The 3 Rs of Education: Reading, Writing, and… Robotics?
Students’ Literacy Development with LEGO® Robotics

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Abstract

Two areas in education that researchers continue to address are: (1) the search for *best practices* to support students who are language learners with academic success (Lesaux & Geva, 2006; Lesaux, Kieffer, Kelley, & Harris, 2014; Wilson, Fang, Rollins, & Valadez, 2016); and (2) the increased inclusion of STEM-related activities in educational settings (Barak & Zadok, 2009; Mitnik, Nussbaum, & Soto, 2008; Sullivan, 2008). The purpose of this qualitative, case study was to examine the use of robotics – a STEM-related activity – with connections to the literacy development of students identified as language learners during an eight-week, community-based robotics program. Additional attention was paid towards the students’ development and application of academic vocabulary within the program. The theoretical framework for this study was framed by Papert’s (1993) theory of constructionism and Long’s (1996) interaction hypothesis for language acquisition. The major findings from this study collapsed into the following themes: (1) informational texts; (2) writing; and (3) dialogue. Overall, findings from this study showed providing students with a specific task (i.e., constructing and programming a LEGO® MINDSTORMS® robot) promoted research, writing, and communication, in which the students encountered and used academic vocabulary. This study demonstrates the potential robotics has in supporting the literacy and academic vocabulary development of students who are language learners, and encourages the need for additional research on the use of robotics in educational settings and non-STEM-related fields.
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Chapter 1

Introduction

Language-minority students enter U.S. schools needing to learn oral language and literacy in a second-language, and they have to learn with enormous efficiency if they are to catch up with their monolingual English classmates (Lesaux & Geva, 2006, p. 53).

There has been a long-standing tradition for teachers to find the best practices in supporting the learning of students who are English learners; however, numerous challenges continue to be faced as educators and other stakeholders work towards this goal (Lesaux & Geva, 2006; Lesaux, Kieffer, Kelley, & Harris, 2014; Wilson, Fang, Rollins, & Valadez, 2016). The U.S. Department of Education Office of English Language Acquisition (2017) identified English learners (ELs) as having, among others, the following characteristics: (1) being non-fluent in the English language; (2) having a home language other than English; and (3) requiring additional supports in academic instruction. As of the 2014-2015 school year, more than 4.5 million public school students were identified as English learners (U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, 2017). Of that population, more than 75 percent were classified as being of Hispanic or of Latino heritage (U.S. Department of Education, 2017). In school, students who are ELs face the difficulty of “simultaneously developing English language proficiency while also learning academic content” (Lesaux et al., 2014, p. 1160), as they have not been afforded the same opportunities as their English-speaking peers to develop and acquire language skills before entering the formal educational setting (Mancilla-Martinex & Lesaux, 2011).

Some challenges educators face when teaching EL students are: (1) first language proficiency factors interfering with second language learning (August & Shanahan,
2006); (2) students not possessing the same amount of background knowledge regarding the content being taught (Townsend, Filippini, Collins, & Biancarosa, 2012); and (3) accessing effective strategies that can support students’ deconstruction of abstract language and concepts (Lesaux et al., 2014; Mancilla-Martínez & Lesaux, 2011). To help address some of these challenges, especially effective instructional strategies, educators have turned to technology to aide students’ learning (Chang, Lee, Chao, Wang, & Chen, 2010). One contemporary form of technology that is gaining recognition in classrooms and other venues is robotics, with its potential in inciting “creativity, social, and cognitive development” and promoting student collaboration (Kazakoff, Sullivan, & Bers, 2013, p. 246).

The use of robotics in educational settings is a trend that has broadened in recent years due, in large part, to the increased attention paid towards STEM education (Barak & Assal, 2018; Eguchi, 2016). Under the Obama Administration, focus on STEM – science, technology, engineering, and mathematics – grew, with the goal of preparing students in the United States to compete in the global job market (U.S. Department of Education, 2015). A number of studies have been conducted looking at the use of robotics in STEM-related subjects (e.g., Barak & Zadok, 2009; Mitnik, Nussbaum, & Soto, 2008; Sullivan, 2008) as robotics correlates with a number of STEM fields, including robot construction, programming, and mechatronics (Benitti, 2012; Mitnik, Nussbaum, & Soto, 2008). While research has started to explore the benefits of using robotics in education, scholars have noted the need to investigate the use of robotics in subject-areas other than those related to STEM.
Purpose of the Study and Research Questions

The purpose of this study was to examine the use of robotics in relation to literacy as a whole, as well as the development of academic language in early adolescent students who are language learners. The focus on academic language was important due to the frequency students in the upper-elementary grades encounter this language in text and classroom conversation. For that reason, the following research questions guided this study:

- How do early adolescent students who are language learners engage with literacy during an eight-week LEGO® robotics program?
- How do early adolescent students who are language learners develop and apply academic vocabulary during an eight-week LEGO® robotics program?
- What are early adolescent students’ understandings of robotics-related academic vocabulary at the beginning and end of an eight-week LEGO® robotics program?

