	35.7% (13.4)	55.8% (15.4)	20.1%**	1.39 95% Conf. Interval: .71 – 2.06
M1s/M2s N = 8	49.4% (15.5)	70.6% (15.5)	21.2%**	1.38 95% Conf. Interval: .25 – 2.46
Non-Emergent Bilinguals N = 77	46.2% (14.4)	60.8% (18.2)	14.6%**	0.89 95% Conf. Interval: .56 – 1.22
Round 2 students N = 104	*44.8% (16.1)*	*47.3% (17.6)*	*2.5%*	*0.15 95% Conf. Interval: -.12 – .42*

** $p \leq 0.001$
** $p \leq 0.001$

Research question three asked how the growth of emergent bilingual students in PBL compared to that of non-emergent bilingual students. Comparing the scores of different student groups' mastery growth on academic content objectives shows that in both grades, emergent bilingual students made more absolute growth than non-emergent bilingual students. The 6^{th} grade emergent bilinguals grew 18.4% compared to NEB students growing 15.4%. For 8^{th} graders, the difference was greater, with a growth in average score for emergent bilinguals of 24.5% compared to 14.0% for their peers. For both groups this growth was mainly from the robotics PBL, because the change in average scores for Round 2 students (who were not participating in the robotics project during the study) was not statistically significant.

Interestingly, the 6^{th} grade group that grew the most was the M1s and M2s, with a 21.2% difference. This may be because the exit requirements for students in this cohort included the more rigorous STAAR exam, as compared to the easier TAKS exam Texas previously used

(Texas Education Agency, 2012b). It is possible that this rigorous standard acted as a gatekeeper, only allowing the most capable emergent bilinguals to formally exit their ESL or bilingual programs. These students may also be better test takers than the students who did not exit the program. Both of these factors create potential for a non-random sample of students in the M1/M2 category, thus accounting for the higher growth these students experienced.

Qualitative Data

Analyzing the observation notes revealed that emergent bilingual students used *Spanish as a bridge to access academic content*. Students held frequent conversations that mixed Spanish and English. Teachers allowed students to use whichever language they were most comfortable in as they spoke with their peers, and this often led to greater understanding of the content. For example, one 8^{th} grade emergent bilingual student was struggling to solve math equations involving Ohm's law, which states the relationship of voltage, currency, and resistance in a circuit. The teacher had explained the problem in English; it was when a bilingual classmate explained the problem to him in Spanish, however, that he quickly solved the problem and said that the problem was "easy."

This was not the only situation in which *Spanish became a bridge*, rather than a barrier, to making meaning. Some students also used Spanish in situations that required quick responses, such as when they urgently cautioned each other at the soldering station to avoid burns. They instinctively turned to their more familiar language to convey important messages. Still others had 'Spanglish' conversations mixing English and Spanish. For example, one student at the soldering iron made a comment about how hot it was in Spanish; his teammate understood the comment in Spanish, and replied in English, saying, "What did you expect? It's like 824 degrees," referring back to the safety lesson that cited the temperature of the tool. In this case, the students mutually understood each other even though each made a decision to speak different languages.

Students also made intuitive leaps to generate technical Spanish terms to describe new ideas they were learning. For example, one student referred to electrical resistors using the Spanish pronunciation of the word, despite not hearing the word pronounced in Spanish in class. Another student explained to his partner in Spanish why the robot was not working, using the cognate *descontectar* for the English word 'disconnect' to describe the problem with the wires.

At other times, students employed code switching mid-sentence as they worked on their project. For example, one student referred to learning "*mucho* knowledge" during the projected. The student also brought Spanish phrases into his discussion, such as when he described how parts of the robot "[stick] together, or *algo así.*" He also felt comfortable being playful in his combination of Spanish and English, such as when he light-heartedly accused a peer of what he termed "*cheat-eando.*" In short, students felt comfortable using both Spanish and English to communicate ideas large and small throughout the project.

Convergence in the Data

The theme from the qualitative data that students used Spanish as a bridge to accessing academic content aligns with the finding from the quantitative data that emergent bilinguals made statistically significant growth in academic content mastery from the pre- to the post-test. It is possible that using *Spanish as a bridge to academic content* enabled certain students to learn more quickly or more comfortably by integrating their knowledge of Spanish and their growing knowledge of English. Although establishing a direct causal link is not possible, the agreement between the two sources of data provides for a more robust answer.

