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The Use of A Computer-Supported Learning Design to Support Oral Language Development among English Language Learners through the Design Process

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The Use of a Computer-Supported Learning Design to Support Oral Language Development among English Language Learners through the Design Process

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Education

by

Adrian Julian Gumpert

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ABSTRACT OF THE DISSERTATION

The Use of A Computer-Supported Learning Design to Support Oral Language Development among English Language Learners through the Design Process

by

Adrian Julian Gumpert

Doctor of Education

University of California, Los Angeles, 2020

Professor Kimberly Gomez, Chair

This study examined a novel learning environment in one kindergarten classroom with 90% Spanish-speaking ELLs. The design combined the interactive whiteboard platform and a student-centered, constructionist pedagogy to structure cooperative tasks, academic language and semiotic formations through the engineering design process within a studio-based learning design. The interactive whiteboard platform consisted of an array of digital and non-digital collaboration tools specifically arranged to support semi-autonomous collaboration, communication, and construction of representational artifacts. The purpose of this study was to explore the potential, if any, that this design may have in advancing access to academic oral language development in STEM-related fields to ELLs.

The dissertation of Adrian Julian Gumpert is approved.

Louis Gomez

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Kimberley Gomez, Committee Chair

University of California, Los Angeles

2020

DEDICATION

To Julie, my lifelong friend. To my children, Alexander and Hannah, for sharing me with this work and with my students. To my father for his steadfast support, and for my mom, Julieta Cervantes, whose love I carry with me in all things that I do.

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Finally, I want to thank my cohort of colleagues at UCLA who have been an invaluable support at each stage of this project. Their wide-ranging work across the K-16 spectrum to address inequity and improve the lives of children continue to be a constant source of inspiration.

VITA

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CHAPTER ONE: INTRODUCTION

Overview

Oral language development is the foundation of literacy. Because low-income English Language Learners (ELLs) have one of the lowest literacy achievement rates in the U.S., a learning environment that supports frequent opportunities for students to be exposed to, and use, contextualized academic language as a foundational literacy skill is critical for academic success. In this study, I developed, implemented, and studied a novel learning environment in one kindergarten classroom with 90% Spanish-speaking ELLs. Student work was centered in an engineering design process within a studio-based learning design. The learning design leveraged a combination of a whole-room interactive whiteboard (IWB) platform and a student-centered, constructionist pedagogy to structure cooperative engineering and design tasks, academic language, and multimedia publication. The IWB platform consisted of an array of digital and non-digital collaboration tools specifically arranged to support semi-autonomous collaboration, communication, and construction of representational artifacts. This study aimed to explore the potential that this design may have in advancing access and academic oral language development in STEM-related fields to ELLs.

Statement of the Problem

Recent data show that by 5th grade, 87% of the English language learners (ELLs) enrolled in school 12 months or more in California had not met state proficiency standards in English language arts, and 91% had not met mathematics standards (California Department of Education, 2020). At City* Elementary School (*pseudonym), the site of my study, the results are similar. Low achievement by the end of 6th grade is a strong indicator of secondary school success and college readiness (Balfanz et al., 2007). If the California Department of Education and City

Elementary School are to meet their stated goal of college and career readiness for all students, then the current rates of ELL achievement in elementary school must change.

City Elementary School is a K-5 school in a large school district in the Southern California region. The district has a significant EL population and in my research cite ELLs make up 50% of the population at City Elementary School. For this research effort, I focused my study specifically on the ELLs in my kindergarten classroom at City Elementary School. While each school is unique, City shares demographic and neighborhood characteristics with many neighboring schools, specifically regarding ELLs and SES.

Language development depends on the opportunity to engage in robust social language activities (Kuhl, 2007). In traditional teacher-centered classrooms, teacher-talk accounts for most classroom talk time while student engagement is higher the less that teachers talk (Hattie, 2012). When academic student talk occurs, in classrooms, it is primarily in teacher-student interactions. The opportunity for sophisticated peer to peer talk is limited. However, research in language development shows that language development occurs not just by listening to adult talk but by engaging in conversation. One example of the value of children engaging in conversation found that a significant correlation was found between children's conversational turns in informal settings and verbal test scores (Romeo et al., 2018). These findings suggest that language environments that provide a high opportunity for children to engage in dialogue are effective language learning environments. Particularly conducive to language opportunities are learning environments that offer hands-on construction and multiple learning modalities, meaning-making, and reflection (Kafai & Resnick,1996). A classroom learning design focused on creating the conditions for high levels of hands-on student participation through dialogue is one way to create a robust language environment in a formal setting.

Collaboration technology affords students the ability to engage in an open-ended structured activity, using software designed to scaffold sophisticated multi-step activity patterns and dialogue without direct teacher guidance (Warwick et al., 2010). Collaboration technology is a promising tool for ELL language development that supports project-based student-centered pedagogy and 21st-century content and skills knowledge.

In this chapter, I first articulate the specific relationship between constructionist pedagogy and the novel arrangement of digital and non-digital tools within the IWB platform that create the conditions for rich language opportunity. Then, I explain how the IWB platform may facilitate both the quality and quantity of oral language in kindergarten ELLs. Finally, I describe the methods I used in this research design to collect qualitative data about student talk and how students engaged in the engineering and design process by presenting and discussing design projects in a studio-based learning design.

Background Information

Oracy, writing, reading, and reading comprehension are the four components of literacy. One way to improve ELLs' English language development is to provide opportunities to participate in language-rich learning experiences that are rigorous and meaningful to students. At the same time, these opportunities must be frequent to provide an abundant opportunity for practice. The contextualized academic exchanges in this study are characterized by either cumulative talk, in which dialogue consists of sharing ideas and elaboration without being critical, and as exploratory talk in which students are actively building on each other's ideas (Mercer, 1996). Evidence for the impact of conversation on children has also been found at the neural level; neuroscientists studying brain activity found that conversation had a significantly higher impact on children's neural activity than just a large number of words heard (Romeo et al., 2018). Oral language opportunity, particularly dialogue in social and academic contexts, can significantly impact foundational literacy skills.

Contextualized academic language practice, combined with significant practice time, is necessary for language advancement. Practice time alone does not account for increased performance. It is the quality of that practice time that results in skills improvement. Malcolm Gladwell (2008) claims that mastery of skills requires 10,000 hours of practice. However, this claim has been challenged for a fundamental reason; it does not account for the quality of that practice. Research has found that not all practice has an equal impact on mastery; that practice must be deliberate and challenging for mastery to occur (Ericsson et al., 1993).

Oral language development is a foundation for reading and writing. Improving oral language development means increasing the frequency of opportunities for ELLs to engage in academic talk. ELLs must be exposed to the academic language that they will encounter during core subjects to access the curriculum and meet achievement standards. ELLs are a particular case for language development because they must do two significant cognitive tasks at once; they must learn English as a second language, and they must learn the same academic content in this second language as their native English-speaking counterparts. They are both acquiring a new language and obtaining academic content. In 2019, the high school graduation rates for ELLs in California was 68.7%, compared to whites at 88.4%. Only 25.7% of ELLs who graduated high school met the UC/CSU requirements compared to the 55.2% of white students who fit these same requirements (California Department of Education, 2020). While all students benefit from more engaging, research-based instructional practices, ELLs are especially impacted by the two-pronged challenge of language acquisition and academic content mastery, compounded by the higher likelihood that they are economically disadvantaged.

The problem of elementary ELLs not meeting state standards, high school graduation requirements, and UC/CSU requirements is multifaceted, and likely requires a multi-pronged and multi-disciplinary solution. The use of digital tools may be a component of the solution to increase engagement and participation by combining the best practices of student-centered learning with digital tools that facilitate these practices. One digital tool that most U.S. teachers have, which studies suggest can increase engagement (De Vita et al., 2014; Hennessy et al., 2017; Kennewell et al., 2007; Maryam et al., 2019; Mercer et al., 2010; Warwick & Mercer, 2011) and ELL achievement (Lopez, 2010), is the interactive whiteboard (IWB).

Nationally, 60% of classrooms were already equipped with an IWB in 2014 (Future Source Consulting Report, 2014). At my research site, City Elementary School, 100% of classrooms had an IWB already installed for at least three years before the study. With a new installation cost of $4,621 for one IWB (Collaboration Solutions, Quote 2014), City Elementary School had chosen to invest a significant amount of its financial resources into this technology. While this collaboration technology platform can serve all learners, the high needs of ELLs who have among the lowest achievement outcomes by high school are especially well served by the visually rich, highly engaging format afforded by this digital toolset.

The existing literature which demonstrates positive outcomes using the IWB have explored a learning design where a single IWB is used as a center rotation in the classroom. These studies focus on student talk quality and demonstrate that specific uses of the IWB can facilitate sophisticated semi-autonomous dialogue. However, existing studies, with few exceptions (Lopez, 2010), have focused on classrooms with non-US, and non-ELLs students. My study contributes to the research literature by focusing specifically on low-SES ELLs in an urban public school in Southern California.

However, pedagogy always precedes the technology; investment in educational technology hardware is only part of the investment needed to integrate technology into the classroom (Higgins et al., 2012). Systemic technology integration is unsuccessful without pedagogical shifts that take advantage of these tools' affordance (Karsenti, 2016). In a 2012 analysis of the impact of digital technology on learning, Higgins et al. report a significant pattern emerging from the research; the most significant impact of technology in the classroom is pedagogical change, not merely having new hardware to improve the efficiency of old practices. Pedagogy is the most critical aspect of technology integration that has a positive impact on student achievement. How the tools are used, not the device itself, impacts student outcomes (Cabus et al., 2017; Hennessy et al., 2017; Higgins et al., 2012; Mercer et al., 2010;).

An emerging body of qualitative and quantitative analysis links the interactive whiteboard's collaborative features to positive student outcomes in oracy and literacy. This research demonstrates how interactive whiteboards facilitate student collaboration and high-level dialogue and how this sophisticated communication promotes student achievement (Hennessy et al., 2017; Kennewell et al., 2007; Lopez, 2010; Mercer et al., 2010; Warwick & Mercer, 2011). In his seminal work outlining typology for the three types of classroom dialogue students engage in, Mercer (1996) identifies three interaction types cited throughout the literature: disputational talk, cumulative talk, and exploratory talk. Disputational talk is characterized by students speaking at one another without responding to one another’s ideas. Cumulative talk is when the speakers add on to one another's thoughts. Exploratory talk is when speakers critically engage with one another's ideas and co-construct new ideas based on this critical discussion. Mercer has identified the latter as the most sophisticated type of talk; it has the most substantial impact on cognitive development because it requires critical thinking; participants necessarily must consider and respond to one another's ideas and in his studies, students in upper elementary school increased use of exploratory talk when using interactive whiteboards.

In Mercer and his colleagues' studies, the sample population was upper elementary native English speakers in the U.K. Among this age group, expectations for high levels of exploratory talk, while unusual, is developmentally appropriate. Among kindergarten students, particularly ELLs at the beginning and intermediate levels of language proficiency, expectations of frequent, sustained, and independent exploratory talk is not developmentally appropriate. However, the precursor to engaging in exploratory talk is cumulative talk: conversational turn-taking that stays focused on the oral language task. While the goal for teacher-scaffolded conversations among kindergarten ELLs is the ability to engage in sustained cumulative talk, sustained and independent cumulative talk among ELLs is more than what is usually expected.

Learning design that increases students' opportunity to engage in frequent dialogue with one another using collaborative learning pedagogy may positively impact language development. Conversational turn-taking in informal settings is the most effective way to develop oral language in children (Romeo et al., 2018). In contrast with other types of oral language interactions, researchers have found that the process of listening and then appropriately responding to others requires, and consequently develops, sophisticated language among children. Whether it be exploratory talk (Mercer, 1996) or conversational turn-taking (Romeo et al., 2018), qualitative and quantitative researchers across fields have determined that verbal collaboration between children is the most effective way to develop language.

The teacher's role in establishing group behavior patterns that promote dialogue plays an equally critical role in student achievement. A significant body of research on collaborative learning has demonstrated that small-group learning has a positive impact on student outcomes when pedagogy focuses on the teacher's role as facilitating and modeling patterns of interaction that foster the conditions for effective peer to peer discussion (Webb, 2009a). My study combined collaborative learning pedagogy and project-based learning with cutting-edge collaboration technologies to enable students to engage in dialogue-rich constructionist computer-supported 21st-century learning and media production.

In this study, I contribute to the research literature by applying the findings of the positive impact on student dialogue to a learning design that is equipped with enough IWBs (a ratio of 4:1) to enable an entire class to engage in small group IWB centered activity simultaneously. The study is the first to examine the use of the studio-based model to engage ELLs in STEM-related language opportunities through the engineering design process.

Significance

While studies using single IWBs for a single small group to support collaborative independent talk have been conducted for ten years, only one research study has explicitly focused on ELLs, which was done in Texas with upper elementary school students (Lopez, 2010). My study was the first to explore the use of the IWB to support dialogue among kindergarten ELLs through the engineering and design process. Also, while Brown (2006) advocates for schools to reimagine classrooms to follow the same principles as the studio model of learning found in architecture and design schools, and the studio model has been found to effectively structure some innovative learning like digital game design (Kafai, 1995), the use of the approach is sparse in the literature. A study of the IWB platform used to scaffold multiple small groups simultaneously in a studio-based learning design had not been conducted in any population at any grade level. This gap in the research may be the result a combination of three factors: (a) the paradigm shift in pedagogical practice required to combine student-centered pedagogy with largely uncharted collaboration technologies, (b) the significant technical fluency necessary to digitally build activities in multiple software platforms as well as integrate the learning design in multiple groups simultaneously, and (c) the current cost of the design.

However, it is highly feasible that the cost of these technologies will decrease significantly in the next 10 to 20 years, based on the rapid decrease in costs for the necessary technology over the last 20 years. For example, between 1998 and 2018, the cost of a Dell Inspiron 3000 laptop decreased from $5,300 to $350. With a cost of over $100,000, a set of 1:1 laptops in every classroom in 1998 would be unimaginable; today, classroom sets of laptops are becoming ubiquitous. Also, the cost of displays has significantly decreased. According to the U.S. Bureau of Labor Statistics, prices for large format digital displays were 96% lower in 2018 versus 2000. A 42" flat display in 1998 cost $23,000 (adjusted for inflation). Today, in 2020, a 43" flat display costs $230. As the cost of large format interactive digital technology and the computers that run on them decreases, the potential to fully replace static walls and whiteboards with a network of large, digital interactive technology will likely become economically viable. This study may be an important first contribution to considering whether a design that fully equips students with small-group access to this multifaceted platform that combines a wide range of hardware, software and digital and non-digital peripheral tools can have a positive impact on student learning. This study may also extend our understanding of how pedagogy can be developed to take advantage of the affordances of increasingly immersive technology integrated classrooms.

Further, my study may initiate interest by school leaders, education researchers, and technology companies in investing in a larger scale study of this novel design, such as a strand within a school or an entire school. An expanded research study may further explore the potential that this learning design may afford student engagement and achievement in a classroom setting that is relevant to students who are expected to be productive and prepared citizens in the knowledge age.

CHAPTER TWO: LITERATURE REVIEW

Overview

This study aimed to explore what opportunities are afforded to kindergarten ELLs to engage in academic language through the engineering design process and studio-based practices of public critique and reflection mediated by the digital creation whiteboard tools and grounded in PBL activities. This was a qualitative study of a learning design that employed the IWB as a multipurpose platform to structure the design process, act as an interface for digital and non-digital tools, serve as a presentation space, and as a platform for publication on social media. The study combined collaborative learning processes with project-based learning activities using digital media creation tools. The study was initiated to address inequity in the K-12 pipeline; ELLs have one of the lowest academic achievement rates, have limited access to STEM classes, and are among the most underrepresented in STEM professions (National Academy of Sciences, Engineering, and Medicine, 2018).

By the end of elementary school, only 13% of English Language Learners (ELLs) in California met the grade-level standards in English Language Arts/ Literacy and 10% in Mathematics compared to white students, 66% who met ELA/Literacy standards, and 54% who met mathematics standards (California Department of Education CAASP, 2020). These low achievement rates of ELLs by the end of 5th grade are critical indicators of secondary school success and college readiness as they enter the 12th grade (Balfanz et al., 2007). California schools have adopted the Common Core Standards with the stated goal of college and career readiness for all students. To meet this goal, the current low ELL achievement rates in elementary school must change. A solution to the problem of ELLs not meeting state standards in literacy or mathematics is multifaceted. However, one tool that 60% of U.S. teachers already have in their classrooms, which can increase ELL engagement and achievement, is the interactive whiteboard (IWB) (Lopez, 2010). An emerging body of research demonstrates how interactive whiteboards have been used to facilitate student engagement and collaboration through dialogue (Hennessy et al., 2017; Kennewell et al., 2007; Lopez, 2010; Mercer et al., 2010; Warwick & Mercer, 2011). Dialogue, in which two or more people engage actively with and respond to one another's ideas, has been identified in the literature as critical for cognitive development and associated with student achievement (Franke et al., 2009; Mercer, 1996; Ryu & Sandoval, 2012; Webb et al., 2009b).

In this literature review, I first examine the relationship between early oral language development and long-term literacy development. From this research, a central theme has emerged: the quality of dialogue, combined with frequent opportunity that young children, particularly ELLs, engage in has a strong correlation with long-term literacy development and achievement. English language learners are a particular case of students that require robust scaffolding and opportunity for participation. I then turn to collaborative learning pedagogy as a well-documented method that engages students in unusually high levels of dialogue and unusually high levels of achievement, when compared to traditional teacher-centered methods. Next, I review the research about interactive whiteboards supporting productive small-group dialogue when used as a student collaboration tool. I then look at PBL as a particular type of collaborative learning design documented to improve student engagement and foster academic rigor and then specifically at the studio-based learning model. Finally, I explore a specific kind of project-based learning model that applies studio principles of making work public and focuses on digital production to develop new media literacies by applying constructionist pedagogy to media and communication technology-integrated learning environments.

Oral Language Development

Oral language development is the foundation of literacy development. Language experiences and language environments in a child's early years have a significant impact on the development of their reading (NICHD Early Child Care Research Network, 2005), language (Romeo et al., 2018), and cognitive development (Bornstein et al., 2008). Oral language is a crucial element of this development, along with early exposure to fiction and non-fiction text. Oral language ability in kindergarten is associated with reading comprehension in third and fourth grade (Storch & Whitehurst, 2002). Engaging in dialogue early on has been shown to have a significant positive consequence on children's cognitive development and academic outcomes through elementary school.

Oral Language is the First Step Towards Literacy Development

Discussion of the relationship between early language environments and the trajectory of literacy development in subsequent years gained traction after the publication of the Hart and Risley's (1995) seminal and still controversial study that examined early childhood language environments. In this research, the language in 42 preschool children's homes was recorded, coded, and quantified over 2 ½ years. They found a relationship between the number of words spoken by the adults and children and the SES of the families; by the end of the study, they found that children from higher SES households, on average, had been exposed to nearly 30 million more words than those from the lowest SES households. Further, in a follow-up study of 29 of these families, Hart and Risley found that language skills at age three predicted language skills in 3rd grade at age 9 and 10. The controversial study initiated three decades of research to understand, refute, and reassess these initial findings. One salient critique is that the interpretation of the findings was based on a deficit model and did not value cultural differences in child-rearing (Johnson, 2015; Kuchirko, 2019). While the Hart and Risley study claims have been challenged, the research it initiated in examining language environments has been significant in understanding the features of early language exposure that impact literacy development and academic achievement.

A significant limitation of this study was that it only measured the number of words spoken in the child's environment; it did not explore how they engaged in these language environments. A more robust study of home language environments that used electronic all-day recording device technology (LENA) was used to measure word count and conversational turns between children and adults in their homes. The 30 million word gap estimation between SES groups was reduced to four million, and conversational turn-taking was identified as the critical language feature to impact language development (Romeo et al., 2018). This study found that quantity matters if it is tied to quality, specifically dialogue that probes and engages children.

Similar findings of the impact of language quality on children have also been found in the classroom setting. The quality and expectations of language between teachers and students have been found to have a significant impact on student outcomes and driving language sophistication that includes students developing language to justify, explain, question, discuss, and evaluate their actions, ideas, and thinking(Alexander, 2008; Franke et al., 2009; Mercer, 1996; Romeo et al., 2018; Webb et al., 2009b). These findings on the significance of language quality on outcomes from preschool to school-age children informed a key design challenge addressed in my study: designing activities that aimed to maximize the amount of time that individual students had to talk in the context of sophisticated academic content and language structures.

Education from a Sociocultural Perspective

An environment where learning is viewed as a principally socially mediated process is rooted in Vygotsky's sociocultural theoretical framework. Language is the medium that enables social interaction, and thinking is mediated through language within these interactions (Vygotsky, 1978). Through carefully guided social interactions between learners of equal abilities but different perspectives, or between an expert and a novice, collaboration has the potential to lead to the co-construction of new knowledge through the process of cognitive apprenticeship (Collins et al., 1987). How students use the language together to co-construct knowledge depends on the conditions of the environment where these interactions are situated. Lave and Wenger (1991) introduced situated learning theory to extend Vygotsky's theory to include the space of social learning as essential to the knowledge building process. Situated learning theory emphasizes the significance of the context in which learning takes place. Learning is embedded within the setting and the culture of the activity. Collaboration is a fundamental part of social learning, and the communities of practice engage students in context-specific actions. Effective communication through language is critical in achieving the activity goals of the communities of practice. My study contextualized academic dialogue within a highly social set of open-ended activities designed to elicit problem-solving and co-construction of design projects.

Productive Dialogues are Essential

However, not all language interactions have the same impact on the collaborative process or cognitive development. Research over the last three decades has focused on exploring the features of different types of dialogue in the classroom and their impact on collaboration and cognitive development. A range of effective and ineffective verbal interactions centered around cooperative classroom activity takes place between students (Johnson & Johnson, 1985), and student appropriation of patterns of talk, such as mathematical thinking strategies and scientific argumentation, have been found to enable productive talk around math and science concepts (Moskovich,2015; Sandoval et al., 2014). Productive dialogue includes students applying domain-specific language, practicing conversation norms, encouraging one another, giving support to one another, challenging ideas, and offering feedback. These types of exchanges promote a favorable social and academic climate among students. Small groups can be conducive to productive dialogue when students have been taught how to engage in elaborated discussions where they are expected to give extended explanations of their ideas and problem-solving strategies (Webb, 1991).