This study provides research in the area of robotics and literacy, a non-STEM related field, and more specifically academic language development. From this study, researchers and educators alike can gain greater insight to relationships present between robotics and academic language acquisition. Optimistically, this study will spur additional research on this topic and generate opportunities to conduct other research using robotics in educational settings.
Definition of Terms

While various terms are used throughout the literature, the following terms were used within the current study:

- Academic language: the oral and written language within academic settings used in thinking and communication relative to a given subject-area; “the language of schooling” (Nagy, Townsend, Lesaux, & Schmitt, 2012, p. 91).
- Academic vocabulary: both general and domain-specific words; a component of academic language (Nagy et al., 2012; Townsend et al., 2012).
- English learners: students with limited English proficiency and in the process of acquiring the language; also referred to as English language learners (Office for Civil Rights, 2015).
- FIRST LEGO® League: FIRST (For Inspiration and Recognition of Science and Technology); created by Dean Kamen in conjunction with the LEGO® group (Gura, 2012); an international organization where teams apply STEM concepts while (1) researching real-world problems; (2) designing, building, and programming LEGO® MINDSTORMS® robots; and (3) competing in table-top challenges (FIRST LEGO® League, 2017b).
- Language learners: students who are English learners, including long-term English learners (Kibler & Valdés, 2016).
- LEGO® robotics: the program in which participants utilize LEGO® products, including bricks and LEGO® MINDSTORMS® technology (LEGO® Education, 2017).
• Literacy: “The ability to identify, understand, interpret, create, compute, and communicate using visual, audible, and digital materials across disciplines and in any context” (International Literacy Association [ILA], 2019).

• Multimodal: the incorporation of various modes within texts, including written, visual, digital, and graphic, that require the application of additional strategies in order for comprehension (Serafini, 2011).
Chapter 2

Literature Review

With the upsurge in STEM education and educators searching for innovative ways to incorporate these subjects into K-12 curriculum, one response has been the inclusion of robotics (Barak & Assal, 2018; Eguchi, 2016). Not only have there been advancements in the market of commercial robots (Williams, Ma, Prejean, Ford, & Lai, 2007), organizations such as FIRST LEGO® League (2017b) have gained momentum, both domestically and internationally, recognizing the use of robotics as a fun, hands-on way to apply STEM concepts. Researchers in various educational fields have found robotics to be beneficial in a number of areas, including STEM-related topics (e.g., Mitnik, Nussbaum, & Soto, 2008; Sullivan, 2008; Whittier & Robinson, 2007; Williams et al., 2007) and students’ inquiry and problem solving-skills (e.g., Barak & Zadok, 2009; Williams et al., 2007). Additionally, these researchers also acknowledged the increase of student engagement when utilizing robotics.

As the development of including robotics in educational settings continues, scholars have noted the need for research on the use of robotics in other subject areas, such as literacy (Benitti, 2011; Toh, Causo, Tzuo, Chen, & Yeo, 2016). One aspect of literacy that has received some attention in conjunction with robotics is language development, particularly among language learners (e.g., Chang et al., 2010; Robinson, 2005; Whittier & Robinson, 2007). To date, studies on this topic have provided limited empirical evidence; thus, the purpose of this study is to add to the existing research on the use of robotics and language development.
This review of the literature begins with a discussion of the current research on the use of robotics in education, including studies on robotics in relation to both STEM and non-STEM subjects. Next, an overview of the literature on academic language and vocabulary is provided, including a brief history of language acquisition, along with a summary of the existing research on academic vocabulary and language learners. The following sections illustrate the benefits that arise from utilizing robotics for language learning purposes, beginning with a discussion of the current state of robotics in education.

Robotics

According to Hendler (2000), there has been a robotics revolution. No longer are robots confined to laboratories and subject-areas such as engineering or technology, they are being utilized by “non-engineering, non-technical instructors” (Chang et al., 2010, p. 13). Robots not only provide students the opportunity to practice mechatronics and programming (Benitti, 2012; Mitnik, Nussbaum, & Soto, 2008), they also have the ability to act as tutors or peers (Mubin, Stevens, Shahid, Al Mahmud, & Dong, 2013). Systematic reviews of the literature on the use of robotics in education (Benitti, 2012; Toh et al., 2016) showed the following themes: (1) most studies research topics connecting robotics to STEM-related fields, particularly physics and mathematics; (2) robotics supports the development of students’ inquiry, thinking, and collaborative skills; and (3) activities involving robotics increase student engagement and motivation.

Robotics and STEM. While scholars have looked at the more obvious areas of technology and engineering within STEM education and robotics, science and its sub-areas were a common topic in robotics and education research (e.g., Barak & Zadok,
Looking at how physics concepts were incorporated into instruction through robotics, Barak and Zadok (2009) noted that students applied concepts presented to them by the teacher into their projects by constructing knowledge through project-based learning. In this study, middle-grade students were presented with various challenges, such as building and programming a robot that could throw a ball into a basket, and to be successful the application of physics concepts was required. Referencing the work of Sternberg and Lubart (1996), Barak and Zadok (2009) stated that students found “inventive solutions” to the problems presented, using scientific processes (p. 296). When needed, teachers provided short overviews of specific topics, for example the concept of force, then students would use project-based learning to apply new physics knowledge.