Research Question 2: Mastery of Language Objectives

My second research question asked, “What is the effect of robotics-based PBL on Latino/a emergent bilingual leaners’ mastery of language objectives?” Unlike the previous question, the answer to this proved quite different for the 6th and 8th grade emergent bilingual students. Because of this, the qualitative notes proved useful in providing context to help interpret the different outcomes.

Quantitative Data

As table 8 shows below, 6th grade emergent bilinguals grew over 150% from the pre- to the post-test. They more than doubled their average score as they increased their overall average from 22.7% to 58.0%, a difference of 35.3% points ($p \leq 0.001$). The emergent bilingual students had a lower average score on the language questions than the content questions (22.7% average score for language questions vs. 36.6% for content objectives), but by the post-assessment, that differential was reversed, with average scores for language increasing to 58.0% (versus 55.0% for content questions). Notably, the emergent bilingual students grew slightly more than the non-emergent bilingual students did (35.3 percentage points versus 34.0 percentage points), and the

Table 8: Average Scores and Growth on Language Objectives for 6th Graders

	Language Objectives: Academic Vocabulary		Difference
	Pre-test	Post-test	Post - Pre
Emergent Bilinguals N = 15	22.7% (20.1)	58.0% (23.1)	35.3%**
M1s/M2s N = 8	26.3% (19.2)	77.5% (20.5)	51.2%*
Non-Emergent Bilinguals (NEBs) N = 25	29.6% (19.7)	63.6% (29.4)	34.0%**
Round 2 students N = 49	*25.3% (20.8)*	*31.8% (27.5)*	*6.5%*

* $p \leq 0.01$ ** $p \leq 0.001$

M1s and M2s grew the most with their increase from an average score of 26.3% to 77.5% ($p \leq 0.001$), a 195% increase. Again, growth for Round 2 students was minimal and not statistically significant.

In contrast, table 9 below shows that 8th grade emergent bilinguals made a modest 11.7% point increase in the average score on the language objectives and, moreover, that the gain was not statistically significant; this was similar in magnitude to the growth of the Round 2 students, which was also not statistically significant. The 8th grade non-emergent bilingual students did make statistically significant growth, though it was a 19.0% point increase ($p \leq 0.001$), modest in comparison to the growth of the 6th grade students.

Table 9: Average Scores and Growth on Language Objectives for 8th Graders

	Language Objectives: Vocabulary		Difference
	Pre-test	Post-test	Post - Pre
Emergent Bilinguals N = 6	40.0% (21.0)	51.7% (14.7)	11.70%
Non-Emergent Bilinguals (NEBs) N = 52	39.0% (27.2)	58.0% (28.4)	19.0%**
Round 2 Students N = 55	*37.1% (28.2)*	*47.6% (24.9)*	*10.5%*

** $p \leq 0.001$

Because the academic vocabulary terms were the same for the 6th and 8th grade students, it is possible to compare the scores for both groups. Comparing the data in tables 7 and 8 reveals that all the 6th grade groups had average scores in between 20-30% on the pretest—22.7% for emergent bilinguals, 26.3% for M1s/M2s, and 29.6% for non-emergent bilinguals; the 8th grade emergent bilinguals scored higher than all the 6th grade subgroups of students, with an average score of 40% (compared to 39% for 8th grade NEB students). In other words, all 8th grade subpopulations outperformed all 6th grade subpopulations on the pretest. By the posttest, however, the same trend was no longer true: all the 6th grade subpopulations matched or surpassed the 8th grade students, with 6th grade emergent bilinguals tying 8th grade non-emergent bilinguals with average scores of 58%, and 6th grade NEB students and M1s/M2s surpassing all 8th grade groups by five to twenty percentage points.

When 6th and 8th grade scores are combined, as shown in Table 10, the increased population size is enough to make Round 2 students' growth in language objectives statistically significant, although the growth is much smaller than the growth of the students who participated in PBL. The growth for Round 2 students could be due to the teachers using the vocabulary more in their regular instruction periods; more research would be needed to determine this. The effect sizes for emergent bilinguals (1.35), M1s/M2s (2.58) and non-emergent bilinguals (0.87) were all large, with emergent bilinguals again experiencing a greater effect than NEB students. The qualitative data collected during the project provide some context to describe different factors driving these outcomes.