Mercer (1996) uses a three-tiered typology to explicitly detail the features of three discussion types that occur between children in a kind of dialogue where meaning and ideas are co-constructed: disputational talk, cumulative talk, and exploratory talk. These three levels of exchange are significant in language-oriented collaborative groups because, through conversation, elaborated discussions can result in developing the thinking of those engaged in the dialogue. Interactions, where ideas are exchanged, are more specifically identified as interthinking (Littleton & Mercer, 2013). Disputational talk is characterized by disagreement among group members without elaboration or justification and is unproductive in developing new ideas. Cumulative talk is characterized by students listening to one another and building on each other's ideas.

In contrast, exploratory talk differs from cumulative talk because students critically engage with each other's ideas to jointly construct new ideas. Webb's findings in the field of collaborative learning, and Mercer, in the area of dialogic talk, demonstrate that the quality of discussion has the most substantial impact on the quality of learning. In my study, eliciting productive dialogue was addressed through the scaffolding embedded in the IWB. This platform used graphics, text, audio clips, and a conversation protocol that were visual reminders and physical checklists to help students navigate and participate in structured academic conversations.

Oral Language Opportunity Matters

Active and frequent participation in language exchanges impacts language development trajectory in children (Gilkerson et al., 2017; Hart, B., & Risley, T., 1995; Hart & Risley, 1992; Romeo et al., 2018). Passive yet frequent language exposure, such as being talked at but not having the opportunity to speak, or questions that require a simple affirmative or negative response, show significantly less impact on language development than active language opportunities. For ELLs in particular, frequent opportunity to practice extended oral language exchanges is essential for language development. Researchers have found that robust opportunity to engage in dialogue, not just listen to a monologue, is critical to language acquisition (Alexander, 2008; Gilkerson et al., 2017; Mercer, 1996; Romeo et al., 2018). The learning design in my study used a pod-based structure, where optimally sized small groups of three to four students (Abrami et al., 1996) engaged in collaborative projects designed to increase the opportunity for interaction and language.

Collaborative Learning

The relationships and interactions between children working together in small groups are central to collaborative learning. In a seminal review of the literature, Webb (2009a) found that four teacher behaviors affect the outcomes of collaborative design: the way the teacher prepares students for group work, the process of group selection, the structure of learning tasks, and the use of teacher talk as a metacognitive model for effective collaboration. Productive dialogue requires the group to build on each other's ideas; teaching students how to listen and respond to each other is essential to increase cooperation and collaborative talk (Gillies & Ashman, 1996). Prevalent among findings is that exploratory dialogue that probes and challenges ideas, either as a guided exploration of mathematical thinking, to joint construction of new understandings, or work in productive collaborative groups, is the essential feature of effective learning environments (Franke et al., 2009; Mercer, 1996; Webb, 2009a).

Effective practices of teachers to enable small groups to make progress towards learning goals requires that students take on the role of facilitators within their groups (Webb, 2009a). Teachers who explicitly teach students how to probe one another's thinking are more likely to increase the quality of talk and problem-solving of those in small groups (Kyle et al., 2006; Pantaleo, 2007; Rojas-Drummond et al., 2001). In one illustrative study, the frequency of language in small groups associated with joint reasoning increased significantly compared to control groups that did not get training on collaborative talk (Littleton et al., 2005). Facilitating cooperative learning practices that help to scaffold interactions, negotiate responsibilities and stay on task have been effectively used to establish patterns of interaction that support the efficient use of time and enable groups to progress towards their learning objectives (Gillies, 2016; Webb, 2009a).

My study examined the affordance of the IWB platform as a multipurpose tool used to structure collaborative learning processes, structure engineering and design language, and serve as a platform to mediate and document artifact production. The design applied what we know about the features of productive small-group learning to the creation of digital scaffolds. I explored whether some of the teacher's scaffolding roles could be embedded within a particular toolset, the IWB platform, to facilitate these processes.

The Interactive Whiteboard

A Digital Tool That Can Facilitate Collaborative Learning

Digital tools and software have the potential to be used effectively to scaffold tasks for learners in two ways: by structuring tasks as well as problematizing tasks (Reiser, 2004). A meta-analysis that synthesized the results of 144 experimental studies of STEM-related learning found that computer-facilitated scaffolding had a consistently positive effect on cognitive outcomes (Belland et al., 2017). The interactive whiteboard is one tool, in particular, that is an especially promising platform for software designed to scaffold group work because of its large size and touch interactive functions. The IWB has been studied as a tool to support sustained focus on academic group work and enable sophisticated dialogue within a group. Within the literature, there is qualitative research that correlates the interactive whiteboard's collaborative features, when paired with student-centered pedagogy, with positive student outcomes. One line of research examines how IWBs facilitate student collaboration, in particular, high-level dialogue, and how this sophisticated communication promotes student engagement. Within this section of the literature review, I first examine specific classroom practices that promote peer to peer dialogue supported around the IWB. These are spaces where high-level peer to peer dialogue occurs around IWBs without direct teacher intervention in a process termed vicarious presence. Then the review turns to a critical study that examines how a pilot study that used IWBs to support ELLs impacted ELLs performance on standardized tests.

Communication and Collaboration in a Digitally Augmented Classroom

When used in its most basic functionality, the benefits of the IWB include increased focus, concentration, and on-task behavior (Karsenti, 2016; Mercer et al., 2010; Warwick & Mercer, 2011). Lessons designed using IWBs have also been found to impact student engagement and interactions (Gregorcic et al., 2018; López, 2010; Mercer et al., 2010). Further, the large format of the IWB affords a shared visual and interactive space for teachers to use as a tool and object for whole group interaction (Beauchamp & Kennewell, 2008; Maryam et al., 2020). They have been found to help elicit an understanding of science concepts drawing on multiple modalities (Gillen et al., 2008) and they have been found to help students to explore, explain and clarify their ideas (Mellingsæter & Bungum, 2015). Mercer et al. (2010) use qualitative design methods to assess the sophistication of dialogue using norms, or ground rules, while using the IWB. Warwick and Mercer (2011) find that this makes students responsible for collaborative talk, while the teacher's vicarious presence maintains order without interfering with peer-peer conversation. Vicarious presence was achieved at the point when students were able to independently use the rules and procedures related to group work that was taught and established by the facilitator. In a study of physics students working in small groups around an interactive whiteboard, researchers found that students took on a teacher-like facilitator role that advanced group discussion without direct teacher presence (Mellingsæter & Bungum, 2015).

Improved Academic Outcomes for English Language Learners

Literature that examines the impact of computer-supported learning using the IWB platform on ELLs is sparse. One study investigating the connection between interactive whiteboards, collaborative learning, and academic outcomes for ELLs was conducted as a pilot project in Texas called the Digital Learning Classroom (DLC) (López, 2010). The first objective of this study was to use statistical analysis to compare achievement on a Texas state high stakes test (TAKS) between ELLs in seven treatment classrooms that received technology training and used IWBs on the one hand, and ELLs and non-ELLs in classrooms without IWBs on the other. The second objective was to determine if ELLs could reach TAKS test score parity with non-

ELLs when IWBs were used to augment their instruction. Parity in this context was defined as the extent to which ELLs performed at similar achievement levels as non-ELL students in the classrooms without the intervention. A significant finding was that performance parity was achieved on 5th-grade math and reading scores. The findings from this study indicated that technology-supported ELL instruction combined with P.D. to support teachers on how to use the technology was associated with the achievement of these ELLs on high-stakes math and reading tests.

Lopez's quantitative approach to measuring performance outcomes related to the use of the IWB is uncommon. Although one other quantitative study displayed moderate (6%) increases in math proficiency for students using the IWB (Cabus et al., 2017), there is not yet enough data on IWBs to determine the impacts of this educational technology on achievement (Karsenti, 2016; Turel, 2010). Throughout the literature, researchers examining this technology primarily use qualitative methods. These qualitative studies assess the impact of IWBs on student perception, engagement, or quality of collaboration (Hennessy et al., 2017; Karsenti, 2016; Kennewell et al., 2007; Mercer et al., 2010; Warwick & Mercer, 2011).

Pedagogy Precedes Technology

The IWB, like most tools, is only useful if the user understands how to use it effectively. Although the IWB affords teachers the tools to engage students at high levels of collaboration, the teacher's pedagogical approach towards technology integration and the training they receive to support them is the critical factor for change to occur (Hennessy et al., 2017; Turel & Johnson, 2012; Whyte et al. 2014). Together, the literature indicates that using the IWB technology to improve academic achievement requires far more than merely putting innovative technology into classrooms, pushing a button and expecting the tool to enhance learning. Research that shows that IWBs can be useful underscore that pedagogy is the essential variable in classes which use the tool successfully. A key feature in each study that found a positive impact on students is that these studies were paired with extensive professional development that addressed the intersection of technology and pedagogy and how to take advantage of the affordance of the collaborative potential of the tool. My study considers the affordance of the collaborative potential of the IWB tool and uses it as a multipurpose tool to engage students in projects that require a broad set of tools with which to build.

Project-Based Learning

While the process of collaboration can be mostly centered around dialogue, in hands-on constructivist design, the method combines dialogue with project processes and artifact building. One particular type of learning design that requires this combination is project-based learning (PBL). It combines effective collaborative learning practices, whether using traditional tools or using digital technology, and can enable students to work together on a shared task. PBL is a specific type of collaborative learning task that requires a high degree of coordination and cooperation among groups of students to engage in extended multi-stage tasks that are oriented to exploring a complex question or achieving a project goal. The processes established of productive group work are prerequisites for successful project-based learning: coordination of work, negotiation of ideas, and shared responsibility. These enable students to engage in multi-stage projects and not just allow students to co-construct ideas, but to apply those ideas to the production of physical artifacts that are authentic responses to student-driven questions.

Research on Effective PBL Design: The role of teachers in the Design Process

The responsibility of teachers in PBL environments is as a facilitator of inquiry processes rather than a distributor of content knowledge. Research that documents the key roles and responsibilities that the teacher has in facilitating the process is similar to the literature about the teacher's part as facilitator in collaborative learning environments (Webb, 2009a). Effective PBL teacher roles have been documented as facilitating student inquiry, scaffolding learning processes, promoting academic challenge, and developing summative and performance-based assessments (Condliffe et al., 2017).

Designing PBL activity that is academically rigorous and meets the learning objectives of the classroom, while simultaneously being open-ended and student-driven is a significant challenge. Similar to issues in collaborative learning, where merely putting students into small groups does not lead to positive academic or social outcomes (Webb, 2009a) unguided or poorly focused projects are unlikely to result in the intended educational outcomes (Barron et al., 1998). Further, if teachers are unprepared for the complex requirements and pedagogical shift required for PBL then the uptake of this approach and adherence to the design principles is weak (Blumenfeld et al., 1991).

Evidence of the Impact on Learning Outcomes

Although student engagement is essential, it does not necessarily lead to improved academic achievement without academic rigor. Therefore, a design that connects the projects to rigorous educational goals and reflective processes, similar to those described in the CGI , dialogic talk, and collaborative learning literature (Franke et al., 2009; Mercer, 1996; Webb, 1991), is the key to successful PBL (Barron & Darling-Hammond, 2008; Thomas, 2000). In Petrosino's (1998) illustrative case study described by Barron et al. (1998), students engaged in a science project to design rockets with key PBL elements added to the traditional build and launch activity: the driving question and reflective practice. While the rocket building project is a common activity that is found to be engaging for students, the researchers found that the students could not articulate a sophisticated understanding of the underlying scientific process of inquiry. The study engaged a treatment group in the same rocket building project with the added rigor of a driving question and reflective practices. These students were able to both join in the project cycle and respond significantly better on exit interviews that explored their understanding of the underlying design principles and purpose of the experimentation.

Similar findings of engagement without increased understanding or difficulty engaging in the rigorous academic goals are found in the literature (Edmunds et al., 2017; Krajcik et al., 1998). Recommendations from PBL studies include PBL design principles that should put dialogue and metacognitive processes at the center of learning (Frederiksen & White, 1998). Further, PBL is most effective when it uses the hands-on project as a means, not an end. Therefore, it should be used to engage students in this sophisticated dialogue process and build on student engagement to increase academic rigor (Barron & Darling-Hammond, 2008).

Evaluating the Impact: Traditional Methods Compared to PBL

Studies that compare PBL to traditional learning methods have found that students in PBL classes have equal or greater content knowledge understanding and academic gains over control groups (Baumgartner & Zabin, 2008; Duncan & Tseng, 2011; Harris et al., 2015). Increased positive attitudes towards learning often accompany these gains. Teachers also have indicated positive perceptions of PBL in the classroom and its impact on student engagement (Beneke & Ostrosky, 2008; Hertzog, 2007). While traditional notions of measurable academic achievement based on standardized testing do not usually assess for the higher-order thinking and problem solving that is associated with PBL (Boaler, 1999), there is evidence of positive learning outcomes related to PBL, mainly when the instruction is expertly implemented (Fogleman et al., 2011; Harris et al., 2015).

Digital Media Production: PBL That Develops New Media Literacies

The idea of learning by doing that form the foundations of PBL were established over a century ago by Dewey (1910) and his protégé, Kilpatrick (1918). In the digital age, these principles have been aptly applied to projects that include digital media production projects that employ 21st-century creative tools. This is an emerging digital-age type of project-based learning that employs digital creative tools and software to engage students in the production of digital artifacts and media content that are meaningful to themselves and their community. Digital projects expand the traditional classroom toolset and open up new opportunities for students to engage in developing 21st-century literacies through the design and production process using relevant technologies.

New Media Literacy: Beyond Pencil, Paper, and Paperbacks

To prepare students to be 21st-century critical consumers and creators of content in a rapidly expanding landscape of multimedia, it is essential that the definition of literacy in school extend beyond the traditional tools and mediums of the 19th and 20th centuries (Barron et al., 2014; Barron & Darling-Hammond, 2008; Jenkins et al., 2006; New London Group, 1996; Share, 2015). New media literacy is a conceptual framework that has developed over the last three decades as a way to expand the definition of literacy as technology, access, and information have rapidly grown in the digital age.

It is important to provide students access to multiliteracy education and production in schools; environmental exposure at home to media does not necessarily mean that students in the digital age are media literate. Despite the ubiquity of multimedia messaging and information, a recent study found that only a small number of the 2,600 middle, high-school and college students surveyed across 12 states were able to critically evaluate the trustworthiness of internetsourced media (McGrew et al., 2018). While creating using these mediums is one way to learn about the medium, students' access to digital media production tools, and ways of using those tools, is often limited by factors related to their SES that perpetuate the "digital divide" (Barron et al., 2010; Warschauer, 2000). A body of research has aimed at developing new media literacies through the production of a wide range of digital media artifacts such as digital game design, video journalism production and podcasts (Costa et al., 2017; Hobbs et al., 2013; Kafai & Resnick, 1996; Parton et al., 2017).

Digital Youth Network: A Study of Project-Based Digital Media Production

The Digital Youth Network (DYN) (2014) is one illustrative example of the way that digital media production as a learning model has been studied. The DYN was a three-year longitudinal study in Chicago that applied the theoretical framework of media literacies developed by the New London Group and the pragmatic outline of new media literacy programs described by Jenkins (2006) to an after-school educational setting for middle-school students. The research team conducted a mixed-methods study that examined the development and implementation of the DYN as a way to provide opportunities for inner-city middle-school students to develop digital media literacies in an after-school program and compared these competencies with a control group of middle and upper SES students in Silicon Valley. The model was a pod-based learning design, in which students chose to work on projects that used digital media production tools. These long-term projects included digital music, robotics, game design, graphic design, spoken word, and digital video. The researchers found that at the end of the study, the DYN students had significantly higher confidence and ability to engage in digital production than the control group.

This study provides evidence of the potential that creative digital tools have to engage students in rigorous language-rich learning contextualized in authentic, productive and collaborative projects which simultaneously develop 21st century technical, social and academic skills. Students in the DYN had higher levels of 21st-century competencies than the control group. Also, those students who exhibited deeper engagement in their digital production activities had gains in technical vocabulary, technological expertise, social learning orientation, and creative self-efficacy.

Studio-Based Learning: A New Learning Environment

The studio-based learning model for schools in general was proposed by John Seeley Brown (2006) in his seminal vision for 21st-century learning environments. It is based on the architect studio model, where projects during all stages of the design process are always on display and discussion and critique are essential features. This model has been proposed as a way for all students to engage in ill-structure problem solving, not just those in professional practices that traditionally use the studio method, particularly as a way to address the higher-order thinking expected of 21st-century learners. The studio approach has been described as a promising design to effectively engage students in after-school programs in the design process that are situated in professional practices (Barron & Darling-Hammond, 2008).

In a study of three different types of design studios, researchers found that the key features of the studio were (1) the particular way space was used to foster collaboration and productivity, (2) the pedagogical activities that engaged participants in iterative design and public critique (3) and the development of epistemological practices that developed the ability to offer claims and rationale of project choices (Brandt et al., 2013). In this design, students participate in critical discussions of their peers' work, and in turn, are expected to articulate and defend their own design choices in presentations and discussions. The studio model adds a physical dimension to PBL because it addresses both projects and the spaces in which these projects occur and the ways that open spaces are used to share and critique ideas. While the studio-based learning model has been proposed, empirical research of its application at the elementary school level has not yet been explored. The learning design of my study was based on the studio model; attention to both physical space and the process of public critique and reflection were central features of the learning environment.

Representational Artifacts in Studio-Based Practice

A central feature of the architecture and design studio is the participants' production of artifacts to represent the proposed large scale structure such as a house or a factory. These artifacts are used to represent the proposed structure that does not yet exist, such as a hospital or a new museum, but is represented in two dimensional plans and three dimensional models (Tellioglu; 2012). In professional practices, interaction with both digital and physical representational artifacts during the presentation and discussion phase of the design process are focal points for discussion among design teams (Schmidt & Wagner, 2004). Four main categories of nonverbal interactions that are integral to the presentation and discussion have been identified: Gestures, navigation, annotation and viewing (Tory et al., 2008). The language interactions in the presentation on discussion phases of the design process are mediated by these physical interactions with representational artifacts. They are constructed by the participants in the studio to explore and iterate ideas by materializing them in sketches and models. They are also used as a materialization and representation of design ideas to present these ideas in what is known in the field of architecture as "crits" (Brandt et al., 2013; Cennamo et al., 2012). These "crits" are the critical discussion and critiques of peers, by peers, as well as the facilitator, of the presented representational artifacts. This public presentation and critique is central to the design process in the architecture design studio and central to Brown's notion of the studio model as a new model for learning environments to promote 21^{st}-century literacies. The learning design of my study was informed by this work and followed the studio model. Further, representational artifacts serve as a shared point of reference to engage in reflection, peer discussion, and critique modeled after the "crits" in a design studio.

Conclusion

In this literature review, I have presented a body of research that is connected by a common theme: the centrality and power of language to negotiate and co-construct ideas, challenge ideas, to collaborate on activities with shared goals, and to share ideas and artifacts using a rapidly expanding media landscape. I opened by exploring early childhood and the evidence that access, experience, and participation in sophisticated oral language is the foundation of literacy development and how language opportunity in early childhood correlates with academic success throughout schooling. I then examined the literature on collaborative learning as a pedagogical process in formal education that has proven to be effective. The effectiveness depends on students' opportunity to participate in sophisticated talk through active participation in small groups and engagement in constructive dialogue with both peers and teachers.

Next, I explored studies about the interactive whiteboard as a digital tool found to facilitate these collaborative processes; in particular, it has shown potential as a digital scaffold to structure students in small group dialogue, without direct teacher presence. Then I examined project-based learning, a particularly productive way to engage students in extended and meaningful collaboration with their peers. I then turned to digital media production as a new type of PBL that uses digital production tools to engage students in projects that develop their media literacy. Finally, I presented literature on the studio-based learning model as a promising complement to structure a project-centered environment. This design enables design professionals, and shows promise for children, to engage in critical reflection of design work and representational artifacts in an open public forum. My study combined digital technologies to support collaborative projects within a studio-based learning design to simultaneously engage students in collaborative academic tasks, develop 21st-century competencies, and empower them by creating digital artifacts that were shared amongst themselves and within their communities.

To explore this effort, I asked the following questions:

1) In what ways does the learning design enable kindergarten ELLs to participate in the engineering design process?

2) In what ways do children use representational artifacts to participate in presentation, peer critique, and multimedia publication during the design process?

3) What is the evidence that students engage in semiotic formations during dialogue about production, presentation, and peer critique of representational artifacts?

CHAPTER THREE: RESEARCH AND ANALYTIC DESIGN

Overview

My study examined the use of a computer-supported learning design and its potential as an apparatus that can be used to facilitate studio-based learning practices. I utilized qualitative methods that examined the nature of student dialogue related to the processes, production, and presentation of representational artifacts. This study required qualitative methods to understand the specific ways that the IWB platform was used to structure collaborative learning. Further, qualitative methods were needed to examine the nature of collaboration and dialogue within this learning design.

The problem I addressed was low literacy achievement among English language learners, focusing specifically on oral language development, and the implication this has on academic outcomes. My study examined a novel use of the IWB as a platform for small-group project-based learning and its potential as a tool that could be used to facilitate academic dialogue and 21st century competencies through project-based collaborative learning on engineering and design projects.

Research Design and Rationale

This study utilized qualitative methods to examine the nature of student dialogue among ELLs as they engaged in the production, and presentation of representational artifacts through the design process. Dialogue was the primary evidentiary source. This was focused on examining talk about what students were doing, how they were doing the work, how they were progressing in their work, challenges and responses to challenges to their progress, and dialogue about the final artifacts.

A qualitative approach allowed me to attend to talk and the surrounding context including the nuances and variation of the talk as the primary focus of the study. Through the use of qualitative research methods, I was able to explore the complex relationships among peers, the artifacts they cocreate, and ways that the whole-class technology apparatus was leveraged to facilitate these processes. Further, qualitative research approaches provided me with the tools to create systematic observations of dialogue and to leverage representational artifacts (Merriam & Tisdell, 2016) to examine the nature of collaboration and dialogue. I considered how students used representational artifacts created through this process to demonstrate their understanding within this learning design. Employing a qualitative data collection approach, I aimed to understand the specific ways that the IWB platform was used to structure collaborative learning and provide the conditions for multi-stage project development, artifact production, presentation, and publication.