Similarly, Williams, Ma, Prejean, Ford, and Lai (2007) found a significant difference in their pretest and posttest results on middle school students’ physics content knowledge. The “physics content knowledge measure,” developed by the researchers, included twelve multiple-choice questions that assessed students’ knowledge in relation to Newton’s Laws of Motion (p. 206). The researchers posited that providing various hands-on robotics activities allotted the students opportunities to construct their own knowledge as they experimented with physics concepts. One example discussed was students completing a downhill racer task, during which students needed to understand, among other concepts, angles, velocity, friction, and weight. Students, in turn, transferred their understandings of these physics concepts to the post-program assessment. Williams and colleagues’ (2007) findings aligned with results from the
existing literature, further supporting the claim that robotics boosts student content knowledge.

Along with physics, the topic of evolution was tackled in a middle school setting by Whittier and Robinson (2007), who found that robots allowed students to experience the process of change that occurs in nature. Their study used a textbook chapter assessment in order to gain a better understanding of the students’ background knowledge regarding the topic of evolution. Whereas Whittier and Robinson noted students did not “master” the concepts presented in the unit, the researchers did acknowledge the notable gains made between the students’ pre- and post-test scores. Whittier and Robinson also addressed how through robotics the students were equipped to “both discuss and write” about science topics, applying academic vocabulary in the process. (p. 24).

Additionally, robotics has been studied in correlation with mathematics. Working with a younger age group, Highfield (2010) found that engaging with robotics helped young children understand math topics, particularly measurement and spatial concepts, as well as numbers and problem solving. Over the course of 12 weeks, students participating in this study were given robotic tasks, which required them to program and observe the movement of their robotic toy. Tasks ranged from structured to exploratory, with structured tasks being more teacher-directed and exploratory being open-ended, affording students opportunities to simultaneously explore multiple mathematic concepts. Examples of tasks included “Robot play and investigation,” where students freely explored their robot, programming it to travel various distances and applying the concept of measurement, as well as “building a robot home,” which entailed students using blocks to build their robot home, developing students’ 2- and 3-D spatial awareness (p. 24).
Highfield’s study showed robots can be an appropriate tool for emergent children while learning mathematic concepts and participating in problem-solving tasks.

**Robotics and inquiry, thinking, and collaborative skills.** Comparable to problem solving, which includes the use of questioning and aspects of trial-and-error (Highfield, 2010), discussion of inquiry skills appeared throughout the literature. Using the National Research Council’s (1996) definition of scientific inquiry, Williams and colleagues (2007) outlined scientific inquiry skills as (1) being able to ask questions, plan, conduct, and understand scientific investigations; (2) utilizing suitable “tools and techniques” to collect data (National Research Council, 1996, p. 105); and (3) thinking “critically and logically about relationships” that emerge during analysis (p. 105). Along with their findings regarding physics content knowledge, Williams et al. (2007) found no statistical significance between students’ pre- and post-test scores for their “scientific inquiry measure,” mentioning that the measure may not have been robust enough (p. 210). However, the researchers noted in their qualitative data analysis various reasons as to why students’ application of the scientific inquiry process was lacking, including program facilitators not wanting to interrupt the students’ engaged open-exploration with robotics as well as the scientific inquiry process being just that – a process. Results from this study suggested that scientific inquiry skills are not something that can be acquired during a short-duration, such as a two-week program, but require time to develop. To support students’ acquisition of scientific inquiry skills, Williams and his collaborators advised for longer durations in robotics programs, along with well-prepared facilitators to provide minilessons in a timely manner when needed.
In line with Williams and company’s look at scientific inquiry skills, Sullivan (2008) addressed how the “open-ended and extended inquiry” activities afforded by robotics connected to the high frequency of thinking skills, such as observation and estimation, used by the students in her study (p. 389). Also using the National Research Council’s (1996) scientific inquiry definition as a guide, Sullivan (2008) found a rather natural connection between thinking skills and science process skills, which the students intuitively employed. Of the eight thinking and science process skill codes, nearly all the participants exercised seven of them, particularly making observations and evaluating solutions. One instance shared was a student who, after observing his robot during the test run of his software programming, evaluated his solution by commenting, “That’s too short. That's way too short…That’s odd, that’s really, really, odd, .20 is too short and .34 is way too long” (p. 381). Sullivan attributed these findings to the open-inquiry pedagogical approach utilized within the robotics program as well as the robotics environment itself.

Not only does robotics provide a setting where students can engage with scientific inquiry and thinking skills, it also creates an environment that allots students the opportunity to work together. Reporting on the efficacy of the Technology-Assisted Science, Engineering, and Mathematics (TASEM) program at Woodcreek Magnet Elementary School, whose goal is to increase interest and prepare students for STEM-related professions, Varney, Janoudi, Aslam, and Graham (2012) noted a number of teachers who identified a high use of “team skills” and how engaging with these skills was effective in students’ character development (p. 80). One fifth grade teacher remarked that students in her class who participated in TASEM in third grade
demonstrated a “better sense of teamwork” than students who were not part of the TASEM program (p. 81). According to the school’s science and engineering specialist, as students developed their robots, they were encouraged to work together, in turn training them in skills needed for successful collaboration.