Table 10: Average Scores and Growth on Language Objectives for 6th and 8th Students

	Language Objectives: Academic Vocabulary		Difference	Effect Size: Cohen's d
	Pre-test	Post-test	Post - Pre	Post - Pre
Emergent Bilinguals N = 21	27.6% (21.4)	56.2% (13.4)	28.6%**	1.35 95% Conf. Interval: .67 – 2.02
M1s/M2s N = 8	26.3% (19.2)	77.5% (20.5)	51.2%*	2.58 95% Conf. Interval: 1.19 – 3.91
Non-Emergent Bilinguals N = 77	36.1% (25.3)	59.7% (28.7)	23.6%**	0.87 95% Conf. Interval: .54 – 1.02
Round 2 students N = 104	*31.6% (25.6)*	*40.2% (27.2)*	*8.6%**	*0.33 95% Conf. Interval: .05 – .60*

** $p \leq 0.001$
* $p \leq 0.01$

Qualitative Data

The importance of *the role of the teacher* was a clear theme explaining why some student groups saw greater language growth than others. The first stage of supporting academic language growth was the initial introduction to the terms. The curriculum presented the academic terms gradually over the course of the project, typically with 3-4 words per week. Students created flashcards for vocabulary words and were able to indicate Spanish cognates for the words, if applicable. One student with proficiency in Spanish benefited from his teacher explaining that the word "manipulate" is related to the Spanish word *manos.*

Teachers also gave linguistic support to students by explicitly teaching the vocabulary terms in ways that helped students make connections to their prior knowledge. The 8th grade math teacher had a conversation with a student that illustrated this:

Teacher: What does 'manipulate' mean?

Student: To control.

Teacher: In what sense? Give me an example about your robot.

Student: I would manipulate the robot with my hands.

Teacher: What else can you manipulate? What in math can you manipulate?

Student: You can manipulate an equation.

Teacher: Yes, you can manipulate an equation to a different form.

She pushed the student to make a connection between the academic language he was learning as he built his robot and the mathematical concepts he was learning in her algebra class. In this case, the teacher's role was in modeling the correct use of the language and pushing her student to make more conscious connections between the new word and ideas he already knew.

Consistency in focusing on vocabulary was also an important role of the teacher, and this is where the 6th grade and 8th grade teachers began to diverge in their attention to sustaining word consciousness through the project. The 6th grade science teacher, for example, consistently reinforced the importance of academic vocabulary when she overheard students using non-specific terms. She asked one group, "What are these? [They are] *nipper pliers.* You need to start using the correct vocabulary to refer to the parts and tools. Do not just say, 'Give me the thing.'"

She also proactively reached out to me to suggest having her students use dictionaries when they were unsure of word meanings. Another strategy she employed was using repetition in authentic contexts to reinforce terms with her students, telling them that before they came to *consult* with her about an unfamiliar word or a malfunction in their robot, they needed to *consult* the dictionary or *consult* with a peer. The teacher also challenged her students to play a game with their team as they built the robot, keeping track of how many times they could correctly use the vocabulary as they worked. Her students became highly engaged in this competition, and they began to make statements like, "I need to *diagnose* the problem with my robot" or "Let's modify this part of the robot's circuit."

To some extent, the 6th grade math teacher followed the lead of this teacher, although she was not as successful in consistently executing so many strategies to reinforce vocabulary terms. In general, the 8th grade teachers emphasized the vocabulary less in their own language and were less successful in building excitement among their students regarding mastering the vocabulary. Their students in particular often wanted to skip the language and academic building skill time at the beginning of the lesson and dive directly into building their robots.

Convergence in the Data

The mixed methods approach of comparing quantitative and qualitative data was again helpful because understanding *the role of the teacher* in supporting language development provides a potential explanation for why 8th grade emergent bilinguals saw limited growth in their language mastery while 6th graders saw significant progress. Namely, the higher language growth among 6th grade students may relate in part to the 6th grade teachers' greater emphasis on modeling and engaging students in authentic practice using the vocabulary terms.

Challenges and Adaptations During Execution

As the project progressed, several unexpected situations arose that forced adaptations. For example, I attended each class for a minimum of 60 minutes a week, and often teachers would have questions for me, or I would see opportunities to offer greater clarification to students. On at least one occasion, a teacher was absent and so I covered the class completely. I chose to take the role of an instructor in those moments because it would have the most positive effect on student learning in the moment. In doing so, I often explained with greater faculty or reinforced vocabulary with higher precision than the teachers did. This means that student outcomes are in part related to any instruction I gave. This is a non-replicable aspect of the study; teachers doing PBL units typically do not have the curriculum designer—or even a second teacher—in the room.