Research Site

The research was conducted at City Elementary school. This site was selected because it met two requirements of the research questions. First, it was a typical urban public school that served the target population of the study: low-income ELLs. Second, it was the only known site that met this first requirement that also had a kindergarten classroom with a whole-class IWB platform. City Elementary School is a pre-k through grade 5 urban school in a large school district in the Southern California region. It is a typical urban elementary school with similar demographics to surrounding schools. At the time of the study, approximately 625 students were enrolled, of which 84% qualified for free and reduced-price meals. The student enrollment by ethnicity was 81% Latino, 13% African American, 3% white, and 4% other. Forty-nine percent of the student body was classified as English learners whose primary language was Spanish. The teaching staff averaged 15 years of teaching experience, which was equal to the district average.

The Rationale for Sample Selection

The participants in my study were the students in my kindergarten class (n= 20). The demographic composition of my class was typical of ELL classes at City Elementary in kindergarten and similar urban Southern California neighborhoods. 100% qualified for free or reduced lunch. There were two kindergarten ELL classes at my site. It was unclear how the students were assigned to either of the two teachers. According to the school district Master Plan, my class should have been 100% ELLs. However, due to a variety of circumstances, 90% of the students in my class were ELLs. It was necessary to use the students in my classroom to answer the research questions because they were enrolled in the only known class that has the whole-class IWB platform and pedagogy which was central to the research questions.

Description of Participants

To ensure that I selected participants that represented multiple ability levels, I utilized the standardized ELPAC exam administered at the beginning of the year. This test identified students' oral language ability within one of four levels: minimally developed, somewhat developed, moderately developed, and well developed. Each student I selected represented a different language level.

Ethical Issues

One ethical issue that I needed to address was that students were assigned to my class as a regular part of the kindergarten assignment protocols without initial consent from their parents. However, since the study was initiated after the end of the school year, the concern of coercion was mitigated since the students who would be contacted were no longer under my supervision;

for parents, there would be no perceived consequence for their child under my supervision if they chose not to participate.

Another ethical issue that I needed to consider was the way that student productions were used as evidence. I ensured that parents had the opportunity to consent or abstain using a modified version of the school district's Publicity Authorization and Release Form. The signed authorization form allowed video and audio of students engaged in classwork to be used for educational purposes. To ensure the participants' need for anonymity, I provided pseudonyms for both the site and the participants.

In terms of managing my role with the school site, the administration team was already aware of and supportive of the learning design. The previous year, the ELL Coordinator, the school principal, and I met on several occasions to discuss an action research project I initiated about technology integration using the same principles of this design and they were both supportive of the project. I framed my study as a way to look at alternative ways to engage ELLs using the IWB technology that were already in all the classrooms at the school and that the school had heavily invested in.

Credibility Considerations

A principal concern that I addressed was my role as both the teacher and the researcher. It is fair to raise concern that there may be conflicts of interest between my role as a teacher for the students, and as my ability to act as an unbiased observer. Teachers want their students to do well. Researchers want to have a neutral position on the data being collected. An additional threat to the credibility of the study was my potential bias as both the researcher observing the class and as the teacher of the class. There was a potential to not fully account for my role in the classroom as the teacher during the data collection periods. To mitigate the issue of observer bias as well as to increase the observation data available, video documentation is a useful tool (Jordan & Henderson, 1995). However, the standard camera has a limited field of view, which makes the question about what is happening outside the frame a valid threat to the credibility of the data. To increase credibility, I used a 360° camera to record the whole classroom, in addition to the six individual cameras. This array enabled me to accurately document my position and relationship to the students during the group work.

The effect of reactivity on student behavior during the video data collection was greatly reduced because the use of audio and video recording was present in daily activity throughout the entire school year. The screen recordings and student video productions were taken as part of the daily routine, so reactivity to that instrument was minimized.

Strategies of Inquiry

Data Collection Methods

To more fully describe my data collection approach, in the context of this study, I have linked the approach I employed to each research question (see Appendix E for a comprehensive data collection and analysis table). To identify and organize artifacts related to particular tasks within a pod-based learning design (Barron et al., 2014), I have used a similar organizational strategy.

Data collection methods for research question 1.

To investigate the first research question (In what ways does the learning design enable kindergarten ELLs to participate in the engineering design process?) I collected original digital files of student projects and original project map templates as data. I also documented the paper-based discussion protocol. To address student use of the scaffolds and project sequences, I used students' self-documentation of their physical artifacts. I also collected and saved the digital artifacts on an external hard drive. These artifacts enabled me to cross-reference the learning design goals with artifacts that provided data about how the design was actually used by students, thus increasing the credibility of the findings (Merriam & Tisdell, 2016). I also used audio, video, and digital screen capture recordings that focused on each of the three selected students as they worked in small groups on their engineering and design projects (Appendix E). I used video recording at each of the six pods, screen capture software connected to an external microphone at each pod, and a 360° VR camera set up in the center of the room. Analytically, I triangulated these sources of data to develop a more complete picture of how the students used the scaffolding mechanisms in the learning environment.

Data collection methods for research question 2. To investigate research question 2 (In what ways do children use representational artifacts to participate in presentation, peer critique, and multimedia publication during the design process?) I collected and analyzed video recordings that showed nonverbal and verbal interaction with the representational artifacts. In addition, I also used the published screen capture video to the class YouTube page.

Data collection methods for research question 3. The following was the third research question: What is the evidence that students engage in semiotic formations during dialogue about production, presentation, and peer critique of representational artifacts?

The type of data I collected was audio, video, and digital screen capture recordings from each small group. I used video recording at each of the six pods, where small groups worked, screen capture software connected to an external microphone at each pod, and a 360° VR camera that was set up in the center of the room. I used data from 64 video recordings of STEM project cycles over six weeks that also incorporated the initial pilot study data. Of these, I transcribed, coded and analyzed 15 design project cycles.

Data Analysis Methods

Research Question 1: In what ways does the learning design enable kindergarten ELLs to participate in the engineering design process?

I used a table that outlined specific project cycles and categorized the various tasks to identify key design process benchmarks associated with the learning tasks (Appendix D). The table outlined the organizing structure of each project, the goals of each task, the type of collaboration that each task elicits, and the digital tools used for each task. This table enabled me to develop a set of metrics that I used to determine the effectiveness of assigned tasks in producing each of the identified outcome expectations. Video analysis of students through the project process was used to identify the process benchmarks that they engaged in and the role of the IWB platform in supporting these processes.

I combined audio, video, and screen capture data into a single digital document for analysis using the Camtasia video editing software. I used Camtasia video editing software, which enabled on-screen annotation and editing. I analyzed the video and examined the relationship between the interactions between students and the process of production mediated by the IWB platform.

Research Question 2: In what ways do children use representational artifacts to participate in presentation, peer critique, and multimedia publication during the design process?

To analyze the way students used representational artifacts through the presentation, discussion, critique and publication, I transcribed the nonverbal actions and communication of the observations and observed the primarily nonverbal ways students engaged or referenced the representational artifacts.

Research Question 3: What is the evidence that students engage in semiotic formations during dialogue about production, presentation, and peer critique of representational artifacts?

To collect dialogue, I video recorded each of the participants. In addition, external microphones were used on occasion to improve sound quality. Also, I used the screen capture recording that the students created of their project. I used the Camtasia video editing software to combine these multiple audio and video tracks. I only analyzed dialogue related to the production, presentation, public critique, and publication of the artifacts. Within this dialogue there was evidence of academic language use and semiotic formations; these informed my understanding of students' emerging ability to engage in 21st century competencies. I analyzed the audio and video data by first transcribing them and then coding them. I also used the physical and digital artifacts produced by students as evidence of students' work. I used the dialogue features identified in appendix D, educational scripts and context-specific academic vocabulary, to analyze the ways in which students engaged in the learning goals. I employed three analytic lenses to analyze the ways that student dialogue reflected their understanding. The first combines two analytic lenses, semiotic formations (Halliday, 1978; Gomez, 2007) and the three tiers of student talk (Mercer, 1996). This was used to examine students' cumulative talk and exploratory talk through the project process and their use of the educational script to proceed through the task. The project consisted of three distinct sections: the production phase, the presentation phase, and the discussion and critique phase. The language during the presentation and discussion phases were examined for student use of phrases and semiotic formations related to facilitating discussion and engineering and design language identified in Appendix D. The production phase was primarily independent and consisted of a combination of academic talk and everyday talk. The presentation phase consisted more heavily of academic talk. Analysis of the presentation phase focused on the ways students used the IWB platform, discussion protocol, and representational artifacts to articulate their understanding of the project process and their use of academic language in this context. A third analytic lens was based on the notion of studio-based learning practices of public critique and reflection (Barron et al., 2011; Brown, 2006). I examined the presentation phase for questions and answer dialogue that was related to students' presentation of their project process and their description of the representational artifacts produced through the process. I used a rubric that assessed questions and answers based on the focus of the questions and the use of semiotic resources, semiotic formations, and educational scripts along a continuum of English language development.   The combination of these analytic lenses enabled me to evaluate the use of the IWB platform in scaffolding academic dialogue through the production and presentation of artifacts used to represent understanding, as well as its effectiveness in providing an environment that enabled public reflection and critique.

During the data collection period, I indexed the artifacts and videos by identifying and tagging language occurrences in relation to the goals (Appendix D). I used the Camtasia video editing and annotation software to do this. This enabled me to locate data during the analysis period efficiently.

Retrospective Analytic Work

An important question to address in preparing the study was whether or not the tasks to be observed, and the expected units of observation will be observable. To confirm this, I implemented the proposed tasks over the course of the 2018-2019 school year as an informal pilot study and collected video and artifact documentation. Over the course of the 2018-2019 school year, students engaged in this process one to three times every week of the school year with increasing fluency. I collected video and artifact documentation of the design process. I used the video and artifact analysis to improve the lesson design. Specifically, the design was improved by increasing the level of academic sophistication both in process and language, while simultaneously increasing the level of student autonomy through improved scaffolding embedded in the software.

I also used the video and artifact analysis to identify the task goals that were observed during the study (Appendix D). These goals were for students to engage in the five-stage design process that culminated in a public presentation, publication, and critique of the project from peers. In addition to design process goals, students were encouraged to use engineering and design vocabulary and educational scripts throughout the process. Through ongoing observation, I had found that the academic vocabulary and educational scripts were most frequently used during the public presentation, critique, and publication stages. Students were observed to use the visual framework, with occasional teacher prompts, to structure their presentation. In addition, a goal that I set for students, and they were able to meet, was the ability to appropriately self-select and use digital and non-digital tools and materials to create, document, archive, and publish their projects. These skills were an identified goal of the projects for students to develop 21st literacy literacies in multimedia creations. Based on the pilot study, Appendix D identifies the categories of student activity, language, and processes I had expected to observe in my study.

Summary

In this study, I addressed the problem of low literacy achievement and STEM participation among ELLs through the implementation and study of a novel learning design. The design leveraged the entirety of the classroom as an apparatus that combined a broad set of digital and non-digital technologies for students to engage in project-based learning. The study aimed to explore three research questions:

1. In what ways does the learning design enable kindergarten ELLs to participate in the engineering design process?
2. In what ways do children use representational artifacts to participate in presentation, peer critique, and multimedia publication during the design process?
3. What is the evidence that students engage in semiotic formations during dialogue about production, presentation, and peer critique of representational artifacts?

Data aimed at exploring these questions was gathered over six weeks. Three analytic lenses were used to analyze student dialogue, focusing on three participants. The analysis focused on the ways that students made use of engineering and design vocabulary and semiotic formations to engage in the processes, the presentation, public critique , and publication of their representational artifacts produced using the tools and structures afforded by the computer-supported environment and the IWB platform.

CHAPTER FOUR: FINDINGS

Overview

This study observed three kindergarten ELL students at City Elementary school over six weeks to examine their participation in a project-based learning environment that used the affordance of a digital platform to structure their engagement in the design process. I observed this process through a combination of video, student-produced screen captures for publication to social media for parent and community access, and digital documentation of the representational artifacts produced, described, and discussed by each participant during the engineering design process. The study's overarching aim was to demonstrate that STEM teaching and learning access, ordinarily introduced to students in the upper elementary or middle school ages, may also be accessible to young, underserved, English language learners at their earliest entry into school. Further, I wanted to examine the ways that students could use their-designed objects, both digital and physical, to elicit productive engineering and design process-specific discussion and critique among their peers in the presentation and feedback stage of the design process. While student dialogue and collaboration have been well-researched, this study is the first to specifically target discussion related to the engineering and design process in this population of students. Specifically, this study demonstrated that when these kindergarten English language learners participated in the rich and context-specific language of the engineering design process, they learned to successfully navigate a complex, multiphase project cycle, using an interactive collaboration technology platform. My findings suggest that the use of collaboration technology to scaffold the design process, combined with paper-based discussion protocols, might be one way to make this engagement, that is, design, presentation, and language use in discussion and critique, possible.

The students were charged with producing and presenting a single, shared set of representational artifacts, in the form of a three-dimensional building model, of a team-selected design project such as a new hotel or a new board game. Through the design process, participants created these projects in both two and three dimensions, as well as produced a project map which they used to organize and document each of the five phases of the design process: pre-planning, two-dimensional planning, three-dimensional production of the two-dimensional plan, testing of the product, presentation and critique with peers, and finally the publication of the project on the class website platform.

The study addressed the following research questions:

1. In what ways does the learning design enable kindergarten ELLs to participate in the engineering design process?
2. In what ways do children use representational artifacts to participate in presentation, peer critique, and multimedia publication during the design process?
3. What is the evidence that students engage in semiotic formations during dialogue about production, presentation, and peer critique of representational artifacts?

Literature

The literature reviewed for this study suggests that, under certain conditions, students can successfully participate in language-rich discussions of science and STEM concepts by planning, building, sharing, and reflecting with peers on their collaboratively constructed artifacts. It has been established that students can engage in complex procedural and problematized tasks when scaffolded by interactive software (Reiser, 2004). For K-5 elementary, research also has demonstrated that student success in collaborative learning requires teacher practices, such as probing, prompting, scaffolding, and coaching to enable the students in small groups to take on leadership roles to make progress towards independent collaborative learning goals (Webb, 2009a). Further, the literature on design projects in the field of architecture suggests that discussion within professional design and architecture studios is mediated by physical interactions and references to representational artifacts created in the design process (Tory et al., 2008). Finally, the literature indicates that when students participate in domain-specific project cycles, such as the presentation and discussion of a science fair project, they use educational scripts and a combination of everyday and academic language to engage in dialogue (Gomez, 2007).

My research questions reflect these findings in the literature. Research question 1 explored the relationship between learning design and student participation. The literature suggested that scaffolding facilitates participation, and digital-based scaffolding can be used to provide more complex scaffolding for more complex tasks than traditional tools. I expected to see the kindergarten ELLs in this study participate in unusually extensive and divergent engineering design projects and to be able to describe and reflect on the multistage project cycle using the visual scaffolding I developed both as software and the discussion protocol. Research question 2 examined the interaction between students and the digital and physical artifacts they created in the design process; I expected that these artifacts would be points of reference for students as they presented their design work.

Further, I expected that having physical objects as shared points of reference would elicit rich discussions between builders and their audience. This was because the visual reference afforded by these artifacts was anticipated to buttress the limited English language ability of the ELLs in the study. Finally, research question 3 investigated the language used by students to present their projects and the discussion and reflection with peers surrounding these design projects. I expected that students would be able to have structured discussions that employed the canon of engineering design talk.

Focus Participants

In this study, I focused on three students and the ways that they participated in the presentation and discussion of their design work in collaboration with their peers. Unlike an individual project, these participant observations were interconnected to their interactions with their teammates verbally and nonverbally during the presentations, discussions, and critiques. This is important as peer scaffolding and peer apprenticeship, supported by the learning apparatus, was a frequent source of support in the observations. The 20 students in the class were all part of the data set of observations. However, the three focus participants, Damon, Brandon, and Jason were selected because they represented a range (at 3 points) of English Language ability in the oral language ability spectrum, based on the state standardized test upon entering kindergarten. Their levels were as follows: Damon, (1) minimally developed, Brandon, (2) moderately developed, and Jason, (3) well developed.

Damon: Minimally Developed English Language Learner. Damon was initially assessed as a novice English learner with minimally developed oral language skills. He had never attended school before and was extremely shy and hesitant to participate in class for the first six weeks. However, he made significant growth throughout the year, in oral and written language. Damon also developed his confidence as a creator of multimedia and STEM projects in the class. Damon's father, a construction worker, commented on how much Damon enjoyed school, specifically the daily hands-on STEM and building projects. In the final 6-weeks of the class, during the time of the study period, Damon showed a particular acceleration in leadership and risk-taking with public speaking. His participation in the presentations and discussions of design is marked by a general ability to participate in the general conversations, as well as an eagerness to help guide others, with a limited ability to apply the more sophisticated educational scripts.

Brandon: Moderately Developed English Language Learner. Brandon had spent the previous year in transitional kindergarten; his summative assessment before entering kindergarten identified his English oral language skills as moderately developed. Brandon entered kindergarten well prepared for an academic environment. From the beginning of the year, he was an eager and frequent participant in group work and discussions, and well regarded as a leader and "expert" among his peers. His participation in the presentations and discussion of design projects during the study period is marked by a strong ability to navigate the digital platforms and apply educational scripts.

Jason: Well Developed English Language Learner. Jason was initially assessed as having well developed English oral language skills. He entered kindergarten as an active participant in daily academic and social activities. Compared to Brandon and Damon, his oral language was more advanced, with fewer grammatical errors. His strong interest in soccer was a frequent source of inspiration for his writing and STEM-related projects throughout the school year. During the study period, several design projects he was involved in were related to soccer. His participation in the presentations and discussion of design projects was marked by a consistent application of educational scripts and demonstration of a strong ability to share leadership roles with peers.

While the study focuses on these three students, all of the students in the classroom were a part of the study data. I included all students in the experience because I wanted to consider (1) how these three participants engaged in the digital and physical scaffolded elements of the learning design, and (2) how the three focal students negotiated and shared this space with their classroom peers in the design teams' effort to present and lead their design project discussion.

In the following analysis, I report the findings of how these three participants engaged in the presentation and discussion phases of the design process through the perspective of three analytic lenses to examine each of the critical elements of the learning activities: structure, artifacts, and language. I describe the learning environment associated with the design activities, the design tools and scaffolding, what the students said and did, and how language was supported, developed, and extended in expected and unexpected ways among the group as well as with the three participants.

Findings

Themes

Three overarching themes emerged in the coding of the transcripts. Each of the three themes aligns with each of the three research questions. In this section, I present the findings under the umbrella of each theme. Each theme is associated with one of the following dimensions of the learning environment: structure, artifacts, and language.

The first theme is tied to the architecture of the learning environment. This is the structure of the learning activity itself and the evidence in the data that demonstrates the ways that the engineering design process, from ideation to planning, building, documenting, and discussion are structured and problematized by the embedded elements in the technology platform and discussion protocol. The findings suggest that scaffolding the design process enabled the students in this study to successfully participate in production, discussion, and critique related to the design process. The findings demonstrate that students used the interactive digital project map throughout the design process to scaffold planning, production, and presentation of their design projects. When presenting their design project, the data suggests that students used the scaffolds to document multiple stages of the design cycle; ideation, planning, and building. This documentation, intentionally organized within the graphic layout (Appendix A), in turn, provides the structure for a rich and systematic oral presentation. The data shows that student talk was paired with the nonverbal use of the digital project map or the discussion protocol across the observations. Digital tools as effective ways to scaffold student talk are previously identified findings in discussions related to scientific argumentation (Reiser, 2004) and language arts (Mercer et al., 2010) but previously unidentified in the engineering design process.

The second theme of findings is related to the ways that the representational artifacts created by students, throughout a design cycle, and produced with guidance from this scaffolded design are used to enable robust discussion through a combination of verbal and nonverbal interactions. The findings suggest that representational artifacts are an essential feature of learning in this study. The data shows that these artifacts are the materialization of cooperative decision making and problem-solving during the building and planning phase of the design process. Students consistently referenced these artifacts as they presented, discussed, and critiqued. These references were verbal, nonverbal, and tactile in actions that talked about, gestured towards, and manipulated the artifacts. The data also shows that these artifacts were central points of shared reference that initiated dialogue between design teams and their audience in multiple instances across all observations during the discussion and critique phases of the design process. This finding among kindergarteners that language was tied to design artifacts is similar to a previously identified finding that had been seen in the design coordination process between architects and engineers that used a combination of physical and digital design artifacts and presentation tools through a 7-month design process (Tory, 2007). However, this is a previously unidentified finding specifically among communities of primary age students engaged in the engineering design process.

The third theme focuses on language related to the engineering and design process. The transcripts reveal that participants, supported by the architecture of the learning design *and* having a robust set of physical and digital representational artifacts to share and discuss, consistently engaged in systematic patterns of language that reflected the semiotic formations and nomenclature in the canon of engineering and design fields. The level of sophistication varied among the participants along the lines of the students' ELL levels. Each was able to participate in the presentations, discussions, and critiques. The findings suggest that sustained, student-led design talk among kindergarten English language learners is possible if the learning environment is scaffolded, *and* the tasks involve hands-on multidimensional (2D and 3D) projects. Effective use of educational scripts is a previously identified finding that had been seen among middle school students engage in the presentation of science projects (Gomez, 2007). However, this is a previously unidentified finding specifically among kindergarten English language learners using scripts to participate in the engineering design process.

Theme one: Learning Design enables Participation through Construction and Discussion

"Design is concerned with how things work, how they are controlled, and the nature of the interaction between people and technology."

Donald A. Norman, The Design of Everyday Things (1990)

Finding #1.1: The digital project map enables students to self-document each stage of the engineering project cycle through a combination of graphic, text, and embedded audio prompts. In this phase of the study, students used the digital project map to structure their self- documentation through the design process. The students used the project map throughout the project cycle to maintain a record of each step of the engineering project cycle. The project maps consisted of prompts intended to elicit student documentation using a combination of writing, photos, and audio recording (Appendix A). The building design map consisted of 10 prompts, and the game design project map consisted of 14 prompts. On average, 91% of the prompts designed to elicit documentation were addressed, as evidenced by an analysis of the documentation on the 15 project maps examined in this study. The following artifacts show the way that Brandon and Jason documented their swimming pool design using a combination of writing, photographs, and audio recording during the design and build of the project. This artifact was typical of the high level of completion found in these artifacts. Triangulation of this set of documents with the video of these students engaging in the process confirms that the documentation followed the order of the design process outlined in the interactive design process flow map.