Looking at a specific idea associated with collaboration, Jordan and McDaniel Jr. (2014) studied how elementary students managed “uncertainty” while engaging in “collaborative problem solving” on a robotics project (p. 491). Due to its relationship to engineering and engineering tasks involving “complexity and ambiguity” (p. 524), robotics was used as the vehicle for this study. Jordan and McDaniel Jr. looked at how students used peer interactions to navigate situations in which they felt doubt, unsure of what might occur, or wondering what influences the past may have on the present. They found that as students experienced uncertainty: (1) peers responded to others’ uncertainties in both supportive and unsupportive ways; (2) supportive peer responses depended on if the uncertainty was shared by many or all group members, how “warranted or salient” the uncertainty was viewed, and if any other uncertainties were troubling other group members (p. 521); and (3) the way in which students managed and shared uncertainties likely change based on peer responses received. With that all being said, robotics was an appropriate medium for looking at how students worked collaboratively and managed situations of uncertainty. Jordan and McDaniel Jr. (2014) also acknowledged the increased interest in the inclusion of robotics in educational settings, by and large due to the amount of student engagement and motivation robotics programs generate.
Robotics and student engagement/motivation. Throughout the literature, one theme that was acknowledged by numerous researchers was the increased level of student engagement and motivation with the use of robotics, regardless of the specific content or topic being addressed (e.g., Barak & Zadok, 2009; Chen, Quadir, & Teng, 2011; Mitnik, Nussbaum, & Soto, 2008; Robinson, 2005). Scholars have attributed this to various factors, including robots being viewed by students as toys (Barker & Ansorge, 2007; Mauch, 2001). Considering many students are familiar with and have interacted with LEGO® products, as students partake in programs such as FIRST LEGO® League, learning morphs into playing and playing into learning.

As previously discussed, while Barak and Zadok (2009) found that students were able to learn and apply STEM-concepts while constructing a robot, the researchers also noted the increased motivation students had to complete the project. Motivation was even greater in students who developed robots for competition. Barak and Zadok stated students in the competition group not only worked independently with little teacher assistance, they also worked late into the afternoon and evening, and even attended sessions on the weekends at the homes of other group members. Likewise, in their study on using robots as autonomous educational mediators, Mitnik, Nussbaum, and Soto (2008) described how students in the control group, who did not engage with robots, commented on how boring their tasks were, whereas students in the experimental group expressed a great desire to continue working with their robots in the same classroom setting.

Investigating robotics-driven activities in the middle school setting, Robinson (2005) noted that the use of robotics materials made learning more “interesting and
relevant” for the students (p. 81). Of the responses from the three teacher participants, all expressed how their students were more engaged and enjoyed working with the robotics materials. One teacher even shared how students were voluntarily coming after school to continue working with and complete the robotics tasks. Robinson also shared how as the students were engaged in the robotics activities, they were able to learn and apply new vocabulary, particularly English as a second language (ESL) students.

Also looking at the language development of students who are ESL, Chen, Quadir, and Teng (2011) revealed among their other findings that the elementary students in their study were highly engaged with their learning as a result of the interactions they had with the computers and robots. Through observations and video recordings, the researchers saw students actively participating and working with one another, in addition to “trying out new materials and…[taking] challenges which were beyond their current level” (p. 556). Robotics not only acted as a motivator but helped create a learning environment in which students felt safe and were willing to take risks they might not otherwise have attempted.

As revealed in the studies discussed, robotics provides ample opportunities to enhance student learning on various topics, including STEM and non-STEM subject-areas (e.g., Barak & Zadok, 2009; Chen, Quadir, & Teng, 2011; Highfield, 2010; Whittier & Robinson, 2007; Williams et al., 2007), promoting students’ inquiry, thinking, and collaborative skills (e.g., Highfield, 2010; Jordan & McDaniel Jr., 2014; Sullivan, 2008; Varney et al., 2012), and actively engaging and motivating student participation (e.g., Barak & Zadok, 2009; Chen, Quadir, & Teng, 2011; Mitnik, Nussbaum, & Soto, 2008; Robinson, 2005). Utilizing the high engagement level robotics affords, there is
great potential in enriching other areas in education, including literacy and, more specifically, language and academic vocabulary develop by students who are language learners.

**Literacy, Language, and Academic Vocabulary**

Conceptually, *literacy* is comprised of many facets, including the traditional ideas of reading and writing as well as the areas of language and communication, and the incorporation of multiliteracies (ILA, 2019; New London Group, 1996). As the world and cultures in which students live evolve, so, too, do the text and technologies they engage with, in turn creating multimodal texts and requiring the application of various strategies in order for comprehension (Serafini, 2011, 2012). Used within these multimodal texts are varying levels of academic language and vocabulary.

Academic language is both a theoretical and practical concept within education. While numerous definitions exist concerning the “language of schooling,” Nagy, Townsend, and colleagues (2012), defined academic language as, “the specialized language, both oral and written, of academic settings that facilitates communication and thinking about disciplinary content” (p. 91). Within academic language is the idea of academic vocabulary, which brings more focus to “language of the disciplines” (p. 96) and includes general academic words that are commonly used across subject-areas as well as those that are recognized as domain-specific.

Overtime, various scholars have identified and created word lists consisting of what researchers consider the most essential words students need in order to be academically successful (e.g., Coxhead, 2000; Gardner & Davies; 2014; West, 1953; Xue
& Nation, 1984). Although the content of these word lists has evolved, Gardner and Davies (2014) deemed these lists as important to assist in:

…establishing vocabulary learning goals, assessing vocabulary knowledge and growth, analyzing text difficulty and richness, creating and modifying reading materials, designing vocabulary learning tools, determining the vocabulary component of academic curricula, and fulfilling many other crucial academic needs. (p. 306)

Academic words can be challenging to both proficient and struggling readers (Sibold, 2011; Townsend & Kiernan, 2015); thus, it is important for educators to find ways to support all learners.