Additionally, part of the reason teachers needed assistance is because I created the curriculum on a rolling basis as the project progressed. This initially allowed me to make significant adjustments based on student pacing and mastery, which was helpful. However, it also meant that the teachers learned the curriculum in a piecemeal method, rather than seeing it start-to-finish. Conversations with the teachers revealed that this negatively affected their overall comprehension, and is the single most significant change I would make to the study.

Pacing was the other major aspect that presented unexpectedly, although in retrospect that should have been obvious. One of the challenges was that teachers took longer delivering the initial part of class introduction to concepts; this is likely due in part to the rollout of curriculum mentioned above. Additionally, middle school students work more slowly than the high school students I was accustomed to working with, and so adjustments needed to be made in the amount of work requested for students to do in groups each day before beginning the hands-on building. Perhaps most significantly, the students struggled with some of the mechanical aspects of building the robots—stripping wire and soldering circuits in particular—and this led to adjustments in the scope and sequence. Both grades extended the projects by one to two weeks. Additionally, some students did not participate in one of the challenges due to needing to still complete their robots. We dropped the planned graphing challenge completely from the 8th grade plan, and hence also dropped the multiple choice and free response questions for graphing from the pre- and post-assessment analysis.

Students also struggled to give each other effective feedback at times. The four roles set up for group members were efficient in many cases—for example, teachers could say, "All science specialists, come meet with me," and then disseminate information to groups that way. On the other hand, sometimes students did not master the information well enough to give quality assistance of feedback to their groups.

Another challenge I did not expect was how difficult it would be to align the robotics project to the state standards for science. Several key objectives that related to robotics are not taught in most middle school years. It made me wonder what the implications are of having state standards that are mainly focused on knowing facts, rather than being able to solve problems or generate new knowledge.

A final struggle that the 8th grade teachers encountered was in organizing supplies. Each robotics kit had multiple pieces, and students also needed tool sets to work with during class. Although the 6th grade teachers developed strong systems for organizing these, the 8th grade teachers' procedures were not completely successful in this respect. Consequently, a few students' materials were damaged or went missing, resulting in students needing to redo work and subsequent feelings of frustration among the few students involved.

Despite these difficulties, there were several strengths of the execution of the project. Materials were easy to understand, and I prepared them for the teachers (including copies), a factor each teacher expressed greatly facilitated the implementation of the project. Teachers' confidence and ability to explain the project also greatly increased over the course of the project: they repeated the project again in the later part of the semester with the Round 2 students, and they reported that the second time carrying out the project was even more successful. Lastly and in particular, the 6th grade teachers took significant ownership of the project. They actively suggested adjustments to the pacing, pushed for more practice, measured student mastery and gave feedback throughout the unit, and facilitated effective group work.

Additional Findings

In addition to facing unexpected challenges, my qualitative data also provided additional findings that extended beyond the scope of my original research questions. These findings all relate to the motivation of students engaging in the project. One notable example comes from an LTELL student in 8th grade, Carlos[7], who came into the project with very low academic

[7] Student names have been changed.

performance. While Carlos often displayed low motivation in his other classes, during the course of the project he sought opportunities to extend his work time to progress further on his robot. Carlos also developed novel solutions to problems he encountered, solutions that extended beyond what I had originally planned for the project. His team members, who included non-emergent bilingual students, grew to see him as an expert in the technical parts of the project. At the end of the project he earned an award from the teacher, a significant accomplishment. A non-emergent bilingual student, Carmen, shared that her participation in the two 6th grade robotics projects made her decide to become a computer scientist—and she was eager to begin learning to code outside of school. Still other students voluntarily sought opportunities to take their work home. For example, Juan was eager to show his soldered wires to his father, who worked in a related field. Students also were very enthusiastic to take their completed robots home at the end of the project. These experiences suggest that, in addition to leading to academic and linguistic growth, PBL can be a powerful motivator for Latino/a emergent bilinguals and their non-emergent bilingual classmates.