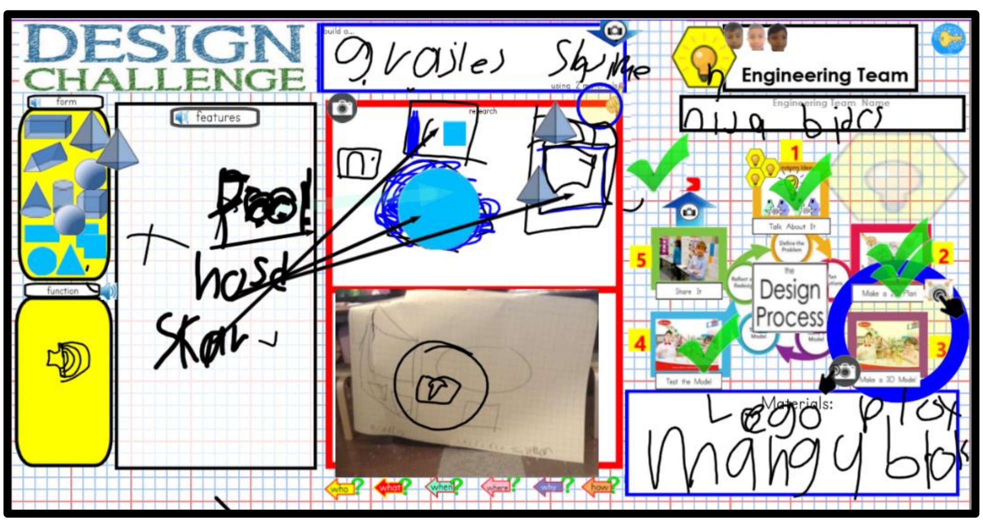


Figure 1. Interactive project map, swimming pool design project.

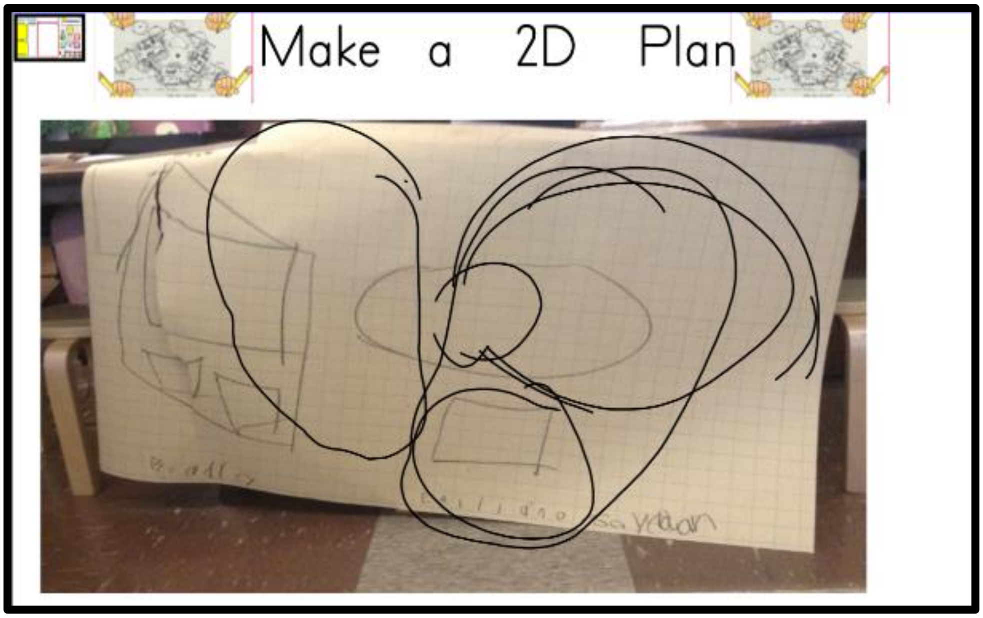


Figure 2. Photo documentation of hand-drawn 2D plan, page 2, hyperlinked from page 1 student photographed and arranged.

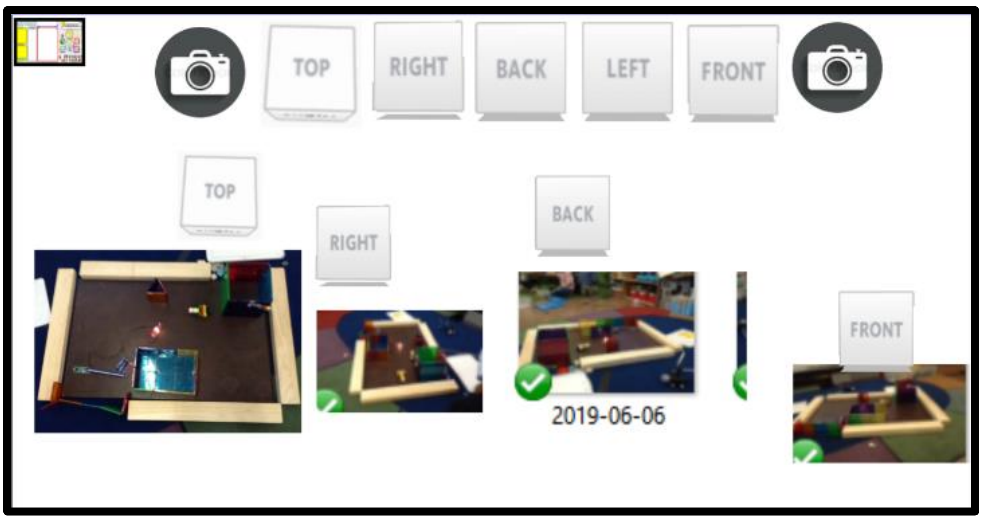


Figure 3. Photo documentation of 3D build, page 3, hyperlinked from page 1 student photographed and arranged from multiple perspectives.

The first page of this 3-page digital document (see Figure 1) shows that the students identified and recorded the members of their engineering team, selected and recorded an engineering team name, and systematically checked off each stage in the design process using the green checkmarks. The students identified and documented the building design to make a graduated swimming pool "grajies swime." This was a reference to a graduated cylinder filled with water frequently used during science experiments. They created an initial sketch of their design idea in the research box, identified the basic 2D and 3D geometric forms that are common in the swimming pool structure. They used the audio recording feature to describe the function of the structure. The audio recording transcript was the following: "The function of the structure is to swim [in]." The students also identified and labeled the basic features of a swimming pool. During the planning phase, the students documented the materials they planned on using for their model: Legos and magnetic blocks. At the end of the planning phase, the students photographed, uploaded, and organized their 2D drawing plan on the main page of the project map as well as a hyperlinked page within the document (Figure 2). Finally, after the building phase, students photographed their model from multiple perspectives: top, right, back, and front (Figure 3). The students uploaded and organized these four photographs, as well as used the interactive perspective elements to label each picture and the perspective it represented. The 10-14 cues embedded in the map provided these students with sufficient guidance and structure to sustain focus on the learning objectives over the course of the 45-minute design-build project.

Finding #1.2: Students rely on the scaffolding embedded in the digital project map to present descriptions of their projects. In this study, the digital project map was used by student teams to help describe their project. Video analysis shows that each participant, in coordination with their design team, engaged in the presentation phase using the project map as a visual and interactive road map. This analysis was conducted by observing students' nonverbal actions while speaking and presenting their design projects to their peers, triangulated with their original digital documents. They also were able to use the map as a display of their digitally documented artifacts. The precision of design language varied, as did the adherence to the educational scripts that made up design presentation. However, invariably student talk was paired with nonverbal use of the completed project map to help articulate what they did.

The following three excerpts illustrate the spectrum of English language sophistication produced while scaffolded with the same project map template. They are presented in order of language level, from Damon, level 1, to Brandon, level 2, and to Jason, level 3. In the first excerpt, Damon and his team presented their design work to plan and build a rock park. This example illustrates the on-task presentation of design elements paired with continuous reference to the project map, but with minimal use of formal educational scripts, typical of Damon throughout the observation period. The second and third excerpts, in contrast, show Brandon and Jason using each cue on the project map to systematically and succinctly present their projects using the graphic and text cues to also support more formalized design language.

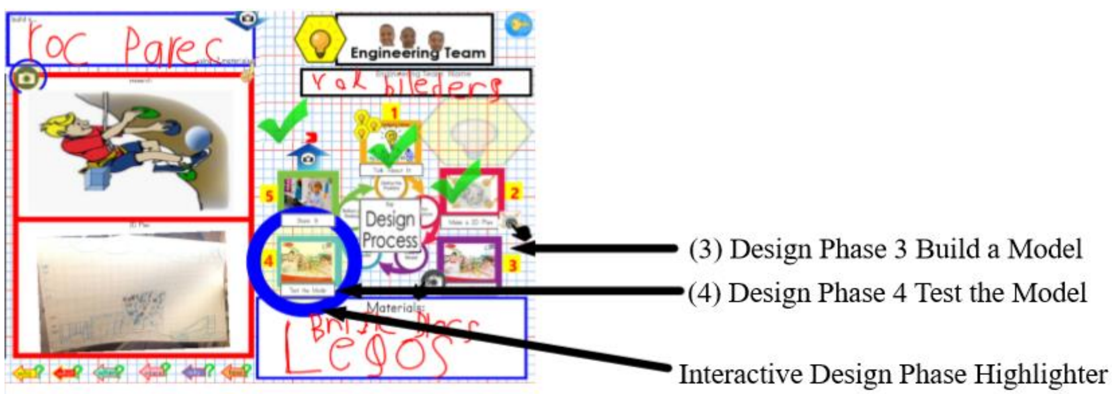


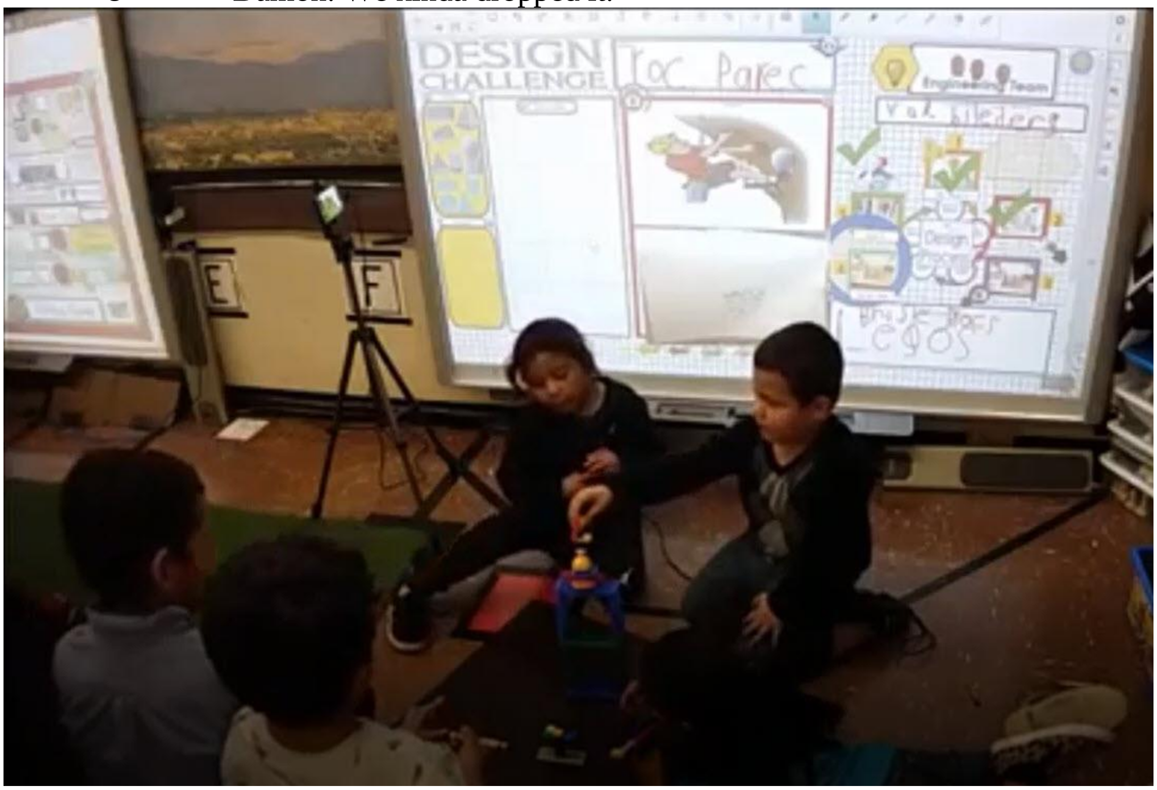
Figure 4. Graphic scaffolding in the project flow map and interactive highlighter.

Phase on project map	Line	Transcript Text *Damon's design team present and discuss their Rock Park design/build project*
(3)	1	Josie: And in the middle is the rope for they can hang on. And we have something in the top. I don't know what it's called.
(3)	2	Damon: That's the roof.
(3)	3	Damon: We forgot to **build** something right here.
(3)	4	Josie: Yeah. And this is my character. And this is the floor. And this is the floor also, it stick together.
(3)	5	Josie: And then, for he can climb.

(3) 6 Damon: I'm all the way at the top.

(4) 7 Josie: And we test it. And then we **tested** it and all the time we move it, it falls.

(4) 8 Damon: We kinda dropped it.



"And then we tested it and all the time we move it it falls."

This excerpt began during phase 3 of the presentation phase, describing the 3D model and ended after the team transitioned to phase 4 of the design process, testing the model for structural integrity. In this excerpt, Damon, an ELL level 1 student, focused on the description of his design project to create a rock gym park. The visual cues in the project flow map and interactive highlighter (see Figure 4) served as graphic and tactile guideposts for Damon to focus on describing the team's design moves between the build and test phases. Josie, an ELL 3, initiated the talking about design phase 3, stating, "And in the middle is the rope for they can hang on. And we have something on top. I don't know what it's called." Damon was able to add on. He was also able to specify a structural feature of his model; he pointed and said, "That's the roof," (turn 2). Josie, an ELL 3, had a greater facility applying the scripts, and Damon let her take a dominant role in the presentation. However, He demonstrated that he understood and was actively listening and able to participate by adding on to Josie's statements and that he could contribute key vocabulary and details from the design process. On line 5, Damon's focus began to diverge from the presentation of the model; he began to animate the Lego character at the bottom of the rock gym and said, "I'm all the way at the top" (turn 6). However, Josie continued to follow the flow map and transitioned to describe phase 4, the testing phase, of the design process. She stated (turn 7), "And we test it. And then we tested it and all the time we move it, it falls." Damon refocused and participated in the systematic description of the design process phases adding on (turn 8), "We kinda dropped it." He demonstrated his developing understanding and his growing ability to participate in describing the stages of the design process by recollecting what happened during the testing phase of the rock gym and sharing that event of the structure "dropping" with his peers.

The presentation followed the pattern of describing elements of the design, but the transitions from each phase of the design process were initiated by his partner, Josie. Damon focused on describing the features of his design project but did not attend to the additional elements of the design process. The combination of graphic scaffolding paired with a more capable peer enabled Damon to participate as a team member in presentations and discussions in similar ways throughout the observation period of the study.

In contrast, the following excerpt illustrates the way the project map scaffolded Brandon, the participant with a more advanced English level, to present the design process with the added sophistication of educational scripts embedded in the visual cues of the project map. For Damon, the graphic layer of scaffolding served as a cue to help him stay focused on developing an expanded description of his project through design phases using everyday language. Brandon moved beyond description with everyday language and some formal vocabulary; the text layer of scaffolding cued him to apply engineering specific language throughout in a way that demonstrated an understanding of the design process using a combination of extended description and application of precise academic vocabulary.

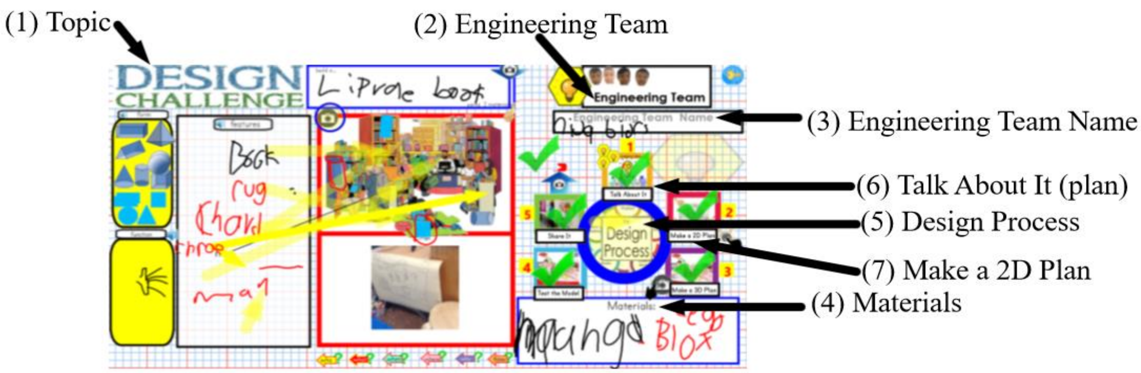


Figure 5. Text scaffolding in the project map.

Alignment on project map	Line	Transcript Text *Brandon and Jason's design team present and discuss their Library design/build project*
(1)	1	Alexander: *{Looks at title on project map}* Today our ... our **topic** is library book .
(2)	2	Brandon: *{looks at the engineering team box on the project map, Jason points at the list with a pointer}* And our **engineering team** is me, Jason, Emilio and Alexander.
(3)	3	Alexander:*{looks at team name box on project map}* And our **engineering team name** is Ninja Builders.
	4	Alexander: Our engineering topic-
	5	Brandon: *{Jason points at Design Challenge box, Brandon looks at box}*Our building and engineering is we make a library book.
(4)	6	Brandon: *{Jason points to materials list, Brandon look at list}* We used **materials**: Magnets, blocks, and Legos.
(5)	7	Brandon: *{Looks at design phase flow map, move indicator to phase 1}* And we used the **design process**.
(6)	8	Alexander: First we **talk about it** *{moves design phase flow map indicator to phase 2}*
(7)	9	Alexander: And first (second) we **make a two-dimensional plan**
(7)	10	Jason: And this is our **plan** *{selects hyperlink to 2D plan}*
	11	Brandon: *{circles element in 2D plan using digital ink}* this is the book.
	12	Jason: That's the bookshelf, over here *{points at 2D plan, then points at 3D model displayed in front of project map}*

"Our building and engineering is we make a library book."

The layout of the project map worked as a set of guideposts to guide students through a structured presentation. In this example, Brandon followed these scaffolds by physically moving the interactive elements to identify for himself and his peers where he was on the road map of his presentation. In turn 1, Alexander initiated the presentation by first looking at the title box on the project map and then announcing, "Today our … our topic is library books." Figure 4 shows that the Design Challenge fillable field was one of the first embedded prompts that the design team addressed, and the visual cues helped maintain that order. The segmentation of prompts was also used to help students negotiate turn-taking; when Alexander completed his introduction, Brandon took this as a cue to take on the presenter role. In turn 2, he first looked at the engineering team field on the project map. Then, after Jason pointed at the team members documented in the field, Brandon stated, "And our engineering team is me, Jason, Emilio, and

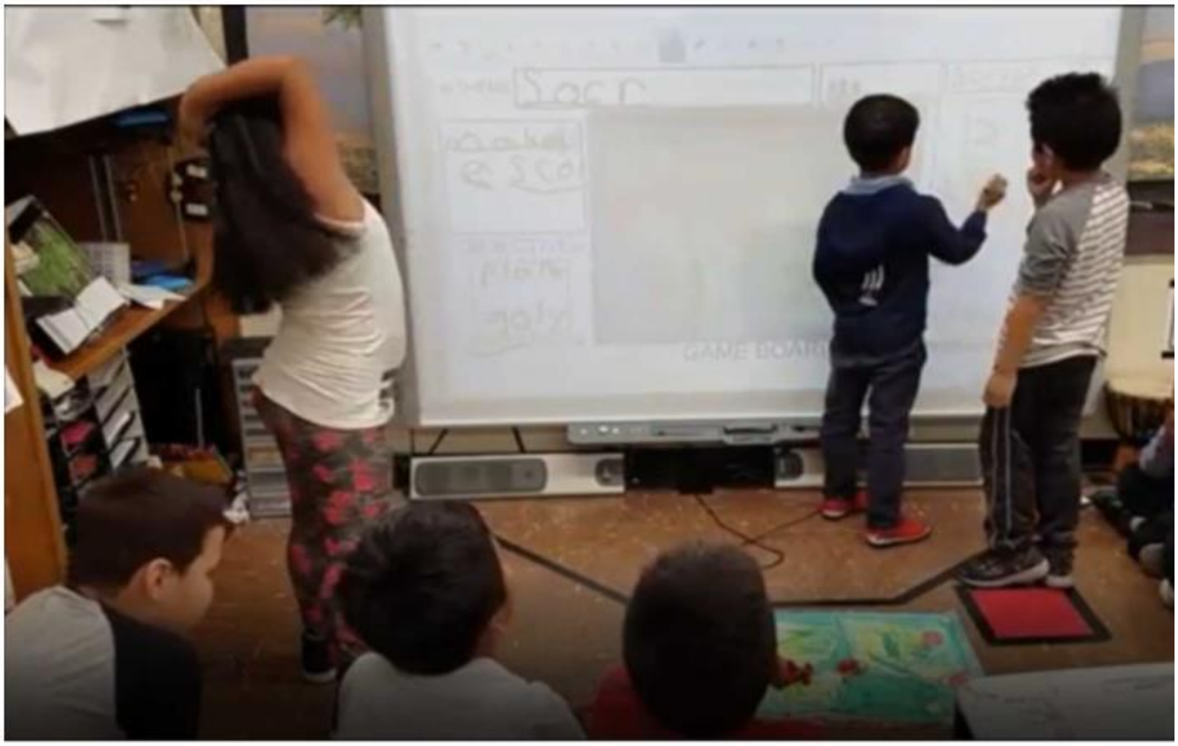
Alexander." This verbal listing followed the order that the team members were documented in the map, suggesting that the graphic and text elements of the map helped him to construct his response. Brandon's partner then pointed to the materials section on the map. In turn 6, after Brandon looked at the list, he reported the team's material choices: "We used materials: Magnets, blocks, and Legos." Like the presentation of the engineering team members, this corresponded with the order listed in the Materials frame.