A well-known and widely used tool for academic vocabulary is Beck, McKeown, and Kucan’s (2002) Three Tier Model (Figure 2.1). Beck, McKeown, and Kucan (2002) recommended focusing on Tier 2 word instruction, due to the frequency of occurrence and application within texts, to “maximize the impact on oral and reading vocabulary knowledge” of all learners (Goldstein et al., 2017, p. 3238). The Three Tier Model can assist educators in developing appropriate vocabulary instruction for students, especially for content-specific words which are chiefly employed in specific subject-areas (Sibold, 2011; Vacca & Vacca, 2008).
Another resource for educators that has gained recognition in recent years is the Corpus of Contemporary American English (COCA; Davies, 2012). Developed by Brigham Young University linguistic professor Mark Davies, COCA is recognized as the “largest freely-available corpus of English,” containing over 560 million words and adjusts based on the ongoing changes in language (Davies, 2009). One tool associated with COCA is the Word and Phrase tool, where after entering a digital text, the “most frequent academic words” are instantaneously identified and additional information can be selected for specific words, such as synonyms and antonyms, and parts of speech (Townsend & Kiernan, 2015, p. 114). As suggested by Blachowicz, Fisher, Ogle, and Watts-Taffe (2006), it is important for vocabulary instruction to be integrated and comprehensive, and for students to have access to “language- and word-rich environment[s],” (p. 527). Moreover, as convenient as resources such as the Three Tier Model (Beck, McKeown, & Kucan, 2002) and COCA (Davies, 2012) are, educators need to be conscious of pedagogical decisions concerning identified academic words. In order to best support students in learning academic vocabulary, words need to be chosen

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**Figure 2.1** Three Tier Model. This figure represents Beck, McKeown, and Kucan’s (2002) three categories for academic vocabulary words (as cited in Sibold, 2011).
carefully, instruction must be intentional, and students should be assisted in developing word-learning strategies (Blachowicz et al., 2006).

Sibold (2011) noted that academic vocabulary, even those considered basic words, are particularly different and more challenging to learn in comparison to conversational language. She attributes this to the specificity and abstractness of some terms, which can make concepts difficult to grasp, especially for language learners. For this reason, it is important for researchers and educators to recognize how language is acquired in order to provide the best practices possible for their students in learning academic vocabulary. A brief history of predominant language acquisition theories and approaches is now presented.


As expressed by Mitchell, Myles, and Marsden (2013), Krashen’s Monitor Model was “an influential first attempt to bring together a range of post-behaviourist findings in a comprehensive model of second language acquisition” (p. 41). Table 2.1 outlines the five hypotheses that encompassed the Monitor Model, including a brief explanation for each individual hypothesis.
Table 2.1  
Krashen's Monitor Model

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition-Learning Hypothesis</td>
<td>Learning and acquisition are separate processes. Learning is the result of teaching (e.g., classroom experience) where focus is placed on linguistic rules, while acquisition is the result of naturally-occurring and meaningful interactions with the target language.</td>
</tr>
<tr>
<td>Monitor Hypothesis</td>
<td>Conscious learning influences the growth of the editor, or “Monitor,” as an individual consciously begins to adjust the output in the target language.</td>
</tr>
<tr>
<td>Natural Order Hypothesis</td>
<td>Rules of language are attained in a predictable order.</td>
</tr>
<tr>
<td>Input Hypothesis</td>
<td>Aligns with the Natural Order Hypothesis, where language is acquired developmentally based on the “comprehensible input” received.</td>
</tr>
<tr>
<td>Affective Filter Hypothesis</td>
<td>Comprehensible input is only beneficial dependent upon how receptive the learner is to the input being received, which passes through the Affective Filter.</td>
</tr>
</tbody>
</table>

Adapted from Mitchell, Myles, and Marsden (2013).

Influencing the work of future scholars, such as Long (1996) and Swain (1985, 1995), Krashen’s (1982, 1985) input hypothesis was the reverse of previous traditional second language practices, which followed the ideology that to learn a second language, L2, one must first learn rules and structures, then practice using the structures in communication, in turn resulting in fluency of the language. The input hypothesis focused on “comprehensible input,” defined as i + 1, where i is the language taken in that the learner can understand and 1 is the input that is slightly above the learner’s level (Mitchell, Miles, & Marsden, 2013, p. 44). Additionally, the input hypothesis views speaking as the result of language acquisition, where speech naturally emerges. Krashen (1985) also avowed that grammar was “automatically provided” when input is understood by the learner by way of a Language Acquisition Device (p. 2).
Building upon this theory, Long (1996) developed the interaction hypothesis which recognizes the weight the environment has on learning a second language. Long asserted that through communication with others, language learners participate in meaningful negotiations with the language, “including repetitions, confirmation checks or clarification requests” (Mitchell, Miles, & Marsden, 2013, p. 48). Long also acknowledged the role of feedback in language acquisition, both positive and negative, and highlighted how feedback assists with learners’ negotiations for meaning. Expanding on Long’s (1996) hypothesis, Swain (1985, 1995) conceived the output hypothesis, affirming input alone is not enough in successfully acquiring a second language; output is what forces language learners to “undertake full grammatical processing… [and promote] the development of L2 syntax and morphology” (Mitchell, Miles, & Marsden, 2013, p. 48). Additionally, both the input and output hypotheses discern the role of “noticing” in L2 learning (p. 179); when learners detect various forms of feedback, they have the opportunity to infer what that feedback means in relation to the new language and whether or not their input and output align with the L2 structure.