Summary

Although I encountered challenges during the course of the project, I arrived at clear answers to my original research questions. Robotics project-based learning had positive impacts on the academic content mastery of 6th and 8th grade emergent bilinguals. A key factor influencing these outcomes was students' use of *Spanish as a bridge to access academic content.* The 6th grade students also had large increases in their mastery of academic vocabulary. *The role of the teacher* was a critical factor in supporting language development for emergent bilinguals, and teacher differences may account for some of the differences in student outcomes. In most cases, emergent bilinguals' had greater academic and linguistic growth than non-emergent bilingual students did, suggesting that some characteristics of PBL have added efficacy for these students. The implications of these findings are addressed more fully in the next chapter.

CHAPTER V

SUMMARY, DISCUSSION, AND RECOMMENDATIONS

This study measured how robotics-based PBL affected academic and language growth for emergent bilinguals. In general, the intervention had positive impacts on student learning. This chapter discusses the implications of these findings, including offering conclusions and recommendations for researchers and practitioners.

Discussion of Results

As chapter one explained, there has been a persistent achievement gap between emergent bilingual students and their non-emergent bilingual peers. The answers to the three research questions, outlined below, explain to what extent PBL can help address this problem.

Research Question 1: Academic Content Growth

The first research question asks to what extent participating in robotics project-based learning helped Latino/a emergent bilingual students increase their mastery of math and science content objectives. The quantitative data indicate that emergent bilingual students experienced significant increases in the mastery of math and science content objectives as measured from the pre- to the post-assessment. Sixth grade emergent bilinguals grew 18.4% points from the pre-assessment to the post-assessment, and eighth grade emergent bilinguals grew 24.5% points. Both of these are larger increases than those reported in Whittier and Robinson's (2007) study of emergent bilinguals completing a LEGO robotics project aligned to state standards. This research project is also the first to calculate the effect size of emergent bilingual students' academic growth in PBL, which at 1.39 indicates an average growth of more than a standard deviation. This study is likewise unique in using released state assessment questions to measure student achievement, demonstrating clearly that PBL can translate directly to state exam results. The qualitative data from the project suggest that one of the reasons for this strong positive outcome is that students' proficiency in their first language enabled them to access academic content in English (Shamash, 1990, as cited in Kamwangamalu, 2010). This occurred in large part because of the classroom climate teachers cultivated that permitted and encouraged students to access both languages as resources—and students did so extensively, as examples in Chapter IV demonstrated.

Taken together, the quantitative and qualitative data clearly show that PBL led to strong academic growth for emergent bilinguals in this study. Additionally promising is 6th grade student Carmen's desire to explore a career in computer science, which provides an example of how authentic, engaging PBL can impact student motivations and aspirations (Barak & Zadoc, 2009; Pendergraft, Daugherty, & Rossetti, 2008). Carmen's goal is particularly significant given the underrepresentation of Latinas in STEM professions (White House initiative for educational excellence for Hispanics, n.d.). Her experience demonstrates how the benefits of PBL can extend far beyond standardized assessments of math and science mastery.

Research Question 2: Linguistic Growth

The next research questions examined how participation in robotics PBL impacted the linguistic development and achievement of middle school Latino/a emergent bilingual students. While previous studies have examined the linguistic opportunities PBL affords emergent bilinguals, this study is the first to actually measure emergent bilingual students' linguistic growth (Campbell, 2012; Mills, Chandra & Park, 2013). Overall, 6th and 8th grade emergent bilingual students grew 28.6% points from the pre-assessment to the post-assessment of linguistic content, yielding an effect size of 1.35. It is noteworthy that the linguistic growth effect size is similar in magnitude to the academic growth effect size, suggesting that PBL can be equally efficacious in promoting both types of learning; this insight is also a new addition to the existing body of research.

The evidence that PBL can help emergent bilinguals acquire both language and content suggests that effective PBL falls in Cummins' cognitively demanding, context-embedded quadrant (Freeman & Freeman, 2011). PBL engages students in real-world projects, giving them an authentic context for learning new vocabulary and ideas; research demonstrates that these factors help emergent bilinguals acquire language (Krashen, 1982; Gottlieb & Ernst-Slavit, 2013; Ellis, 2007, as cited in Echevarría, Richards-Tutor, Canges & Francis, 2011; Bunch, Shaw & Geaney, 2010). This is partly because this approach allows students to build on funds of knowledge from their personal lives—as Juan did, when he connected his robotics project to his father's profession (Moll, Amanti, Neff, & González, 1992). When teachers also provide strong linguistic support, emergent bilinguals can master challenging academic content (Buxton, Salinas, Mahotiere, Lee & Secada, 2015). Carlos is an example an emergent bilingual learner who blossomed while participating in PBL: his effort and outcomes in the robotics project were markedly different than in the traditional classes he had the rest of the day.