At each turn, Brandon and his design team had at least one kind of interaction or reference with the project map before speaking, and these nonverbal references are evident in the verbal presentation. In line 7, he physically moved the interactive digital highlight; that move corresponded with him describing the next phase. Brandon looked at the design phase flow map, reset the phase indicator to phase 1, and stated, "And we used the design process." Brandon used the elements of the map in three ways; first, he used it to move forward with the presentation. He was able to advance the presentation without teacher prompting. Finally, he employed the key design vocabulary, "we used the *design process,"* that was centrally displayed on the process map. Though these individual instances are brief, they occur throughout this presentation.

The following excerpt illustrates how Jason, like Brandon, used the project map scaffolding to describe the design by following the cues and structure of the project map, and he additionally was able to apply the more sophisticated scripts by following the scaffolding. He demonstrated a systematic approach to presenting his game design, and with greater sophistication than Brandon, aligned each statement about his team's project with one of the graphic and text cues on the design process map.

Figure 6. Game design project map.

Phase	Line number	Transcript Text *Jason's design team present and discuss their soccer game design/build project**some text has been omitted to focus on Jason's responses
2	1	Noel: Today we're gonna share our game design about soccer.
3	2	Jason: The objective of the game is to make a score on the goalie, and I forgot to write that.
4	3	hyperlink prompt: *{Jason selects the hyperlink prompt} Who are the characters in your game?*
4	4	Noel: The characters in our game...
4	5	Jason:...is the soccer player and the goalie.
4	6	Jason: The characters are the soccer player and the goalie.
5	7	Jason: *{selects hyperlink recording of himself} The first rule is no hands.* The first rule is no hands.
5	8	Jason: Say *{selects hyperlink recording of Noel} Second rule no kicking feets*.
5	9	Jason: *{selects hyperlink recording of Noel}Rule four, no jet packs*. Rule four, no jetpacks.
6	10	Jason: And our mechanics its three dice,
1	11	Jason: ...and our team name is Soccer Builders. And our logo is a happy face.
7	12	Jason: And this is the game board.



“And our mechanics it’s three dice…”

In this example, like the previous, the design team presented their project in an order that mapped onto the structure of the project map. Jason, a more advanced ELL in comparison to Brandon and Damon, exemplified the way the project map can scaffold a further sophisticated and concise presentation of the design. He led the presentation and systematically presented the key elements of the game design with his peers using semiotic formations that reflected the scaffolding. In lines 1-2, after his teammate announced, "Today we're gonna share our game design about soccer…" Jason immediately described the elements of the game design by following a counterclockwise pattern that matched the layout of the project map.   It is evident from the triangulation of the transcript with the project map document and the nonverbal actions in the video that he used the structure of the project map to structure his presentation. Starting from the top, his team presented the game elements in counterclockwise order as it appeared on the project map. Jason initiated the presentation by introducing the game theme, which was positioned at the top of the project map. He stated, "The objective of the game is to make a score on the goalie." He immediately followed by indicating a prompt he did not complete. He said, "...and I forgot to write that." He was aware that the embedded prompt was designed to cue written documentation of this game element.

However, it is also evident that Jason and his team did not strictly match the procedural order of the design process with the order in the presentation. During the project cycle, Jason led his team effort to proceed through the game design process methodically; they determined a design project, documented the team members, determined a game design team name, and then designed a team logo. During the project, these elements were the first to be decided. However, during the presentation, these were the last to be shared (line 12). This suggests that the graphic layout in the project map was not sufficient in always helping the students map precisely the order of what they did with the order of their presentation.

Finding #1.3: Participants use the discussion protocol to structure the discussion and take on the role of facilitator

In this study, students successfully used the discussion protocol to take on the role of facilitator without teacher support in 92% of the observed exchanges. The discussion protocol is used by student teams to engage in the feedback process with peers. They solicit and respond to feedback using the protocol (see Appendix B for an in-depth description of the protocol). Peer feedback and the process of challenging and justifying ideas are essential for children to develop critical thinking skills (Gillies, 1996) that are central practices in the field of engineering and design (Tory et al.,2008). Children can take on leadership roles that facilitate this practice if this practice is scaffolded and taught by the teacher (Webb, 2009a).

The following exchange illustrates one way that students use the discussion protocol in 13 of the 15 observations to scaffold the 3-part discussion structure. It also shows how the protocol is used as an object by students to represent the role of facilitator and, in turn, negotiate leadership. This plays a significant role in a student-driven discussion as it enables students to systematically share the role of facilitator and simultaneously move the discussion forward with minimal intervention from the teacher.

Line	Transcript Text *Damon and Jason's design team present and discuss their race car board game design/build project*
1	Amy: What does critique mean?
2	Jason: Let me get it *{walks away from group, returns with discussion protocol, hands it to Damon}.*
3	Damon: Critique means, like, a sad face *{Jason hands discussion protocol to Damon, Damon shows discussion protocol to Amy}*
4	Amy: Oh!
5	Damon:*{hands-off discussion protocol to Jason}*
6	Jason: *{looks down at protocol}* One question? Milagra.
7	Damon: No *{looks down at protocol with Jason, points}* one like *{looks at protocol, confirms order}.*
8	Jason: *{looking at protocol}* One like.
9	Milagra: I like about your thing, you did your cars, and you did your thing fast *{looks at the 3D model while speaking}.*
10	Jason: That was not even fast, that took a long time. Thank you for that like *{looks at protocol, holds it in front of his face}.* Second like, Amy.
11	Amy: I like how you made the cars *{looks down towards the car model}*.
12	Jason: Thank you for that like, Amy *{looks down at discussion protocol}*. Questions, *{looks down at discussion protocol}* any questions?
13	Andrew: My turn, you gotta to take turns*{hands pointer to Damon, reaches for protocol, Jason keeps hold of protocol}.*
14	Jason: Any questions, any questions?*{looks at protocol}*

"Critique means like a sad face."

In this excerpt, student talk was paired with nonverbal references to the discussion protocol. This excerpt began at the transition between the presentation and discussion phase. The students had just finished describing their race car game to their peers and were ready to initiate the discussion and critique phase. In turn 2, Jason helps prepare for this systematic dialogue by first retrieving the discussion protocol. Amy, an audience member, asked, "What is critique?" after the team announced that it was time for "critique." Jason, a member of the design team, responded to Amy by saying, "Let me get it," referring to the discussion protocol. When he returned, he handed the protocol to his design partner, Damon, and Damon in turn 3 responded to Amy, saying, "Critique means, like a sad face." At the same time, he showed her the protocol, and she replied, "Oh!" possibly indicating that she understood. The language Damon used to explain "critique" was limited to everyday language; he associates it with "a sad face," possibly referencing the like/suggestion element of the discussion. However, his actions demonstrated that he understood critique as part of the discussion process. After handing the protocol to his partner, Jason, he helped him proceed through the compliment/question/suggestion phases. In line 6, Jason asked his peers, "one question?" Damon, pointing down at the protocol, indicated to

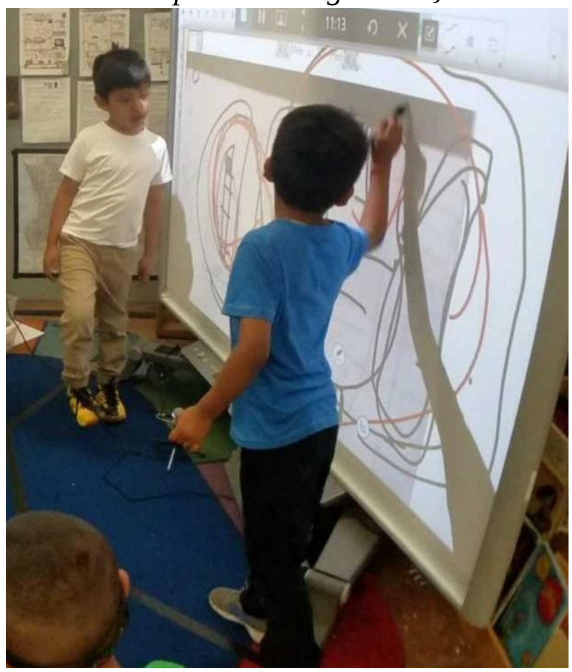
Jason that the protocol of the critique was first to offer compliments. He pointed at the protocol and said, "No. One like." Jason accepted Damon's guidance, but first conferred by looking at the protocol, and in line 8, changed his request to his peers from a question to a compliment. This exchange between group members as they attempted to conduct the discussion process by pooling their varying degrees of understanding of the process to navigate it successfully as a team was typical in the observations.

The discussion protocol was also used among group members as an object that represented who the facilitator was. Jason, after first retrieving the protocol in line 2, handed the protocol to his partner Damon. This move indicated the speaker's role, and Damon then, only after holding the protocol, responded to his peer's questions. The facilitator role was often fluid across the observations; Damon’s actions illustrate this when he then handed off the protocol back to his partner Jason. Once Jason held the protocol, he looked down at it and proceeded to initiate the discussion. Even when Jason mistakenly began the discussion in line 6 by soliciting a question, Damon did not interrupt his role as the facilitator. Instead, he spoke directly to Jason and reminded him that compliments were the first phase of the discussion. He did not take over as the facilitator but instead helped his partner facilitate according to the protocol. Student leadership, enabled by the scaffolding of the graphic discussion outline indicated in the protocol, combined with the cue that the student holding the protocol was the facilitator, enabled the discussion to proceed primarily as a student-led process. This example illustrates the way students were able to use the discussion protocol throughout the study. In the 13 observations where students used the protocol, 90% of the 116 exchanges were facilitated independently by students. Moreover, in 92% of these exchanges, students asked and received responses in accordance with the protocol: compliments were offered during the compliments phase, questions were posed during the question phase, and suggestions provided during the suggestion phase.

Finding#1.4: I relied on the embedded scaffolding to support students through the design process and develop students' ability to use the scaffolding independently. In this study, most of the classroom talk was peer to peer dialogue, and the majority of teacher talk was aimed at facilitating peer dialogue and scaffolding students through the design process. 84% of all conversation during the observations was student talk, compared to 16% teacher talk. In nearly a third (32%) of these teacher-initiated exchanges, I referred directly or indirectly to the project map or discussion protocol when facilitating student dialogue. The exchanges I had with the students were also used to model for students how to use the project map and discussion protocol scaffolds. In addition to findings 1.1-1.3, where the embedded scaffolds were used by *students* independently, as the facilitator, I *also* used the embedded scaffolds as guideposts to reinforce patterns of design talk and discussion. The following examples illustrate some of the ways that I used the shared scaffolds to guide students through the presentation and discussion phases of the design process. The examples spotlight the role the interactive scaffolds played for me as the facilitator.

Line	Transcript Text *Brandon's design team present their town design/build project*
1	Teacher: All right, so you're done with the features *{referring to the Features section of the project map}*. Good. You talked about it *{referring to Phase 1 on the interactive road map}*.
2	Brandon: Check *{referring to project map road map}*.
3	Damon: Check.
4	Brandon: Now, it's time for make a 2D plan.
5	Teacher: Yeah, tell us about your plan, your 2D plan*{referencing Phase 2 on project road map}*.
6	Frank: This is our 2D plan
7	Teacher: And, how did you improve it? How did you improve your design?

8 Arturo: The plan was to make a cone on the top.
9 Brandon: The 2D plan is to make it more better.
10 Teacher: But, how did you make it more better? ‘Cause I see that you made some changes to your plan. What did you do to make it better?
11 Arturo: I made. I made it better so I made a passcode on each triangle door.
12 Teacher: Show where that is on the plan.
13 Brandon: *{circles element on the plan with digital ink}*



“What did you do to make it better?...Show where that is on the plan.”

In this exchange, the two members of the design team were at the initial stage of their presentation; they had finished describing the main feature of the Town design. From lines 1-5, my role as the teacher, I engaged with them, using the project map as a shared reference, by narrating the systematic progress and procedure. I observed and noted, “All right, so you’re done with the *features*. Good. You talked about it." I used phrases and terms that were linked to the graphic and caption elements of the project map, a visual reference shared by all participants: the design team, the peer audience, and myself as the facilitator. By highlighting these as guideposts during the presentation, I identified to the presenters and the peer audience the importance of confirming and addressing the procedure laid out in graphic and interactive elements of the project map. I used this interaction, and interactions similar to this in the study, to communicate to presenters and the audience the procedural expectations during the planning, building, presentation, and discussion. The presenters immediately responded by saying "check" and simultaneously moved the interactive checkmark on the project map to the checkbox on the road map.

In the following turn, Brandon interacted with the project map, moved the interactive highlight from the initial discussion stage to the 2D planning stage, and said, "Now it's time for make a 2D plan." In my role as the teacher, I helped rephrase this, referring to the project map, responding, "Yeah, tell us about your plan- your 2D plan." This comment was a reference to stage 2 of the design process road map with the graphic element of a 2D architectural plan paired with the text "2D Plan". I used the shared visual reference to develop further Brandon's range of grammatical structures that the project map was designed to elicit but were not explicit. Brandon, initially having used the road map and the 2D plan signpost to "make the 2D plan," mistakenly used that same phrase when referring to it as a past activity that was presented to his peers. I clarified how to use the "2D Plan" signpost and the multiple educational scripts it could elicit. When producing the plan, Brandon could employ the script with his teammates "now we make the 2D plan." Brandon reframed that semiotic resource, "2D Plan" within a new semiotic formation, "Now we will tell you about our 2D plan". As opportunities like this arose throughout the study, as the teacher, I used them to extend the range of semiotic formations employed by the students and increased their ability to use the graphic and text clues embedded in the scaffolding to trigger these scripts.

As the teacher, I could also use the embedded scaffolding in the project map to support my effort to encourage students to combine the semiotic resources embedded in the layout to describe their activity. The following example illustrates the way that I used nonverbal cues to refer students to the project map as a visual cue to elicit the design team to form a more detailed announcement to let their peers know they were ready to initiate their presentation.

Line	Transcript Text *Damon's design team present their restaurant design/build project*
1	Milagra: We're ready to present.
2	Teacher: Present what? Be specific *{points to project map}*.
3	Milagra: Our, our... *{looks behind her at project map and to Damon}*
4	Damon: *{Looking at the project map then at Milagra}* Our Design Challenge.
5	Milagra: Our Design Challenge...
6	Damon: Our Design Challenge {*looks at Design Challenge: Restaurant fillable field 1*} is to make a restaurant.

"Present what? Be specific."

Sometimes, as exemplified in this excerpt, the teacher support I provided was brief but sufficient because it redirected students to use the embedded scaffolds of the project map. This exchange began when Milagra initiated her presentation of a design project to create a restaurant by stating to her classmates, "we're ready to present." This statement was sufficient to initiate the presentation, but, as the teacher, I used the project map scaffolds to help the student to expand her announcement. In line 2, I referred to the Design Challenge fillable frame, "Present *what?* Be specific." I maintained eye contact with Milagra, and pointed towards the project map. It is evident that this direction to follow the project map was a sufficient cue; Milagra turned and looked at the project map, then to Damon. She then responded, "Our..our.." Her response indicated that she understood the cue, and was working through connecting two semiotic resources, "present" and "design challenge." Her partner Damon recognized her struggle and, in a quieter voice, and taking on a peer mentor role, helped her with the formation. He said, "Our Design Challenge," which Milagra then repeated in a volume high enough for the entire class to hear. Damon completed Milagra's initial announcement, "We're ready to present…" by announcing, "...our design challenge to make a restaurant." Initiated by my brief prompt in line 2, the student team was able to formulate a series of short phrases “We’re ready to present. Our Design Challenge… is to make a restaurant” that together, were developing towards the target semiotic formation: "We're ready to present our design challenge to make a restaurant." Both ELL students, with my support as the teacher, were working towards a more sophisticated formation. These findings suggest that the same scaffolds that are useful to students to work through the design process are also valuable to the teacher to provide additional support to students as they develop their abilities to participate using these educational scripts and procedures.

Theme two: Representational artifacts serve as shared reference points among students that elicit dialogue

“Children don’t get ideas, they make ideas. Constructionism suggests that learners are particularly likely to make new ideas when they are actively engaged in making some type of external artifact which they can reflect upon and share with others.”

Kafai & Resnick, Constructionism in Practice: Designing, Thinking, and Learning in A Digital World (1996)

Finding #2.1: Representational artifacts are used by students to present their designs to their peers and engage in peer discussion. Interactions with digital and physical representational artifacts were pervasive and integrated across the observations of students sharing their design projects in the study. This observation was in line with the idea of the function of cognitive artifacts (Norman, 1991) as well as findings from professional design work where the construction of artifacts is essential to eliciting detailed description, reflection, and discussion related to the design process (Cunningham and Lachapelle, 2014). The importance of the 3D and 2D representational artifacts are evident in the following example, which is representative of the centrality that the paper and digitized plan and the physical models had in eliciting discussion about the design projects throughout the study.

Line	Transcript Text *Jason, Damon, and Brandon’s design team present and discuss their bakery design/build project*
1	Jason: *{presses hyperlink on project map, links to digitized 2D plan}* And this *{points to 2D digitized plan with finger and pointer}*
2	Jason: Brandon, what was this? *{points to 2D digitized plan looks at Brandon, looks at plan}*
3	Brandon: You remember the thing? The bread.
4	Jason: This is the bread *{pointing to 2D plan}*
5	Damon: The bread's right here *{walks up to 2D plan, points}*.
6	Brandon: That's the cake *{points, touches 2D plan}*.
7	Jason: ... and this is the bread *{touches interactive project map}*.
8	Jason: *{walks to Damon, hands him the pointer}*
9	Damon: This is a circle,
10	Damon: ...*{walks from 2D plan to 3D model}* like the window right here *{points to 3D model with pointer}*

11 Teacher: Oh, right. So, we can see the same thing where they built it. Great. Thank you for pointing that out.

"...and this is the bread."

In this exchange, the three members of the bakery design team used the interactive project map to present two representational artifacts of their design project: the two-dimensional plan of the bakery and the three-dimensional model of the bakery. The students engaged in a discussion that hinged on these shared visual representations as the point of shared reference among the design team and their colleagues.

Language was integrated with the nonverbal interactions with the artifacts. In line 1, Jason began with nonverbal actions; he hyperlinked to the digitized 2D plan that he had drawn on graph paper with black crayon earlier and documented with a digital camera. He then examined the project plan and said, "and this…" However, he paused and asked his partner to help clarify the plan. He asked, "Brandon – what was this?" making a circle gesture around the unknown element. Brandon responded, "remember the thing?" suggesting that he believed that they had a shared experience and understanding of the artifact.

Brandon asked Jason to remember. When he did so, I argue, Brandon assumed that the artifact's meaning was shared. By asking Jason to "remember" suggests that the artifact was an important element in the team's process and it aided team members as they presented that process as a shared memory (Fiore & Wiltshire, 2016). This suggests that Brandon and his team depended on this shared artifact to function similarly to the shared digital documentation; it was used as a shared cognitive artifact that augments their ability to recall their design project. Norman (1991) describes artificial devices in general as cognitive artifacts if they "serve to maintain, display, or operate upon information in order to serve a representational function and that affect cognitive performance." The students in this example move between the digitally documented representations and the representational physical model, and together, refer back to these two sets of artifacts to confer and confirm a shared memory of process and meaning of the design artifacts.

Jason then pointed to the 2D digitized plan and identified where the bread in the bakery was located. In line 5, he pointed to the plan and stated, "the bread is right here." In this case, the artifact was being used to make the connection between the plan and the model. In a similar finding, Schmidt and Wagner (2004), in the study of design studio practices, found that the use of a combination of 2D and 3D design artifacts was essential when design teams share ideas with collaborators. Similarly, the different artifacts in the present study were used at multiple stages of the design process by the students to describe the plan and the model. Notably, the connection between the artifacts was often made. In lines 9-10, Damon stated, "this is a circle," pointing to a circle on the plan. He then immediately walked from the 2D plan on the interactive whiteboard to the floor where the 3D model was located and pointed to the 3D model. He moved fluidly between the multiple representations across multiple dimensions with ease and with purpose to show the relationship between the various artifacts exhibited. He said, pointing to the 2D plan, "This is a circle" and then immediately turned his body and pointed at the 3D model on the ground in front of him and his peers whom he is addressing, saying, "like the window right here." Damon moved between two representations; physically by walking to and from the 2D projection, and the 3D model on the floor and verbally by explaining the connection.

The artifacts enabled Damon and his peers to move across multiple dimensions and show the relationship between those two representational models. Throughout the study, these physical objects bolstered the ability of young ELLs, like Damon, to describe their structures and convey the complexity of decision making and representation behind their designs built of common classroom materials. This example illustrates a finding that emerged consistently across 15/15 of the observations; that is, that students used the digital and physical representational artifacts (digital interactive project map, digitized 2D sketched plan, 3D model) to present their design to their peers and prepare for a peer discussion and critique.

Finding#2.2: Students were able to use multimedia production tools to document and publish their presentation and discussion of representational artifacts on social media.

The literature has suggested that students need more opportunities to participate in the classroom as 21st-century citizens (Barron et al., 2014; Barron & Darling-Hammond, 2008; Jenkins et al., 2009; New London Group, 1996). In this study, students demonstrated that they are developing evidence that they can organize, upload, and share, for public viewing and potential critique of their designs. Using the digital apparatus students' simultaneously presented their designs and prepared a digitized multimedia document to be shared publicly on the internet.

The affordances of the digital apparatus extended students' opportunity to learn new media literacy skills. In 11 observations, students recorded and published the presentations of their design projects and artifacts as part of the digital publishing process. Students' representational artifacts functioned to initiate potential dialogue between the design team and two public spheres. The first public sphere encompassed the presentation to their classmates. The second public sphere encompassed their published video to the class YouTube site for the families(see Figure 6).