In regard to language acquisition and language learners, and the specific topic of academic vocabulary, Sibold (2011) addressed the need to make connections between new vocabulary and students’ prior knowledge and experiences to better support students who are English learners. While researchers have noted students gain access to academic language largely through texts (Corson, 1997; Townsend, 2009), conversation has the promise to act as a springboard in students’ development of academic language and vocabulary (Wilson et al., 2016).
**Academic vocabulary and language learners.** According to Lesaux and Geva (2006) literacy development is: (1) a “cumulative and componential” process (p. 54); (2) manipulated by “individual, contextual, and instructional factors” (p. 54); and (3) begins in early childhood and carries on into adulthood. Referring to the works of fellow researchers, Kieffer (2011) outlined the phases of reading development (Figure 2.2), stating it is likely that language minority (LM) students will move through the reading phases similarly to their English-proficient peers, particularly in the primary grades. It must be noted, however, that although reading comprehension appears towards the end of this model, instruction and supports for comprehension in the primary grades is important and necessary (Duke & Pearson, 2002; Mahdavi & Tensfeldt, 2013). In Lesaux, Koda, Siegel, and Shanahan’s (2006) review of the literature, they detailed that while LM learners show gains in literacy in the primary grades, their struggles re-emerge or increase in the later grades.

![Figure 2.2 Phases of Reading Development. This figure is adapted from Kieffer (2011).](image)

Researchers have attributed these struggles in the upper-elementary and middle school grades to various aspects of literacy (e.g., Garcia, 2003; Kieffer, 2011), one specific aspect being the complexity of academic language and vocabulary in higher-level texts (e.g., Lesaux et al., 2014; Townsend et al., 2012). In the primary grades, decoding and word reading skills are noted as contributing factors in students’ reading comprehension, while oral language skills, including vocabulary, are recognized as a
predictor for older students’ comprehension abilities (Mancilla-Martinez & Lesaux, 2011; Gámez & Lesaux, 2015). As the complexity of academic language and vocabulary used in upper-grade texts increases, the reading comprehension of LM learners, unfortunately, decreases (Gámez & Lesaux, 2015; Kieffer, 2011).

In their study on academic vocabulary instruction with linguistically diverse students, Lesaux, Kieffer, Kelley, and Harris (2014) saw significant gains in students’ overall academic vocabulary knowledge and expository text comprehension. These scholars attributed the growth to the provided intervention and identified the need for “explicit instruction to build up [adolescent students’] knowledge of the words they will inevitably encounter in text” (p. 1184). For example, discussing the effects on students’ academic vocabulary knowledge, expository text comprehension, and morphological awareness and written language skills, Lesaux et al. noted that the results were significant when specific instruction was provided for academic words the students were sure to engage with.

Comparably, looking at the word knowledge of middle school students from linguistically and socio-economically diverse populations, Townsend, Filippini, Collins, and Biancarosa (2012) observed a “distinct gap” between the two groups. Students identified as LM and from low socio-economic status (SES) backgrounds were outperformed by their English-only (EO) and higher-SES peers on all administered measures. Additionally, the researchers noted the intersection between language and SES standing, even though analysis showed there were no significant interactions between SES and language background. Owing to these results, Townsend and colleagues indicated the need for additional supports and promoted the use of various vocabulary
instructional practices for all struggling students in order to help them achieve the same academic success as their mainstream peers.

While various instructional strategies have been identified in supporting language learners, including explicit instruction (Lesaux et al., 2014) and numerous exposures to academic words (Townsend et al., 2012), Wilson and her collaborators (2016) advocated for increased and enhanced speaking opportunities for English learners. In their study, Wilson, Fang, Rollins, and Valadez (2016) uncovered a disproportion between the amounts of time ELs spent speaking in the classroom in comparison to their EO classmates. The more individuals involved in the conversation, the less EL students participated; when speaking in pairs, each student spoke an equal amount, however in whole group, EL students’ academic speaking decreased to 11%. Wilson et al. suggested the following pedagogical approaches to support ELs’ oral academic language development: (1) hold all students to the same high expectations and include objectives for language; (2) highlight academic words and provide specific instruction for that vocabulary; (3) scaffold and offer procedures for students to utilize when engaging in conversation; and (4) heighten opportunities for talk in low-stress, safe environments. Implementing the various practices identified by these researchers (Lesaux et al., 2014; Townsend et al., 2012; Wilson et al., 2016) can help students who are language learners achieve similar, if not equal, academic success as their language proficient peers.