Yet unlike the academic growth measures for 6th and 8th grade—which were both statistically significant—the linguistic growth of 6th grade emergent bilinguals differed from those of 8th grade students. The 6th grade students grew 35.3% points on the measures of academic vocabulary, while 8th grade emergent bilingual students' growth of 11.7% points was not statistically significant. The qualitative data recorded during the project suggest this difference is at least partially due to the 6th grade teachers using many strategies for supporting linguistic growth, such as directly teaching key terms and then continually using them in context throughout the project. The modest growth overall for eighth graders is likely due to the more limited opportunities for practicing language acquisition during the project, a fact reinforces the idea that project-based learning, like regular instruction, needs to include specific strategies for linguistic accommodation (Baker, 2006; Richard-Amato & Snow, 2005; Echevarría, Short, & Powers, 2006). In the absence of that support, non-emergent bilingual students (who can access content in English) may improve, while emergent bilingual students do not—which is precisely what the 8th grade scores demonstrate. Because of the important implications of these findings, I address the role of the teacher in more detail below.

Research Question 3: Effects Differentiated by Linguistic Group

The final research question asked if project-based learning is equally efficacious for emergent bilinguals and their non-emergent bilingual peers. This question is particularly significant because, as mentioned in Chapter I, overall measures of student progress indicate that there is a persistent and, in some cases, a widening gap between the performance of these two groups. Because of this, it is particularly important that in almost every instance in the study, emergent bilingual student grew as much or more than their counterparts. The effect size for academic growth was larger for emergent bilingual students than for M1s/M2s or non-emergent bilinguals. In eighth grade academic content, the gap between the emergent bilingual and non-emergent bilingual students narrowed from 14.7% points in the pretest to 4.2% points at the end of the project. M1s/M2s showed the largest growth in linguistic achievement, with an effect size of over 2 standard deviations (2.58). Emergent bilingual students also showed more growth

(28.6% increase) than non-emergent bilingual students (23.6%); this growth closed the achievement gap between the two groups on the pre-assessment by more than 50%.

This was the first study to compare the academic and linguistic growth of emergent bilingual students to non-emergent bilingual students, and so it is a new finding that emergent bilingual students benefited as much or more than non-emergent bilingual students from participating in PBL. The project itself pushed students to learn content from science Texas Essential Knowledge and Skills (TEKS) that extended *beyond* their grade level, making the students' growth even more impressive.

Unanswered Questions

In addition to these findings, I also have unanswered questions, one of which relates to the role of teachers in PBL. Specifically, the teachers in the study had very different linguistic backgrounds and professional experiences. It is unclear what impact those differences had on the outcomes of the project. For example, were 6th grade students' linguistic gains greater because their teachers were native Spanish speakers? Or were the differences due to the 6th grade teachers having more years of experience (and thus better classroom management and more experience working with emergent bilinguals)? Another possibility is that the differences were related to their experience the previous semester teaching a different robotics project. Ultimately, the qualitative data I gathered could not answer these questions, nor could it isolate the impact of my participation in the project, both as a curriculum designer who has learned Spanish as a second language and who is trained in bilingual education, as well as in my capacity as a co-teacher at times during the project.

My qualitative and quantitative data do lead me to hypothesize, however, that teacher quality matters greatly. This aligns with the SIOP approach, which invests in providing teachers extensive training in how to teach rigorous content while supporting language development (Short, Echevarría, & Richards-Tutor, 2011). My observations, for example, support the notion that one of the biggest struggles for the math and science teachers was supporting language development, particularly in the case of the monolingual teachers. This is in agreement with the findings of Gottlieb and Ernst-Slavit (2013) regarding the need for targeted professional development to teach strategies for language development. Additional training is also needed when teachers shift away from teacher-centered instruction to a student-centered approach like PBL, particularly as they plan for integrating language and content support (Ernst-Slavit & Mason, 2011; Stoddart, Pinal, Latzke, & Canaday, 2002). A characteristic of effective PBL curriculum would thus include sufficient professional development before and during implementation of the project to ensure teachers are able to effectively deliver the curriculum.