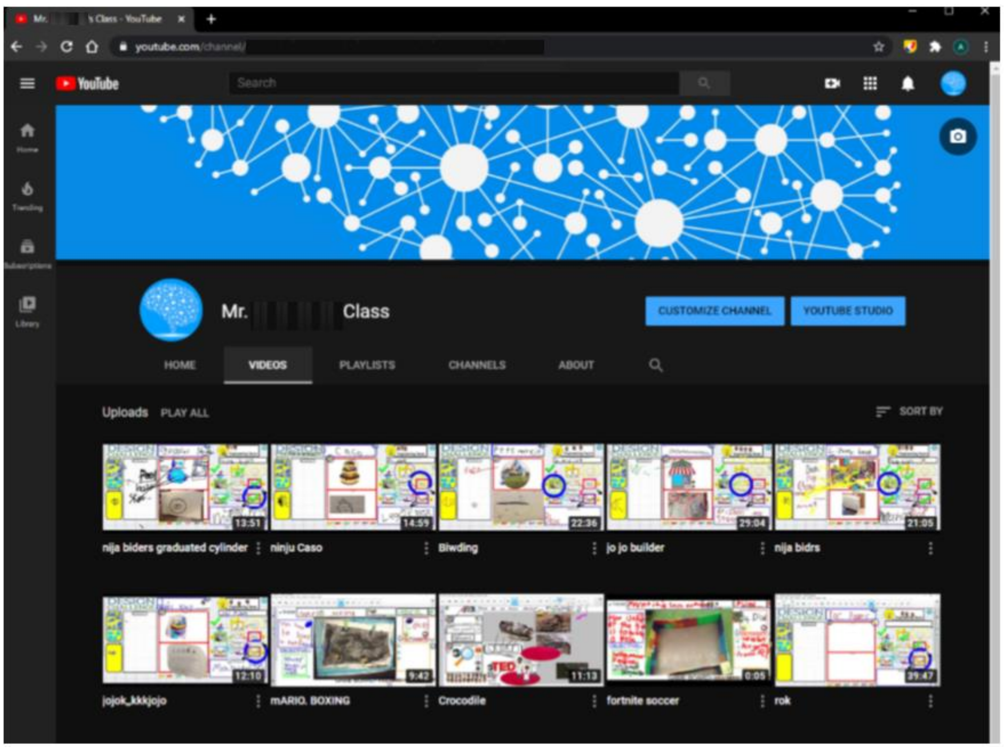


Figure 6. Publication of projects on YouTube social media, class website.

Students recorded and published their presentations onto their class YouTube website (Figure 6), By using multimedia creation tools that were integrated with the interactive whiteboard platform students were able to extend the potential for a discussion focused on their representational artifacts to their homes, families, and communities. When recorded, digitized, and published as part of their sharing phase, the representational artifacts that had served as shared objects of discussion between design teams and their peer audience, now also were available to function as potential sources of conversation with students' families. The majority of the video data during the publishing process were a brief series of nonverbal steps to save, title, archive, and upload the completed recordings of the design presentation. However, in one instance, during the presentation of their town design project, two presenters engaged in a side conversation that captured their awareness that their work would be made public beyond the classroom.

Line	Transcript Text *Damon and Brandon's design team present and discuss their Town design/build project*
1	Alberto: {*side conversation with Damon}* We can put this in the paper *(classroom daily newspaper)*. And then my mom is gonna be so happy! Guys! We can put this in the paper and show it to our family.
2	Damon: We can put the QR code.

In this excerpt, Alberto's side conversation with Damon was captured on video because of their chance proximity to the camera. While Brandon was taking a turn presenting their shared project, Alberto in Line 1 pulled Damon aside and said, "We can put this in the paper, and then my mom is gonna be so happy!" This was referring to the classroom newspaper, that the students helped to publish, print, and distribute, that documented students' projects from each day's effort. Alberto's comment showed that he was aware of the public nature of this work and was excited about it. Damon then responded, "We can put a QR code." Damon's comment, building on the idea of public sharing, suggested adding a feature that would increase accessibility and ease of viewing for the public. This exchange offers an example of how students can cumulatively build on one another's ideas. Damon connected the static media to the dynamic multimedia element of the newspaper and added that the video could be linked using a QR code embedded in the newspaper. This instance was fortuitous in that it captured a side conversation about these students' feelings and ideas about publishing their work. However, there were many instances of design teams initiating the screen and audio recording software and then uploading their project videos to the class' YouTube site, providing evidence that the participants, and their design teams, had developed an ability to document and post on social media and a recognition that the artifacts were public for their classroom as well as for their families.

Theme three: Semiotic Formations specific to the language of Engineering and Design Process are evident in this study

"Why the emphasis on language? Because language is not just vocabulary and grammar: Language is a system of resources for making meanings."

Jay Lemke, Talking Science (1990)

Finding #3.1: Students use educational scripts to structure their talk about their projects within the construct of the design process. The following excerpt illustrates a common feature in this study; students applied design-related academic language within educational scripts to systematically communicate the design process to their peers. Scripts are predetermined, stereotyped sequences of action that define well-known situations and enable people, in this case, the ELLs, to apply explicit language scripts to articulate their procedural work through the design process (Schank &Abelson, 1977). In this illustrative example, Brandon and Jason used educational scripts to structure the introduction to their design project.

Line	Transcript Text *Jason and Brandon's design team present and discuss their Swimming Pool design/build project*
1	Brandon: Our design challenge is to make a graduated swimming pool, and our engineering team is me, Jason and Emilio… The form is there is a circle, square, and pyramid. Then the feature is there are pools… First, we talked about it. Then we make a 2D plan…
2	Jason: And this is our 2D plan.
3	Brandon: Now we make a 2D plan, (then) we build it.

4 Jason This is the structure.

"First we talked about it. Then we make a 2D plan."

The students systematically introduced the swimming pool design project, following a predictable pattern and using educational scripts that demonstrated the students' systematic approach to their project. It is important to note that based on the English language standards, the structured, systematic, and metacognitive language about the design process that the students demonstrated using the educational scripts was unusual for any 5-6-year-old, particularly students at the emerging and expanding stages of second language development (California ELD Standards, 2012, p.20). Brandon began with a clear introduction, focusing on the design challenge addressed: "Our design challenge is-." The script used that immediately follows then introduced the collaborators of the project: "Our engineering team is-." He then said, "The form is-" showing that the design team considered the major elements-form and function- of the structure of a swimming pool before initiating the 2D drawing plan.

Further, this script enabled the students to employ vocabulary describing the general two dimensional and three-dimensional geometry of the structure. Brandon said, "the form is-"

followed by "-a circle, square, and pyramid." This script enabled the students to articulate the massing of the structure using formalized engineering vocabulary as well as establishing expectations of the kinds of formations that they expected from their peers during the critique phase.

Also, this example shows that the students both engaged in the pre-planning phase of a design project and were aware that this was a critical stage in the design process. Brandon structured his description of the pre-planning, planning, and building stages using the "First, Then, Next" educational script. He said, "First we talked about it. Then we make a 2D plan. Now we build it." The script itself helped students organize their work through the process as they engaged in a design project. It also was later used to articulate this process to their peers, setting the norms for a structured dialogue that followed the presentations. These interactive documents, combined with the graphic and text elements of the template, helped students to weave together a series of scripts to present a coherent account of their arc of the design process.

This example illustrates that through a combination of hands-on construction and structured dialogue, students applied engineering design language. In doing so, the participants develop their understanding of design principles and the design process (Cunningham & Kelly, 2017). While this is unusual, similar observations of engineering concept development have been found among ELLs engaged in hands-on design challenges (Yocom de Romero et al., 2006).

Finding #3.2: More capable peers use educational scripts to apprentice one another to present their projects within the construct of the design process.

Throughout the study, Brandon was a peer mentor; he apprenticed less capable peers as they applied educational scripts at each stage of the presentation and discussion of the design process. Peer to peer apprenticeship is especially successful in collaborative design projects where technology is shared among students, and expectations for peer-led support is established (Ching & Kafai, 2008). The shared space and shared visual and tactile access to the structuring elements helped Brandon to engage in this peer apprenticeship. The following exchange illustrates the kind of peer-led navigation through the design process found in four similar observations. It begins as Brandon prompted Andrew as he presented his team's design challenge to build a town. This excerpt illustrates peer apprenticeship as Brandon prompted and probed Andrew to present their work using engineering and design semiotic resources and formations.

Line	Transcript Text *Brandon's design team present and discuss their town design/build project*
1	Andrew: *{speaking to the whole group}*And, I made this. I made this.
2	Brandon: *{speaking to team member, Andrew}* Where? Andrew!
3	Frank: Is that where they enter?
4	Brandon: *{speaking to team member, Andrew}* you need to do the features- What is your design challenge?
5	Andrew: *{speaking to the whole group}*Our design challenge is a town, right?
6	Brandon: *{speaking to team member, Andrew}* Yeah.
7	Brandon: *{speaking to team member, Andrew}* And what is your engineering team? And what is your engineering team name? And what is your features?

The exchange started with the design team presenting their design project of a town with multiple structures at the introductory stage. Andrew, the less capable peer, initiated the presentation by identifying the elements of the build that he helped create. However, he was not specific. In line 1, Andrew stated, "I made this. I made this." Brandon appropriated the role of a mentor and prompted, "Where?" and followed up by reminding Andrew about the systematic introduction process. In line 4 he advised, "You need to do (talk about) the features." Referencing the project map protocol, he then prompted, "What is your Design Challenge?" Brandon's attempt to guide Andrew is evidence that he was cognizant of the systematic structure of the presentation and had that same expectation for his peer. He reminded Andrew first to introduce the project in the organized presentation and to be detailed.

Brandon's comments for Andrew to be specific echoed the same way that I used the project map and protocol as references when helping students navigate the multistep process. Andrew responded to Brandon's prompt by using a complete sentence and the educational script that employed the academic language. In line 5, Andrew asked, "Our design challenge is a town, right?" By checking with Brandon at the end of this response suggests that he presumed that Brandon had a firm grasp of applying the scripts and that his affirmation was sufficient to proceed. Andrew's response indicates that he recognized Brandon's role as a mentor by responding to his peers in the same way he would be expected to respond to the teacher. Brandon continued to prompt Andrew using the educational scripts and the project map to structure the interaction. He asked, "And what is your engineering team? And what is your engineering team name? And what is your [building's] features?". This indicates that Brandon felt confident extending guidance to his peer on how to use academic instead of everyday language to formulate the presentation.

This exchange also exemplifies the way a more linguistically skillful EL kindergarten student was able to make use of the available scaffolding to scaffold his less linguistically adept peers in the same way as the teacher. While Brandon was the only participant to engage in peer apprenticeship of how to use educational scripts in multiple observations, peer apprenticeship took many other forms throughout the study. These included peer probing (35 instances) seeking peer guidance (15 instances) peer to peer encouragement of adherence to educational scripts (12 instances), and peers checking each other's work and offering guidance (5 instances). Most of these instances used everyday language, often with some formal language and structure. This suggests that peer support was along a continuum of language development. Brandon's ability to use more formal scripts to prompt his peers indicates the potential of the more advanced end of the continuum of this participant; when given the teacher modeling, practice, expectations, and control of tools, he was capable of taking on the role of the facilitator that encouraged and supported formal design language.

Finding #3.3: Students engage in systematic probing of one another's design choices using educational scripts. The following excerpt represents the kind of probing of design choices found in the 11 of the observations. This probing typically used interrogative words within an educational script to initiate a question about a particular choice the design team had made. Though each response was unique as it depended on the specific question, the structure of the response by students in the study typically followed the academically relevant semiotic formation: students used keywords and scripts to probe and, in turn, the answer embedded keywords from the question. The following excerpt exemplifies this probing.

Line	Transcript Text *Brandon's design team present and discuss their classroom design/build project*
1	Alexander: ...Any Questions
2	Josie: Why did you want to make your building Legos?
3	Brandon: We make our building Legos-
4	Alberto:…because…
5	Alexander: … it would make our street-
6	Alberto: …so that it could connect-

In this example, a three-student design team continues a formal discussion with their classmate, Josie, by asking, "Does anybody have any questions?" Josie responds by probing the team's design choice of materials. She says, "Why did you want to make your building Legos?" By embedding the question into their response and completing the utterances of one another, the three students demonstrate they have all listened to the question, are listening carefully to one another, and are engaged in the conversation. Brandon begins the reply, saying, "We make our building Legos …" Alberto extends this saying, "because" ensuring that he intends to justify the material choice. The third teammate, Alexander, continues this response with the material choice justification. He says, "It would make our street." Alberto extends this justification, identifying a specific property of the material as the rationale for selecting it. He adds, "So that it could connect," and Brandon adds, "so that it could stick with something." This example illustrates a pattern of dialogue found across the study; students were able to question one another's design choices. The following finding, 3.4, is focused on how students used scripts to justify these design choices.

Finding #3.4: Educational scripts support discussions where students question and justify design choices. During the study period, participants were able to question and justify design choices, a key feature of exploratory talk (Mercer et al., 2010). Students became increasingly adept at asking probing questions and responding with a rationale for design choices. In fact, 7 of the 9 discussions where one or more incidence of probing and justification exchange were observed occurred in the final week of the study. In the following examples, the three focus participants along the ELL continuum engaged in the beginning stages of exploratory talk that prompted students to justify their choices. This talk centered around questions that probed peers' choice of building materials and reflected whole group discussion about the role materials played in the building process. Group discussion of the importance of material choices reflected engineering practices that emphasize materials as a significant feature in design as their properties impact the function of the structure as well as the structural limitations of it (Wastiels & Wouter, 2008). In the following set of examples, students exchanged questions and answers about material choice using semiotic formations related to design discussion.

Line	Transcript Text (excerpt 3/3) *Damon (Level 1) responds to probing question about his soccer game design/build project*

1	Andrew: And why did you do the tiny balls? Why did you do this rectangle prism, like all the Magna tiles?

2 Damon: We used the rectangle prism- because… Because we could say we tried to make the soccer like real, like the pretend one outside.
3 Brandon: Yeah, like the soccer outside.
4 Alberto: Like real life soccer.

Line	Transcript Text (excerpt 1/3) *Brandon(Level 2) responds to probing question about his soccer game design/build project*

1 Frank: Why did you use aluminum to represent the balls?
2 Brandon: We use aluminum to represent the balls so that (it could be a) sphere of(like) a ball.

Line	Transcript Text (excerpt 2/3) *Jason (Level 3) responds to probing question about his soccer game design/build project*

1 Frank: Why did you use the tiny blocks to represent your character? And why did you use Legos?
2 Jason: All right, we used Legos because- so, we can make our characters more easy. And Amy wanted to use the little blocks to represent our character. It's right there.

These three brief question and answer exchanges illustrate three ways that students used representational artifacts as shared reference points that were central to probing talk around design. They represent some of the ways students justified their design, which occurred during 28 instances across the study. Exploratory talk took the form of the student asking a question that explored or questioned peers' design choices. For example, in the first of these three excerpts, the student asking the question *explored* their peers' design choice, particularly the use of a specific material, aluminum, to represent a ball. The student demonstrated he had listened carefully to the question by responding using the educational script: *we did* x *because of* y. He explained that the material was used to "represent" a ball so that the representation could be a sphere.

Excerpt 1: : Question: Why did you do this rectangle prism?

Response: *We used the rectangle prism- because...*

It is evident that the student listened to his peers, considered their question, and responded using an educational script that echoed the question. This structured exchange occurred in each of the other two examples:

Excerpt 2:Question: Why did you use aluminum to represent the balls?

Response: *We used aluminum to represent the balls because…*

Excerpt 3: Question: why did you use Legos?

Response: *We used Legos because…*

In each excerpt, each participant in the study was able to respond at least in part to the probing questions. This is important because it shows that each participant at each language level was able to produce a semiotic formation that used design language to respond to another peer probing their design's features. Further, the examples show students as deliberate about design choices. Damon, in excerpt 1, justifies that he used the rectangles prism tiles to look like the soccer goalposts used outside, probably referring to rectangular prism soccer goals on the school soccer field. Jason, in excerpt 3, justifies using Legos as a way to create the models rapidly. Brandon, in excerpt 2, demonstrates that he applied design thinking to select the aluminum to build his model. He considered the form and function required of the model, in this case, a ball for his soccer game, and considered his available resources that would best match the structure and function. Based on an inventory of building materials available in the classroom, there were no spheres in any of the available material sets. As there were no building materials already in the shape of a sphere to represent the ball, he chose a mailable material, aluminum, to shape into a “sphere.” This decision is also significant because it demonstrates an understanding of the design task, which was to create a game that could be played. All three excerpts also illustrate a pattern of probing and the varying degrees that participants had developed their ability to justify their design choices, particularly during the final week of the study.

Summary

In this study, I examined kindergarten ELL student interactions, dialogue, and artifacts as they participated in the design process structured by a combination of digital, physical, and teacher scaffolds. From this study, three salient themes emerged.

The first theme is related to the structuring elements of the learning environment. The combination of a multimedia interactive project map and a tangible discussion protocol enabled students to navigate a multiphase design process learning sequence by using the structuring and problematizing scaffolds embedded in the classroom. The graphic, text, and audio embedded scaffolding served as guideposts for students. These guideposts enabled students to participate and negotiate leadership roles in the design practice of systematic documentation of the 2D planning and 3D building. They also helped guide students to use that documentation to present their design projects to their peers. As evidenced by the analysis of video and design project maps, these scaffolds enabled the students to progress methodically through the design, build, and test phases culminating in the presentation and discussion of a collaborative design project. I found this by analyzing the digital design project maps students used to document each phase of the design process. 90% of the embedded prompts on the design maps were successfully addressed, as evidenced by examination of a combination of photos, written text, and audio recordings produced by the design teams.

The second theme is related to the role of representational artifacts produced during the design process. Through video analysis of nonverbal and verbal interactions, I found that students heavily relied on the two and three-dimensional objects they made to bolster their ability to communicate details and relationships between two-dimensional plans and three-dimensional models. Further, peer discussion centered on the representational artifacts. These objects functioned as shared points of reference between the design teams and their peers. Further, these artifacts had the potential to initiate opportunities for design talk beyond the scope of the classroom, in the form of multimedia video that students published on social media and shared with their families.

The third theme is related to the ways that students engaged in engineering and design language. By analyzing transcripts, I found that each of the participants, along the continuum of English language development, was able to employ a range of engineering and design specific language and educational scripts in the presentation, discussion, and critique of their design work. By examining the transcripts in relation to the graphic, text, and audio cues in the interactive project map and discussion protocol, I found a consistent relationship between these scaffolds and what students said.

CHAPTER FIVE: DISCUSSION

The purpose of this qualitative study was to explore the ways that kindergarten ELLs may access and participate in the engineering and design process using academic language with the support of a novel scaffolded learning environment. This goal was to be achieved with a combination of interactive multimedia digital tools, a discussion protocol, and limited direct teacher support designed to sustain a high degree of student autonomy. This chapter consists of a discussion of the significant findings and their contribution to the prior literature. Specifically, I consider the value of the findings in light of the literature on oral language development in young children, namely around the study of computer-supported learning environments, development of domain-specific language supported by educational scripts, project and studio-based learning, and new media literacy. I conclude with a discussion of the study's limitations, suggestions for future research, and a final summary. In this study, I sought to understand how a learning design that I had employed in my kindergarten classroom enabled kindergarten ELL students to participate in an engineering design process. I was interested in understanding how the children used representational artifacts to reflect on their work and to receive and respond to questions and suggestions about that work with their peers. I also hoped to locate evidence that the students engaged in semiotic formations during dialogue about production of their designs.

The findings from this study suggest that there were three dimensions of the learning environment used by students to navigate, organize, present, and discuss their engineering and design work. These findings fell under three themes:

(1) Having a tangible scaffolding framework, in the form of the interactive project map and the discussion protocol, was useful as a mechanism to embed both structuring and problematizing scaffolds for students to navigate the design process.

(2) The two and three-dimensional representational artifacts of design ideas helped elicit detailed accounts of the design process. They also served as focal points between the design team and their peers during discussions and critique.

(3) Students were able to apply design language and educational scripts at varying degrees of sophistication that aligned with the graphic, text, and multimedia cues embedded in the instructional scaffolds.

Each of these scaffolds helped the English language learners in this study to develop their engineering and design language and participate in engineering and design practices.

Importance of Structure

I began this investigation by pointing to the dearth of information about the use of an interactive whiteboard platform to scaffold collaborative design projects among kindergarten ELLs and the need for understanding how teachers could leverage this platform to enable kindergarteners to participate in the design process. My findings add to the literature on computer-based scaffolding. While computer-based scaffolding has been examined across the K-12 spectrum, there are no studies that have examined an interactive whiteboard platform as a scaffold for the engineering design process in kindergarten. The results suggest that scaffolding embedded in the digital interactive project map in the form of graphics, text, and audio clips can be used by students to navigate the design process successfully. Reiser (2004) described the use of computer-supported learning environments as having two types of scaffolds; scaffolds that structure and scaffolds that problematize. My findings confirm that computer-based scaffolding for kindergarteners can be effectively used for both. The design process was structured using a graphic interactive flow map that enabled students to mark themselves at each stage of the design process visually. The design process was also problematized; embedded in the map were graphic, text, and audio prompts that prompted students to consider essential questions in their projects' design.

My findings reveal that the discussion protocol facilitated student-led discussion and critique after students presented their design projects. In the literature, on the use of interactive whiteboards to support independent student collaboration, Mercer (2011) found that upper elementary students were able to maintain the protocol for group work and group talk after being taught through direct instruction. The teacher's presence, Mercer's team found, was maintained in the small group as exemplified in their observations of students appropriating the structured discussion protocol in their discussion. In addition, my findings expand the age range to the lower limits of elementary where students were able to appropriate the expectations of group discussion; and points to the value added of the additional graphic scaffold of the discussion protocol in which was used in 92% of the group discussion exchanges. The findings further indicate that having a tangible discussion protocol also played a significant role in enabling student-led collaborative discussion to progress efficiently.

Together, these findings also align with the literature on effective teaching practices that enable collaborative work to be successful; effective student-led facilitation occurs when teachers establish clear expectations and procedures on role negotiation in collaborative groups (Webb, 2009a). My study adds to this literature on effective collaborative group work because of the added element of a physical protocol with visual cues for younger ELL students. This suggests that visual and tactile elements may be an effective way to bolster scaffolding that enables the independent practice of collaborative group expectations and role negotiation.

Another significant finding was the role the digital interactive map served as a resource for direct teacher scaffolding through the presentation and discussion process. Previous studies have focused on the ways IWBs were used by teachers in whole-group settings to demonstrate concepts using the graphic and tactile features of the tool (Beauchamp & Kennewell, 2008; Gillen et al., 2008; Maryam et al., 2019). The findings of my study extend these findings by suggesting that teachers can use these features to model for students how to use the IWB in small-group settings by learning how to use the scaffolding independently. I accomplished this by using the embedded scaffolding first, as a teaching tool during direct instruction, then leaving these elements as permanent guideposts, remaining in place as my guided scaffolding faded. In my study, rather than a classroom emphasis on teacher-led talk, a significant amount of teacher talk focused on redirecting students to use the embedded scaffolding to structure their conversation and progress through presentations and discussions. This suggests that one way a teacher may use the IWB effectively is to teach students how to use the tool independently and to use a graphic and multimedia interface that is accessible and intuitive to children.