Summary

Previous research has documented the advantageous use of robotics with respect to STEM education (Barak & Zadok, 2009; Chen, Quadir, & Teng, 2011; Highfield, 2010; Whittier & Robinson, 2007; Williams et al., 2007). Collaboration, inquiry,
motivation, and thinking skills have also been explored in relation to robotics (Jordan & McDaniel Jr., 2014; Mitnik et al., 2008; Robinson, 2005; Sullivan, 2008; Varney et al., 2012). Additionally, researchers have documented the importance of supporting students’ academic language and vocabulary development (Blachowicz et al., 2006; Goldstein et al., 2017; Nagy et al., 2012; Townsend & Kiernan, 2015), particularly among language learners (Lesaux et al., 2014; Sibold, 2011; Townsend et al., 2012; Wilson et al., 2016). While the potential of robotics to increase student achievement has been highlighted (Barker & Ansorge, 2007; Kazakoff, Sullivan, & Bers, 2012; Mitnik, Nussbaum, & Soto, 2008), limited research exists examining the relationship between literacy, academic language and vocabulary, and robotics.

The current study, however, investigates how students who are language learners engage with literacy as they work with robotics. When used within a setting that promotes exploration and collaboration, robotics can act as a vehicle to incite student communication through group work and promote the use of academic vocabulary in an authentic environment. The review of the literature illustrated the potential robotics in education has in relation to student achievement, more specifically literacy and the development of academic vocabulary. This study focuses on students’ use of academic vocabulary, with particular attention on analysis of the frequency of academic vocabulary used. The focus provides a unique connection between robotics and ELs’ academic language.
Chapter 3
Methodology

Using a qualitative, case study research design, this study looked at the development of academic vocabulary in four early adolescent students who were identified as language learners during an eight-week community-based LEGO® robotics program. Case study was used to investigate “a contemporary phenomenon in depth and within the real-world context” (Yin, 2014, p. 16). More specifically, an intrinsic case study was conducted to learn more about “a particular case” (Stake, 1995, p. 3). In this study, the case, or phenomenon, at hand was the LEGO® robotics program and how students in the program engaged with literacy as well as academic vocabulary. In intrinsic case study research, the case is central and “of the highest importance” to the study (p. 16), and the goal of the researcher is to understand what the case is and how it works; therefore, case study was the appropriate design for this study.

The following research questions guided this study:

- How do early adolescent students who are language learners engage with literacy during an eight-week LEGO® robotics program?
- How do early adolescent students who are language learners develop and apply academic vocabulary during an eight-week LEGO® robotics program?
- What are early adolescent students’ understandings of robotics-related academic vocabulary at the beginning and end of an eight-week LEGO® robotics program?
The following sections describe the methodology for this study, beginning with a discussion of the theoretical framework, centering on Papert’s (1993) theory of constructionism and Long’s (1996) input hypothesis for language acquisition. Next, an overview of the researcher’s background is presented, followed by the research design, including: Setting; Participants; Data Collection; Limitations; and Data Analysis.

**Theoretical Framework**

The theoretical framework for this study was drawn from both the theories of constructionism (Papert, 1993) and the interaction hypothesis (Long, 1996). Constructionism served as the guiding theory for learning, while the interaction hypothesis supported the theory for language acquisition. Creating a relationship between the two theories provided the foundation on which this study was built. The following sections discuss both the theories of constructionism and the interaction hypothesis individually, then describe how the theories worked simultaneously in this study.

**Constructionism.** Drawing from the works of theorists such as Jean Piaget (1954) and Lev Vygotsky (1978), Seymour Papert’s (1993) theory of constructionism asserts that learning occurs when the learner, who is central and an active participant in the learning process, creates his or her own understanding of knowledge through the physical construction of an artifact that can be shared in a public forum (Baytak & Land, 2010; Karahan & Roehrig, 2015; Papert & Harel, 1991). To explain constructionism, the theories of constructivism (Piaget, 1954) and social constructivism (Vygotsky, 1978) must first be explored.
Initiated by Jean Piaget (1954), constructivism affirms that learning is not a one-sided practice, where knowledge is transferred from an expert to the learner (Rogoff, Matusov, & White, 1996), but rather a process in which through curiosity, the learner is motivated to explore problems in search of finding solutions (Overall, 2008). Piaget viewed children as “active scientists” (p. 66), and as they pursued understandings of what they encountered during their lives, they consequentially construct knowledge. In addition, knowledge is not solely constructed at one point in time, but rather evolves as the learner develops (Ackermann, 2001; Overall, 2008). More simply stated, the understanding constructed by a child at a given point in time is what is appropriate at that time based on the child’s cognitive development.

Building upon the basis of constructivism, Lev Vygotsky (1978) formulated the idea of social constructivism, purporting that learning and constructing knowledge is not a solitary act. On the contrary, Vygotsky viewed learning as a social activity and believed that learning occurs most effectively when interacting with others and recognized the role environment plays in learning and development (Overall, 2008). Within the environment, other entities, such as adults or teachers, supplement learning and assist with the development and construction of knowledge. This does not mean that knowledge is transferred from the expert to the novice, but instead illuminates the role of others who help facilitate and enhance learning opportunities.

In line with constructivism and social constructivism, which considers learning as “building knowledge structures,” whether individually or through social interactions, constructionism recognizes the conscious engagement by students as they construct a
“public entity” (Papert & Harel, 1991, para. 2). Meaning, the mindful interaction with a task allows individuals to create, or construct, their own understandings.