A related question deals with the fact that several variables, including teacher quality, impacted the outcome of the project. Other potential confounding variables include the implications of my own background and role, the fact that the project took place at a charter school (with an accompanying sorting effect), and the different prior experiences of 6th and 8th grade students with robotics PBL. Because of this, further research is needed to more fully explore the most important factors contributing to students' success. Gaining greater clarity around the criteria for successful PBL is important because not only did the project lead to academic and linguistic growth, but it also led to higher teacher and student engagement in learning: as teachers repeated the project with the Round 2 students (and in subsequent years), they took ownership for the project and felt a strong sense of satisfaction from this single project during a single hour of their day. One teacher even contacted me the follow school year to request materials to carry out the project with students in another city where she had moved.

Recommendations

Based on my experience in carrying out this study, the following are my recommendations for researchers and practitioners. Because I tend to approach problems pragmatically, and because my own role in education is as a practitioner, I have more recommendations for those working directly with students and teachers.

Recommendations for Researchers

- *Conduct similar studies to isolate which aspects of this project-based learning approach had the most impact on students*. Because this robotics project included several aspects of quality instruction, including objective-aligned content, it is not possible to disaggregate the impact of those two. Further research could provide greater understanding of which different aspects of PBL are most critical.
- *Follow up with additional research on teachers as they grow in proficiency in delivering PBL.* The teachers who participated in the project all went on to teach the project again that semester, as well as in the following school year. They report that the project ran more smoothly and efficiently, and it would be useful to study teachers' development over time and the impact their growth has on student learning.

Recommendations for Practitioners

- *Consider PBL as a strong option for teaching language and content objectives*. This study demonstrates that PBL can help students—emergent bilingual students and non-emergent bilingual students alike—learn academic content aligned to standards assessed on state exams while additionally developing greater linguistic proficiency. Practitioners should be aware of research showing that many ELLs engage in extensive (but less effective) test-prep activities, and consider PBL as an alternate approach to instruction.

- *Offer intensive, on-going professional development for teachers learning to teach through project-based learning*. The observation notes indicate several areas in particular that teachers faced some challenges with, including…
    - Classroom management and procedures in a student-centered classroom.
    - Content knowledge in writing and language development.
    - Practice delivering strategies that support language learners.
- *Allow emergent bilinguals to use Spanish as a bridge to academic content and formal English during PBL*. In this study, allowing students to use both Spanish and English did not detract from learning academic and linguistic content; in fact, students frequently used Spanish to ask questions and express ideas related to the objectives of the project.
- *Build repeated practice attempts that reinforce key ideas for students, so that they can demonstrate increased mastery over time*. Students in sixth grade who received repeated opportunities to practice and use vocabulary in context showed the most mastery of language objectives.
- *Provide PBL teachers a chance to repeat the project several times so that their ability to facilitate the project improves*. Because teachers unanimously reported that the second time delivering the project was much easier and more successful than the first time teaching it, planning opportunities for teachers to lead a project multiple times can lead to gains overtime.

Summary

The growing numbers of emergent bilingual students in this country often receive instruction that fails to meet the criteria researchers have set for successful language instruction. I conducted a study to examine the academic and linguistic growth of middle school Latino/a emergent bilingual students engaged in robotics project-based learning. My findings show that on average, emergent bilinguals made statistically significant gains in academic mastery. Sixth grade students showed statistically significant growth in language as well, although eighth grade students did not. This study adds to the existing body of research because it demonstrates that overall emergent bilinguals grew as much or more from engaging in PBL as non-emergent bilingual students did. PBL is a meaningful approach to engage emergent bilinguals in standards-aligned instruction that is also rigorous, hands-on, and authentic.

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BIOGRAPHICAL SKETCH

Prior to earning Master of Education in bilingual education at the University of Texas Rio Grande Valley in May 2016, Melinda Hardy attended Brigham Young University, where she graduated *magna cum laude* in 2009 with a Bachelor of Science in economics. She taught high school ESL and AP Literature in the lower Rio Grande Valley for several years before moving to San Antonio, where she currently resides and works as director of instructional coaching for a local school district. A native of New Mexico, Melinda is usually planning her next road trip to a place with good hiking.

Her permanent address is 342 Thorman Pl, San Antonio, TX 78209.