Hands-on Artifacts

When I initiated this study, I noted that representational artifacts have been examined in the context of professionals and adult students in the fields of architecture and engineering but not in the context of kindergarten ELLs participating in these practices. My study has illustrated the ways in which representational artifacts were used by kindergarten students to elaborate during each phase of the design process and as focal points for discussion between design teams and their peers. Often, students were able to communicate design ideas and key features of their design even when they did not have the precise vocabulary to verbalize the feature or concept. In the literature examining the role and use of representational artifacts in architecture and engineering work, researchers have found that objects created by engineers and architects to model potential future designs are central to the discussion among these professionals (Brandt et al., 2013; Cennamo et al., 2012; Tory et al., 2008). My findings confirm and extend these studies; young children who build models, like adults, use them as fixed points of reference when recounting the design process and detailing the design work.

A possible explanation could be that the objects were the materialization of internal problem solving, design solutions, and imagination. While the final models that students presented were static artifacts, they were built with the collaboration of three to four students over a period of 30 to 45 minutes. Perhaps these artifacts elicited recollection, detail, and discussion because students were unpacking a complex and richly detailed physical, cognitive, and social experience, represented in the materialization of the physical objects.

This study extends what we know about the potential age range of who can participate in engineering and design projects that echo those practices of engineers, architects, and designers. The kindergarten English learners in this study, whose age and second language proficiency may otherwise constrain their ability to express their grasp of sophisticated design and engineering processes, demonstrated that they could participate in these STEM processes with the aid of robust hands-on experiences and building artifacts to share and reference.

Design Language among ELLs

A central interest in this study concerned the development of engineering and design language among ELLs through meaningful experiences in design practice. The findings indicate that participants were able to apply design language and educational scripts along a continuum of English language development. These findings fit what we already know about elementary children's ability to learn how to participate in sophisticated conversations when given effective scaffolding. The literature on children engaging in domain-specific language and concepts across a variety of science (Gomez, 2007; Lemke, 1990; Sandoval et al.; 2014) and mathematics

(Franke et al., 2009; Moskovich, 2015) domains has shown that students can appropriate patterns of talk that are part of the canon of these fields. However, studies on engineering and design, particularly among early elementary ELs, have sparse exploration, to date, in the literature (National Academies of Sciences, Engineering, and Medicine 2018). My findings confirm that young children can participate in STEM learning that is conceptually and linguistically rigorous, using STEM language along a developmentally appropriate continuum, and conversation patterns to demonstrate their understanding of STEM concepts.

John Seely Brown (2006) argues that the studio model can be a new way of structuring learning environments. Brown identifies the critique phase as substantially significant because the conversation about design work enables students to question and understand design choices. My findings support this claim and extend the potential age range to the youngest elementary students. My results indicate that the kindergarten EL students in this study were able to speak confidently about their engineering and design projects in a combination of formal and everyday ways. They were able to use educational scripts to methodically speak about their design projects, describe the design process, and conduct structured discussions between design groups and peer observers. They were able to speak using educational scripts to systematically solicit compliments, questions, and suggestions about their projects. Additionally, in multiple observations, the students demonstrated at least one instance of developing the ability to justify their design choices to their peers.

Taken together, this research effort contributes to what we know about the potential for five and 6-year-old kindergarten EL students, with the support of multiple scaffolds, to participate in contextualized hands-on engineering and design language and, in turn, develop their language around the engineering and design process.

Limitations of this study

This study was not without its limitations which can be located in the limits of size, demographics, and my dual role in the study. The study was conducted in one classroom at a specific time and place. The findings cannot be generalized beyond City School. While the demographics of City School are similar to those in its surrounding neighborhood, it is nonetheless a unique community as were the students in the classroom. The study was limited by the time frame as well. Study data was collected over six weeks, the majority of which was collected during the final three weeks. The data was limited in the sense that I was unable to observe changes in design language over the school year. While I did collect a large amount of video and audio data of the students' oral language participation in other STEM and media production projects, I did not include these as part of the study.

Another limitation was my multiple roles as the teacher, designer, and researcher; I needed to collect data and facilitate the classroom projects simultaneously. As a consequence, particularly during the first two weeks, I gathered video data that was missing sound, instruments that lost power, and in some cases, video recordings that did not record. Also, my dual roles, as teacher and researcher, increased the potential for researcher bias. I tried to mitigate this with the addition of the 360° video camera during all data collection. Frequently, during the data analysis of the videos, I would refer to the 360° video to understand what may be affecting students beyond the frame of the standard video cameras. However, I am aware that the effect of bias could not be eliminated, and as the classroom teacher, I was invested in the success of the students in the class. Despite these limitations, this study offers a useful contribution to our understanding of potentially effective ways to engage English language learners with hands-on, language-rich studio-based engineering and design.

Implications for Practice

I undertook this study to explore a novel way that teachers in a large urban school district may be able to engage ELLs in engineering and design learning by applying project-based collaborative learning pedagogy to the affordances of interactive whiteboards, a widely available technology in the school district where the study occurred. This study demonstrates that, under the conditions outlined in this study, even children as young as five and six years old, having little to no previous experience using collaborative software on large-format interactive digital tools, can navigate them and use them as tools that support sophisticated learning cycles of dialogue supported by digital documentation, systematic recording, and workflow mapping and visualization.

Educators who teach English language learners are always searching for ways to meet the social, academic, and second-language-learner needs of their students. Project planning maps and discussion protocols can help structure and problematize learning cycles and increase the academic rigor of STEM learning by establishing patterns of dialogue that facilitate academic talk with the support of visual, tactile, and multimedia guideposts.

The practical implications for the 60% of U.S. teachers who already have this IWB platform in the classroom may be to reconsider the dominant paradigm that these technologies are primarily teacher tools with a central purpose of improving teacher-centered lesson delivery. Teachers can reframe the apparatus as a hands-on student toolset that encourage, scaffold, and structure young children’s language use. Teachers can structure STEM learning cycles with a range of multimedia interactive elements and prompts that enable the youngest ELLs to participate in the challenging but potentially accessible task of frequent, extensive, student-driven, STEM project cycles, and STEM learning.

Recommendations for Future Research

While this study focused on discussion and critique as an end phase of the learning sequence, future research may consider the impact of what happens to design projects *after* the discussion and critique and in what way these public discussions shape future iterations of student design work. Longitudinal research could be undertaken over more extended periods than the present study, and change over time, both in student language and the designs, could be studied. The value of this would be to develop our understanding of the learning over time that may be possible with large format collaborative digital learning platforms.

Future research could also explore the ways that other young EL students in other communities engage with this digital learning platform. This would help understand whether what was conducted in the present study is replicable. Interviews with students would be a valuable additional layer of data collection that may offer supplemental understandings of what students perceive about the experience. This could also be extended to teachers who use these tools; interviews with them as they learn, design, and implement a computer-supported design process learning cycle could provide insight about what they perceive about their experience.

Another line of research could focus on the ways that the learning design changes over time based on observations made by teachers in response to micro or macro scaffolding that are needed to reach and extend learning goals. The affordance of the digital platform is that the software and all the digital tools are editable and therefore customizable to meet the needs of the user. Micro and macro changes can be made in real-time and be distributed to all or some students across the whole room digital platform. These changes can increase or decrease scaffolding based on the user's needs, and the changes, paired with documentation of the way students interact with those changes, could provide a valuable understanding of the ways teachers use the platform to meet their needs. This may provide insight into the technologies beyond closed programs designed for users, in this case, teachers, to implement and instead be examined as frameworks that are a set of building tools for teachers to develop and adapt lessons and learning environments.

In addition, I suggest a longitudinal study that could explore the impact that early and robust engineering and design experiences within this design framework may have on the identity and future careers of EL students historically underrepresented in the STEM fields. We know that children develop their identities far earlier than a middle and secondary school; if students from marginalized communities find joy and success in STEM fields when they first enter school, they may be able to build opportunities for communicating what they are learning in a classroom context that highlights their use of language and their capacities and identities in the STEM fields.

The last 10-15 years of research in students' use of technology have pointed to the value of studio models of education where public critique of media and engineering design work offers a promising approach for 21st-century learning (Brown, 2006; Barron et al. 2014). Brown's call for studio-based learning environments insists that this new learning design is explored and takes advantage of information, digital, and multimedia technologies. The success of the Digital Youth Network shows that this model of multimedia production, critique, public examination, and publication could be an effective way to engage underserved students in STEM work. These recommendations for future research aim at continuing to break ground on what and how these new learning environments may be conceived, engineered, implemented, and studied.

Conclusion

One of the criticisms of computer-supported learning proponents is that, too often, the role of the teacher in the CSLE is overlooked or undervalued. Usually, the technology, not the teacher's moves in wielding the technology in the service of pedagogy, is highlighted as the instructional element that can impact student learning. In this study, I was the designer, teacher, and researcher. I aimed to make the structuring visible to understand the relationship between what students were able to accomplish in the learning sequence, both as being able to produce physical and digital artifacts as well as to speak about them and the process. My teacher role was to facilitate students to navigate the design process with the aid of a computer-supported environment. As the designer, my role was to design a set of scaffolding that would increase student independence and decrease student reliance on direct teacher intervention. Further, my part as the designer was always to observe student progress and challenges and to iterate on the design at both the micro and macro levels to respond to student and teacher needs through design. Practitioners who want to apply for the work from this study can approach implementation in two ways. The first is to take on the dual role of the teacher and designer. This is not an unfamiliar dual role that many teachers take on, though the digital tools may be. That would mean taking the digital learning design as a starting point but making changes based on the specific needs of the students. Alternatively, the already developed interactive project map could be used in its current form. For teachers who choose not to adapt and edit the files, they can implement the design process with the digital project map using their large format interactive displays or even laptop computers. While this would disable the teacher from tailoring the design, it would enable them to have an interactive engineering and design project map for students to use. In either approach to implementation, the teacher's role in facilitating, modeling and developing student independence would remain central to the application.

This study explored how project-centered STEM learning could be designed in a way accessible to English language learners in their first year in elementary school. STEM project cycles are multi-phased, iterative processes that often combine a broad set of technologies with in-depth project cycles. This complex, hands-on learning is an opportunity that rarely is available to underserved student populations in the early elementary years, and is usually, if at all, available as elective or after school classes during the middle and high school years.

As we continue through the year 2020, there is an unprecedented imperative to reconsider the supporting role technology can play in designing studio-based learning environments. The abrupt shift to online learning across the nation in Spring 2020 and into the Fall of 2020 due to the COVID-19 pandemic has exacerbated the digital divide and instantaneously put a demand on all educators to work in a wholly digital environment. It has also made clear that technology integration that enables communication and collaboration in education is no longer a choice but an imperative. The question remains: how will the technology be used once we return to the classroom? Will it be used to improve the efficiency of teacher-centered mechanisms for information and assignment delivery, or will it be used to reimagine ways to improve student-centered collaborative learning?

Three decades ago, Pea and Gomez (1992) described a vision for the future of distributed multimedia learning environments where communication and interactive multimedia technologies could enable collaborative learning both within a classroom and through remote learning. Although many of the advanced communication, software, and hardware technologies they outlined as precursors were not then invented or easily accessible, they are now available, and in the majority of American schools, already a part of the classroom. Unfortunately, the vision set forth by Pea and Gomez (1992) has not yet been systematically leveraged and is not seen in schools across socioeconomic lines. In order for the vision to be more fully realized, schools must transform students' learning environments and opportunities so that children are not stuck in the shallow end (Margolis, 2008). I hope that this work can contribute to the collective imagination of the possibility for new digitally augmented learning environments that bring together project-oriented learning in a multimedia studio design in ways that support collaboration, communication, creativity, and innovation.

APPENDIX

Learning Design and Environment

Appendix A: Digital Interactive Project Map

The project map is an open-ended fillable document, analogous to a fillable PDF. The interactive project map is composed of five elements: moveable elements, fillable fields, hyperlinks, sound links, and a recording enabled sound link. Together, they are designed to scaffold the five-phase design process and the four-phase presentation and discussion process. The moveable elements are digital objects that can be touched and moved on the map. They are

There is a combination of moveable elements that scaffold the design process. Students move the large blue circle during the plan/design/build phase. It is also used during the presentation phase to structure the systematic presentation of each phase in the design process. The green checkmark is used to mark off each phase completed; it serves as a reminder to check off each phase. The six colored arrows are the moveable interrogatives used to prompt peers to identify specific elements of the presented work to probe. These help focus student questions on the material presented in the documentation. The two and three-dimensional shapes in the "form" section are moveable; students move them to the photographed or hand-drawn image of their design, populated in the "research" frame during the planning phase. These two and three-dimensional forms scaffold students to identify the Euclidean geometry of their structures using mathematical vocabulary. The geometric figures are also used to identify the geometry in the students' 2D plans. The blue circle, moveable element 4, is intended to scaffold students as they track their progress through the design process.

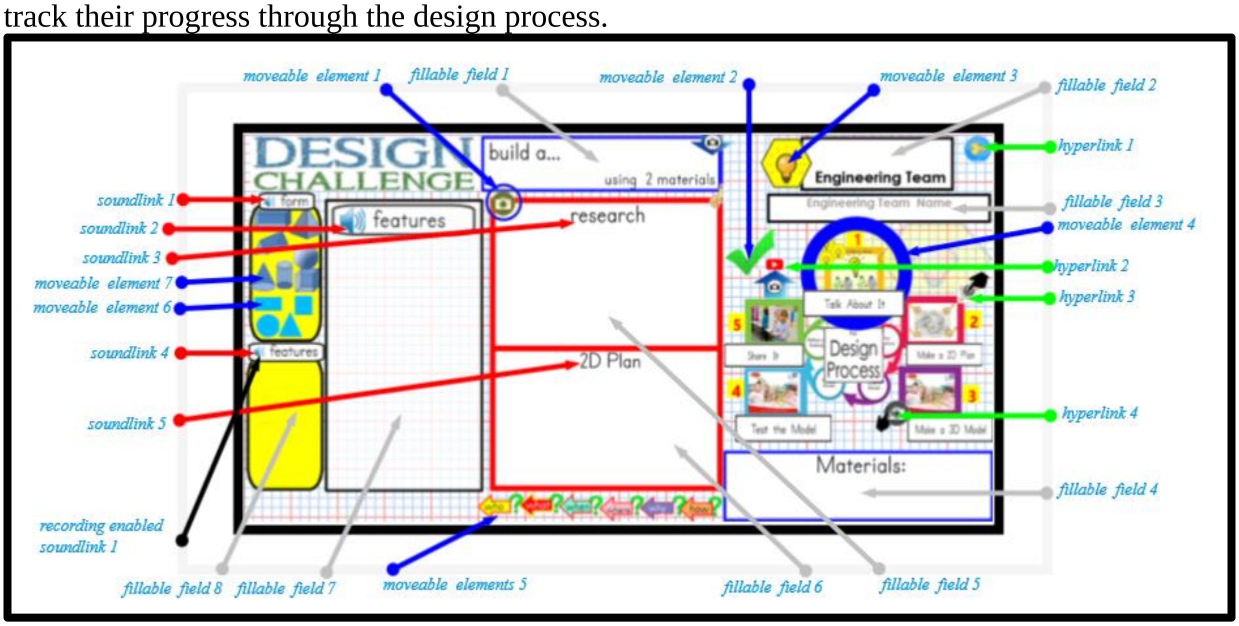


Figure 7. Interactive project map template, identifying each scaffolding and problematizing element, page 1. See table B1 for key.

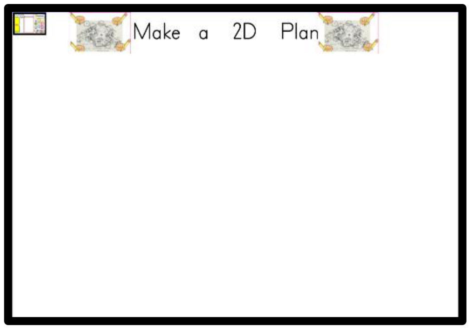


Figure 8. Photo documentation of hand-drawn 2D plan, page 2, hyperlinked from page 1.

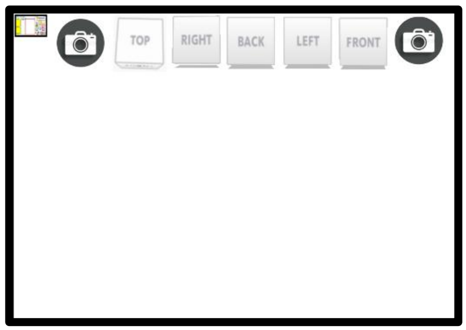
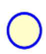


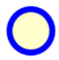
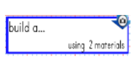
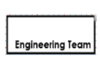
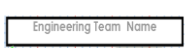
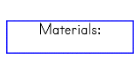
Figure 9. Photo documentation of 3D Build, page 3, hyperlinked from page 1.

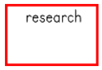
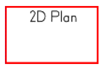
Appendix B: Interactive Project Map Key

Table B1

Interactive Project Map Key

Interactive Project Map Key **some elements have been magnified to ease viewing*			
Project Map Element	* elements	Function	Scaffolding mechanism (Reiser, 2004)
Moveable element 1		Prompts students to identify a source of information of structure during pre-planning phase Choices: photograph (field documentation *or* internet search) or collaborative sketch	structure
Moveable element 2		Prompts students to track and check-off progress as they move through each phase of the design process. During presentation, prompts students to articulate each phase of the design process.	structure
Moveable element 3		During the initial ideation phase, prompts students to use yellow hex blocks (digital or	problematize

		physical) to physically represent the collaborative brainstorming phase; ideas that build on one another are physically connected to represent building on one another's ideas. Promotes Exploratory Talk (Mercer,1996).	
Moveable element 4		Prompts students to track progress as they move through each phase of the design process. During presentation, prompts students to articulate each phase of the design process.	structure
Moveable elements 5		During the discussion phase, prompts peers to use interrogative words to identify specific elements of the presented and documented work by the design team. Each of the six interrogatives are moveable.	problematize
Moveable elements 6		Prompts students to consider, identify, and abstract structural features as a combination of two and three geometric shapes. Prompts students to use two and three dimensional geometry vocabulary.	problematize
Moveable elements 7		Prompts students to consider, identify, and abstract structural features as a combination of two and three geometric shapes. Prompts students to use two and three dimensional geometry vocabulary.	problematize
Fillable Field 1		Prompts students to choose and document a design project, establishes resource limitations and to use the phrase "built a… using…materials"	problematize
Fillable Field 2		Prompts students to identify and record the members of the engineering team, and to use the phrase "engineering team" when presenting	structure
Fillable Field 3		Prompts students to cooperatively select and record an engineering team name and to use the phrase "engineering team name" when presenting. Establishes the design process as a collaborative endeavor. In later iterations, this is likened to creating a company, where teams develop a Logo and present their projects as proposals.	structure
Fillable Field 4		Prompts students to discuss, determine and record the building resources needed for the design project and to use the vocabulary "materials" when presenting.	problematize

Fillable Field 5		Prompts students to research the proposed structure prior to creating a 2D plan. This is either by photographing and uploading structures in their immediate environment, conducting an internet query, or collaboratively sketching. During the presentation phase, this prompts students to identify their background knowledge prior to introducing the 2D plan and 3D model.	problematize
Fillable Field 6		Prompts students to develop a two dimensional plan then document record it. During the presentation phase, this prompts students to use the vocabulary "2 dimensional plan".	structure
Fillable Field 7		Prompts students to discuss and label salient structural features during the pre-planning phase. During the presentation phase, this prompts students to use the vocabulary "features".	problematize
Fillable Field 8		Prompts students to discuss, identify, and record the main function that the structure serves using the voice recorder feature. During the presentation phase, this prompts students to employ the academic vocabulary, function, within the educational script, *"The function of the structure is…"* .	problematize
Hyperlink 1		Hyperlink to Key English Language Standards and Science and Engineering Standards addressed in the design project, for teacher, parent, and administrator use. *Function removed due to repeated accidental use by students.*	
Hyperlink 2		Hyperlink to class YouTube page. Used to prompt students to screen record and publish their presentation and discussion for viewing by peers and family at home.	structure
Hyperlink 3		Hyperlink to two dimensional plan documentation, page 2. During presentation, used to display, discuss, and markup a digitized version of the hand drawn plan.	problematize
Hyperlink 4		Hyperlink to three-dimensional model documentation, page 3. During the presentation, used to display, discuss, and markup images of the physical model.	problematize
Sound link 1		Audio prompt, student voice: "What is the form of the structure? What is the shape of the structure?" Used to increase student	problematize

		independence from the facilitator for information seeking queries. Developed in response to frequently asked questions by students to redefine this term and repeat the instruction.	
Sound link 2	function	Audio prompt, student voice: “What is the function of the structure? What is it for?” Used to increase student independence from the facilitator for information seeking queries. Developed in response to frequently asked questions by students to redefine this term and repeat the instruction.	problematize
Sound link 3	features	Audio prompt, student voice: “Features- what does it have?” Used to increase student independence from the facilitator for information seeking queries. Developed in response to frequently asked questions by students to redefine this term and repeat the instruction.	problematize
Sound link 4	2D Plan	Audio prompt, teacher voice: “Two-dimensional plan.” Used to increase student independence from the facilitator for information seeking queries. Developed in response to frequently asked questions by students to redefine this term and repeat the instruction.	problematize
Sound link 5	research	Audio prompt, teacher voice: “Research.” Used to increase student independence from the facilitator for information seeking queries. Developed in response to frequently asked questions by students to redefine this term and repeat the instruction.	problematize
Recording enabled Sound link 1		Cloneable sound link. Students record their response to the prompt and embed the recording into the project map. Increased student interest by creating a multimedia presentation, as well as reducing time needed to hand write and upload response, thus focusing the engineering team on the design/build task while also eliciting and documenting response to prompt.	problematize

Appendix C: Discussion Protocol

The protocol is a 6"x6" rigid laminated card located beside the interactive whiteboard and retrieved by a team member at the onset of the discussion, per classroom protocol. It is used to structure the three-part discussion. It is purposely designed using a primarily graphic interface as standards for kindergarten reading levels are limited to three-letter words; their conceptual understanding of terms such as critique, protocol, discussion, engineering, three-dimensional, compliment, suggestion, and question outpaces their first-year phonics decoding skills. The size of the protocol is specifically designed to be large enough to hold and pass from one team member to the next, while not being too large as to be a visual interference or awkward during the discussion. The icons used to represent each of the three discussion phases are familiar symbols used throughout the school year; this strengthens students' understanding of each distinct phase as they are able to draw on prior understanding of how to formulate a question, compliment, and suggestion. The protocol is a symbol of the facilitator role equivalent to the "passing of the gavel" which commonly represents the one who holds authority. It is a reminder to identify and share roles in the group as well as to systematically progress through the compliment/question/ suggestion phases of the feedback cycle.

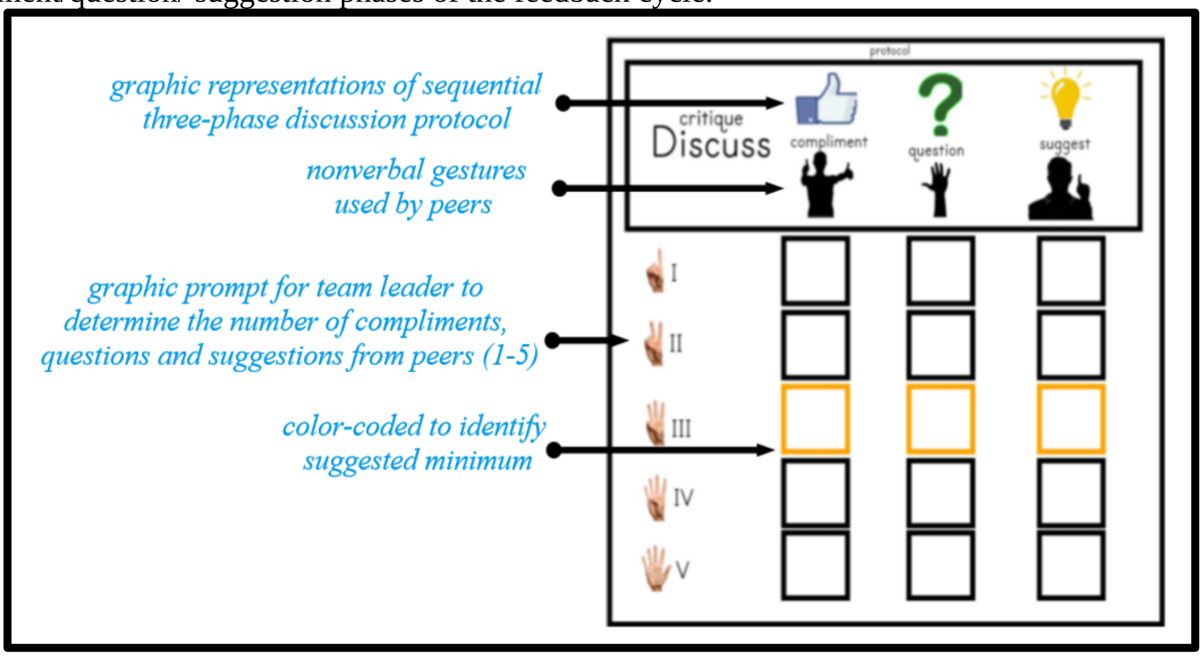


Figure 10. Discussion protocol.

Appendix C: Units of Analysis and Observation

Research Question	Units of Observation	Data Collection Methods
In what ways does the learning design enable kindergarten ELLs to participate in the engineering design process?	Software embedded ● Prompts and visual cues that guide dialogue ● Prompts that guide turn-taking ● Prompts that guide activity procedure ● Prompts that guide the organization of information ● Prompts that guide artifact production ● Prompts that guide artifact layout ● Prompts that guide role ● Prompts that guide responsibilities ● Prompts that guide time management ● Prompts that guide use of the digital knowledge base ● Prompts that guide the use of online resources ● Prompts that guide inquiry and questioning ● Prompts that guide language structures ● Prompts that guide design cycle Students ● Use of digital pens to comment on each other's work ● Use of digital eraser to comment on one each other's work ● Use of digital eraser to change their work based on peer feedback ● Use of highlighter to ● Use digital highlighter ● Use digital "magic" pen ● Use art supplies to illustrate ● Use a digital timer to pace activity ● Use a digital timer to ensure equal time for each student to share ● Use screen capturing software to record a presentation ● Use microphone to record a presentation ● Use of internet browser to search for information ● Use of internet browser to search for images related to a topic ● Use of networked file sharing system to retrieve information about peers ● Use of visual cues to prompt students to prompt one another to extend talk (i.e., high five symbol cues peers to count each instance that the speaker gives a detail. Peers illicit extended descriptions using five details) ● Use of visual cues to prompt peers to stay on topic ● Help-seeking strategies among peers	Video and audio recordings of each pod Student created Digital files of project maps Student Published Screen captures To class YouTube channel

<table>
<tr><td></td><td>

Use of collaborative learning processes established as “ground rules” during whole group discussions but used by students independently
Take turns
Negotiate turns through body language
Negotiate turns through an object that represents turn (microphone)
Negotiate turns through an object that represents turn (pen)
Ask for help from peers (verbal)
Gesture for support from peers (nonverbal)
Offer help to peers by pointing
Assist peers by using a pen (without speaking)
Provide help to peers by using a pen (with speaking)
Provide support to peers by speaking (directions)
Assist peers by asking questions (probing)

Teacher Role

Point to visual cues on IWB to elaborate discussion
Provide verbal prompts to elaborate discussion
Guide students to use help-seeking strategies
Provide instruction in communication skills
Nonverbal guidance for students to use communication skills
Provide direction in reasoning skills
nonverbal guidance for students to use reasoning skills
guide group selection
Student self-selection into groups
Teacher instruction of effective group interaction
Verbally prompt reciprocal questioning
Nonverbally prompt reciprocal questioning
Prompt role specialization (i.e., jobs in the group)
Redirection of off-task behavior using visual cues on IWB
Provide direct technical support
Verbally prompt students on how to resolve a technical issue
Nonverbally guide students to solve a technical issue

</td><td></td></tr>
<tr><td>2) In what ways do children use representational artifacts to participate in presentation, peer critique, and multimedia publication during the design process?</td><td>
Students

Point to digital or physical artifacts
Touch digital or physical artifacts
Gesture toward digital or physical artifacts

</td><td>Video and audio recordings of each pod

Student created Digital files of project maps</td></tr>
</table>

		Student Published Screen captures To class YouTube channel
3) What is the evidence that students engage in semiotic formations during dialogue about production, presentation and peer critique of representational artifacts?	Questions ● Body language that accompanies conversation ● Clarification ● Help-seeking language ● I will need to determine whether to focus on a single activity type (peer interview) or all activity types. The dialogue in each activity is different. Peer interviews are question and answer; Engineering Design is idea building; Math Games are logical reasoning. ● Questions that focus on the topic ● Questions that attend to what is already known about the subject (i.e., if it is already known that the interviewee likes the color red, then a question that asks what things you have that are red?) ● Questions that are not related to the topic ● Questions develop from simple questions (i.e., Why do you like cats?) to complex questions (i.e., Why do you like cats and what kind of cat do you have at home?) ● Responses develop from abbreviated to elaborated over time ● Question variety increase over time ● The relationship between questions and topic (on-topic?) ● Attention to questions in student response	Video and audio recordings of each pod Student created Digital files of project maps Student Published Screen captures To class YouTube channel

Appendix D: Coding Table

Table D1

Coding Table

		Analytic lens Dialogic Talk (Mercer) Semiotic Resources	Analytic lens Semiotic Resources	Analytic lens Semiotic Resources (Gomez)	Analytic Lens Multiliteracies	Analytic lens Collaborative Learning (Webb)
Task	Goals Organizing Process	Goals Educational Scripts	Goals Core Academic Processes	Goals Core Academic Vocabulary	Goals 21st Century Literacy	Goals Collaboration Self-organization
Design Process: Building and Engineering	5-step design process 1)discuss/ identify design challenge 2) plan 3)build 4)test 5) share/ publish	Describe each step and decision in the design process 1) Identify the design challenge, Collaborate/ build on one another's ideas 2) create a 2D plan on grid paper 3) build a 3D model 4) Test the structure 5) Present The project describing each step and decision Critique process: Likes about design Questions about design and process Suggestion for design improvement	Writing Oral language development of academic vocabulary and speaking patterns Application of Mathematics	Design process Design challenge Engineering Team Form Function features Idea Plan 2-dimensional plan 3-dimensional plan Grid paper Model Test Stable Unstable Building Materials Sketch Perspective Improve Suggestion Idea	Produce and publish a YouTube video about a design challenge, the process, and the final product	In small group: Negotiate project focus Coordinate work Distribution of roles Small group to large group: share ideas

Appendix E: Data Collection and Analysis Table

Table E2

Data Collection and Analysis Table

	description	participants	Artifact	Data collection	Data analysis: dialogue	Data analysis: nonverbal use of representational artifacts and scaffolds	Participant 1:	Participant 2:	Participant 3:
Task									
Production of artifacts	Design process stages 1-4	Small group	Digital Map[1], completed	Close-up video, Transcript, 360° video	Code transcript	Code video (nonverbal production of artifacts, Use of classroom resources, use of digital map to scaffold design process)	Time:	Time:	Time:
Presentation of artifact	Design process stage 5a	Small group + whole group	Digital Map, completed Published screen capture, 3D structure	Close-up video, Transcript, 360° video	Code transcript	Code video (nonverbal use of artifacts and networked apparatus to scaffold dialogue)	Time:	Time:	Time:
Public critique of artifact	Design process stage 5a	Small group + whole group	Published screen capture	Close-up video, Transcript, 360° video	Code transcript	Code video (nonverbal use of artifacts and networked apparatus to scaffold dialogue)	Time:	Time:	Time:
Publication of artifact	Design process stage 5b	Small group	Published screen capture, Printed newspaper	Close-up video, Transcript 360° video	Code transcript	Code video (nonverbal use of artifacts and networked apparatus to scaffold dialogue)	Time:	Time:	Time:

[1] The engineering design process map is a digital workspace that is an interactive design process protocol. It serves as a nexus between analog and digital artifacts. Physical artifacts are digitized using a camera and populated onto the map, and digital artifacts, such as the map, images from the map and an audio/video screen capture of the map as a representational artifact, can be made physical using 2D and 3D printers.

Appendix F: Comparison of participants' language, first observation to final observation

The following is a side by side comparison of participant observations from early in the study and at the end of the study. It was an initial examination of how participant language may have developed over the course of the study. While a developmental analysis was beyond the scope of the present study, this may be a course of analysis in future research.

	Damon, Participant 1	
	Observation date: 05-22-2019 Race Car Game Design	Observation date: 06-05-2019 Restaurant Design
Presentation	Damon: Present, testing, testing. Damon: Testing, testing. Damon: No, you. Damon: My name is Damon Damon: Those are not spikes, those are regular spikes. Andy, why are you using the magic pen? Damon: You guys are kicked out. Damon: I'm telling [the teacher] on you. Damon: No. Damon: A trap! Damon: No, I'm not going. Damon: Because you. Damon: I already went, now go. Damon: They're gonna ask about the other bumps. Damon: No, you go to the bumps where you pop. Damon: No, you don't die, you just get out. Damon: No, that's a highway. That's not a, that's nothing. Damon: Oh yeah, that's the burning thing to burn the wheels. This is also mountains. Damon: We did a rocket ship right here *because* in an accident we put the square right here. Damon: Andrew, get your and lets play. Damon: You're cheating me, you're cheating me. Damon: It starts over there! Damon: One, two, three, four. Damon: No no, that's 30, 31, 32, 33, 34. Damon: I got 49 . Damon: I touched the lava. Damon: So you have to roll the dice *and* whatever you get and then if you get zero You stay where you're at. Damon: You can still go like this, wee!	Damon: Our Design Challenge. Damon: Our Design Challenge to make a restaurant. Damon: Testing, testing, 1,2,3. Damon: (whispers) Frank ready? Damon: My name is Damon. Damon: Well, yourself is Frank. Damon: Well, that was Kyra's idea to be our team name to be JoJo... Damon: Builders. Damon: Well, that's Kyra's idea and Milagra's. Damon: And... Milagra, you need to do the topics. Damon: The topic! Damon: No, the topic. Damon: To eat pizza. Damon: Talk about the form. Damon: What does this mean? Damon: This? Damon: The blue thingies? Damon: This is the couch, this is the walls.
	Words:181 Complete sentences:9 Compound sentences:2 Engineering and Design Vocabulary:6	Words:80 Complete sentences:7 Compound sentences:5 Engineering and Design Vocabulary:5

Discussion and Critique	Damon: Critique means, like, a sad face Damon: One like . Damon: How about two? Damon: Mylie. Damon: put the dices colored? Damon: We put all the same colors of the dice because Damon: We can't even get a questions. Damon: We put the dice the same because we can know they, like, we use magic. Damon: Ideas? John Damon: No, you can do it third. Damon: We already did that. Damon: No but look it, we did two of them. Damon: John? Damon: Milagra can't go again. Damon: Here? Damon: Thank you for the idea, Milagra. Second idea? Damon: Okay, are we done? Damon: Game design about Damon: Our team name is Golden Damon: Gold dices. Damon: And our team is Jason, me, and	Damon: What does this mean? Damon: This? Damon: The blue thingies? Damon: This is the couch, this is the walls. Damon: Let someone else have a turn. Damon: This is the second like? Damon: This? Damon: Emilio. Not 'Miliano. Damon: Here. Damon: Thank you for that like Noel. Damon: He like about the car I build. Damon: John. Damon: what? Damon: Thank you for that like John. Damon: It's a like. Damon: Five. Damon: Frank, you choose. Damon: I think Kiley put yellow and red because Damon: You let Frank choose. Damon: We forgot to Damon: Yeah, we forgot to take a picture of that. Damon: Yeah I was making lines for she could take a picture of that. Damon: Alberto, just go. Damon: Jason already said that. Damon: You can't talk about the car again Alberto. Damon: Like, why did we put this thing right here? Damon: Lights. I said the lights. I forgot to put in the lights. Damon: I forgot to put the lights. Damon: I forgot to put the lights Damon: That's why, its the light outside. I forgot to put it outside. Damon: There's a light right there Damon: We can't run out of time. Damon: We can Damon: Like, we could switch our design challenge? Damon: Because this doesn't look the same? Damon: We're making it Damon: To make it teamwork. Damon: Show us Damon: Like, we could Damon: Like, should we put something like this? Damon: By copying? Damon: Oh. Like put this thing? Damon: Oh, this thing right here. Damon: Oh, like to make copy catter. Damon: That means that's the last one. Damon: No, fourth. Damon: Yeah, he have a lot now. Damon: The what? Damon: Like the magma (magna tiles)? Damon: Maybe we could change this to like 3. Damon: Or, like we can make the door.

	Words:104 Complete sentences:9 Compound sentences:1 Engineering and Design Vocabulary:4	Words:262 Complete sentences:21 Compound sentences:0 Engineering and Design Vocabulary:0

	Brandon, Student 2	
	Observation date: 05-20-2019 Classroom Design	Observation date: 06-05-2019 Swimming Pool Design
Presentation	Brandon: and our engineering team is: Alexander, me, Leonard, and Allen. Brandon: Our team design is Roadblocks God Brandon: And,the forms and the forms, have square have a, have a have a keyboard, looks like... Brandon: The computer Brandon: rectangle. Brandon: Rectangle prism. Brandon: Go ahead, Alexander. And the feature have a board Brandon: then our plan, our plan was to build This is our 3D plan. Brandon: and this is and this is for the number 5 and this is board number 5 What is this board number? Brandon: No, wait, this is board number 6 . Brandon: Alberto, Brandon: And this is board number six. And that's And that's Brandon: And who is . Brandon: Go to the next stage. Brandon: then we make a plan then we make a 3D plan. Brandon: 3D model. Brandon: We have the top perspective and a front perspective. Brandon And Alexander: Or back perspective or right perspective. Brandon: I'll look at it Alexander.	Brandon: Testing, testing Brandon: Everybody, team one. Brandon: Is everybody ready? Are we ready? Hi, my name is Brandon. Brandon: Today, we're making a game design. Our game design challenge is Brandon: Our design challenge is to make a graduated swimming, and our engineering team is me, Jason, and Emilio. The form is there is circle, square, and pyramid. Then, the feature is there is pools. And, the structure is there is pool. What's this? House. And then Brandon: Square. And then, our engineering team is First, we talk about it . That's our talk about it . Then, we make a 2D plan. Brandon: Make a 2 make a 2D plan. Brandon: Jason, talk about it. Brandon: This is the light . Brandon: this is the pool. Brandon: Now, we make a 2D plan. Now, we build it. Brandon: This is the house right here, and this is the Belgium flag. Brandon: No, this is from Belgium. Brandon: This is for It's upside down because Brandon: And, this is Frank.
		Brandon: And then, this is the pool , and the other pool is a triangle. We tried to make a square, but there was run out of squares. There was one square, but Jason talk about it. We can make it like a boat like a door. And then, this is the light. We need circuits for the light. Brandon: We need the lights, in daytime, when somebody go to the pool so they could see the flag. Brandon: And why did you use these Brandon: We use these because it's for it could protect, and this is a door for the pool. This is the lock.

	Words:163 Complete sentences:7 Compound sentences:0 Engineering and Design Vocabulary:10	Words:293 Complete sentences:24 Compound sentences:5 Engineering and Design Vocabulary:10
	Brandon: One likes. Brandon: No, how about me? Let me popcorn. Brandon: Alexander: Alberto: Go Damon. Brandon: Alexander, you're covering Brandon, Alexander, Alberto: Jocelyn. Brandon: We make our building Legos Brandon: So it could stick with something. Brandon: Any suggestions? Brandon: Allen, choose who want our idea. Brandon: No, one idea. Brandon: No! Any suggestions? Brandon: Popcorn somebody Allen. No, Allen need to popcorn. Brandon: Popcorn Allen. Brandon: Andy, you don't need to stand up, you just need to stay. Brandon: Thank you for that suggestion Andrew. Bye. Brandon: I hope you like Brandon: No, he said one? Our building design.	Brandon: Now, is time for Now, it's time for talk about it. First Third like or third question and third suggestion. Brandon: Yeah. Brandon: Yeah, these are the plans. Brandon: Yeah Brandon: Now, it's time for talk about it. We did this work. Now, we talk for talk about it. Third like and third question and just third suggestion. First like? John. Brandon: You like the lights? Brandon: It look amazing ? Brandon: Thank you for that like, John. Brandon: Two like. Brandon: Say second like. Brandon: Thank you for that like, Noel. Brandon: Someone have a like? Brandon: Thank you for the like, Amy. Any questions? Three questions. First question. Somebody have a question? Does somebody have a question? John. Brandon: John. Brandon: We didn't connect everything because it looked like it going to break. What is connect, we connect with the house and the pool, but we try to take it out, but it got destroyed. So, that's why we don't So, we don't connect our pool and the house. Brandon: Say second question. Brandon: Somebody have a question? Brandon: We like circuit because we need light, so we could see the thing and we wanted it because it look like It look like a light from the writing. Brandon: Third question. No, you don't need a pointer. Brandon: Third question? Someone have a question? Brandon: Milagra? Oh, Milagra, Milagra. Brandon: Third questions. Brandon: Why we put the light? Brandon: Oh, this? Brandon: We put the light because we need lights so still we don't see anything. If we don't see something, maybe we get hurt. And then, Jason built this. It's not a sport. It's a door. Brandon: Any suggestions? First suggestion? Brandon: Four suggestion. Noel! Brandon: Good suggestion, Noel. Any suggestion? Popcorn Milagra.

Discussion and Critique		Brandon: Thank you for the suggestion, Milagra. Brandon: Any suggestion? Third suggestion. Brandon: No, he said you. Brandon: So they can see all of them? Brandon: Thank you for the suggestion, John. Any suggestion? Four. Andy, do you have a suggestion? Amy? Brandon: Andreas. Andreas. Brandon: Thank you for the Brandon: Bye. Brandon: Four. Brandon: Any suggestion? Brandon: Does someone have a suggestion? Brandon: Do you have a suggestion? Amy. Do you have a suggestion? Brandon: Milagra. Bye. We are design challenge. Brandon: Of graduated school. Brandon: Graduated swimming.
	Words:98 Complete sentences:5 Compound sentences:1 Engineering and Design Vocabulary:6	Words:256 Complete sentences:33 Compound sentences:5 Engineering and Design Vocabulary:6

	Jason, Participant 3	
	Observation date: 05-06-2019 Classroom Design	Observation date: 06-06-2019 Swimming Pool Design
Presentation	Jason: Hi, my name is Jason. Jason: Milagra, you did it messy. Jason: No, that's the board. Jason: Why is this like that? And that's the closet for all the puppets. Jason: Oh, we had a . Jason: No, that's a desk. Jason: No, that's [the teacher] you said that to me. Jason: Stop, the board. Jason: That is the mini board. Jason: This is the walls. Kyra will walk you through right here. Jason: No, the desk.	Jason: My name's Jason. Jason: Circ? Jason: And then, we make a Jason: And, this is our 2D plan. Jason: Over there. And, this is the house. Oh, it's here. Jason: There's double pools. Jason: This is the structure. Jason: No! It's not time to talk about it. Jason: You look like
	Words:62 Complete sentences:9 Compound sentences:0 Engineering and Design Vocabulary:0	Words:40 Complete sentences:5 Compound sentences:0 Engineering and Design Vocabulary:2

Discussion and Critique	Jason: No four, four. Jason: A lot of questions. Jason: Brandon! Jason: Two likes. Jason: Frank. Jason: Noel?	Jason: Because. Jason: Pick Noel. Jason: Third like? Jason: Amy. Jason: John again. Jason: Melissa. Jason: Third question? Jason: Popcorn Andy. Jason: Emilio, give this to- Jason: It's a door because when you try, when you try to get in this closes. Jason: Noel, and then it's John, then Milagra. Jason: I popcorn Jason: One more. John. Jason: Oh, guards over here. Jason: We didn't put guards because we have electrics on the camouflage on the things and they gonna 'lectric. Jason: Thank you for that suggestion, Andreas. These are camouflage of suggestion. Jason: Bye. Jason: Any suggestion? Jason: Melissa. Jason: Milagra, you have a suggestion? Go Milagra. Jason: Popcorn Milagra. Jason: Thank you for that suggestion, Milagra. Jason: No, graduated pool! Jason: There.
	Words:12 Complete sentences:0 Compound sentences:0 Engineering and Design Vocabulary:1	Words:100 Complete sentences:10 Compound sentences:2 Engineering and Design Vocabulary:2

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