Seymour Papert (1993) developed the theory of constructionism while having students actively interact with Logo, a computer programming interface of his own creation. This idea came about after Papert witnessed a group of art students creating soap carvings, which they continued to work on for many weeks, allowing students time to think, dream, talk, observe others, and try new ideas (Papert & Harel, 1991). Like the soap carvings, Logo acted as the medium in which students were allowed to create freely and learn-by-making. Furthermore, constructionists believe that knowledge is constructed more efficiently when learners are creating “meaningful products” (Karahan & Roehrig, 2015, p. 105), for both themselves and others, which can then become sharable artifacts (Bruckman & Resnick, 1995; Karahan & Roehrig, 2015).

Harel (1991), a colleague and collaborator of Papert at the Massachusetts Institute of Technology (MIT) Media Lab, noted three facets of Papert’s theory: (1) during the process of learning, constructionism and cognitive development are greatly entwined; (2) constructionism involves a technologically rich learning environment; and (3) constructionism highlights individual differences. Papert asserted that constructionism, as a framework, lent itself to the “full range of intellectual styles and preferences” of learners (Papert & Harel, 1991, para. 6). When provided the opportunity to actively engage with a task, learners constructed their own understandings in correlation with their preferred learning style, whether it be abstract thinking or interaction with physical objects; constructionism allows learners to use their own styles of thinking to make knowledge their own (Papert, 1993; Papert & Harel, 1991). By constructing sharable
artifacts, learners were developing more concrete ideas, and personal feelings and connections to new knowledge (Baytak & Land, 2010; Karahan & Roehrig, 2015).

Creating personal connections is advantageous, particularly because it grants a sense of ownership to the individual. As emphasized by Sibold (2011), making connections between students’ prior knowledge and experiences, and new vocabulary should be an essential practice. Given that students encounter academic language regularly in texts (Corson, 1997; Townsend, 2009), interaction and conversation can assist in the development of students’ academic language and vocabulary knowledge (Wilson et al., 2016), further supporting their literacy skills and overall learning.

**Interaction Hypothesis.** Long’s (1983, 1996) interaction hypothesis expanded on the work of Krashen (1982, 1985) and his input hypothesis. Krashen (1985) believed language is acquired through “comprehensible input,” which is L2 input just beyond the current L2 comprehension of the learner (Mitchell, Miles, & Marsden, 2013, p. 44). Long’s (1996) interaction hypothesis noted the importance of the environment in language acquisition, particularly the interactions between native and non-native speakers. Mitchell, Miles, and Mardsen (2013), referencing the early works of Long, discussed how when performing tasks such as “informal conversations or game-playing,” language learners were given context in which they could engage in meaningful language negotiations, including “repetitions, confirmation checks, [and] clarification requests” (p. 160). Long (1996) believed the negotiations made by language learners, including those elicited from negative feedback, were essential to the language acquisition process (Mackey, 1999).
Adding to the interaction hypothesis, Swain’s (1985, 1995) output hypothesis illustrated how a learner’s output, or product, supported “intake of new language” through the interactions had with other speakers (Mitchell, Miles, & Marsden, 2013, p. 161). Further filtering this idea, Mackey (1999) stated that as the learner interacts with others in the second language, “their effort to be understood in the target language [is] pushed,” which in turn, boosts production and leads the learner to take additional risks in trying new forms of the target language (p. 559). The interaction hypothesis provides great potential for native and non-native speakers to further develop their input and output results. When coupled with Papert’s (1993) theory of constructionism, learners actively engaged in language while focusing on constructing a community project, removing stress that may be commonly associated with language acquisition in a more formal academic setting.

**Constructionism and interaction hypothesis.** Considering constructionism’s foundation in technology-based activities (Papert, 1993), the use of robotics as the medium for constructionism was appropriate for this study. LEGO® MINDSTORM® robot kits (LEGO® Education, 2017) were used during an eight-week robotics program, held during the summer at a community-based location. Through robotics, students were offered the opportunity to construct their own understanding and use of academic language within an authentic experience. Additionally, language learning students developed and acquired new language, in this case academic vocabulary, through their interactions with more proficient English-speaking language-learners as well as native-speaking peers (Long, 1996). Via the conversations had by the students, language
learners acquired the input needed and negotiated their own meanings for academic vocabulary (Mackey, 1999).

In sum, the theoretical perspective of constructionism (Papert, 1993) and the interaction hypothesis for language acquisition (Long, 1996) combine and work in partnership to establish the framework for this study.

**Researcher Background**

Maxwell (2005) noted an important question a researcher should acknowledge when deciding on a research topic: “Why are you doing this study?” (p. 15). Strauss and Corbin (1990) added that a person’s own experiences, “may be more valuable [for a] potentially successful research endeavor” (p. 35-36). Personal experiences and background can provide a greater sense of motivation for a researcher to investigate a given phenomenon.

Various experiences have contributed to my interest in the areas of research that focuses on adolescent language learners and optimal teaching practices. I began my career in the field of education while obtaining my master’s degree in education, after

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**Figure 3.1** Constructionism and Interaction Hypotheses.

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**Figure 3.1** Constructionism and Interaction Hypotheses.
which I taught at the elementary level. My teaching experiences include being a general education teacher at the third, fifth, and sixth grade levels for four years, as well as being an after-school program instructor for over seven years, teaching and facilitating drama programs, and STEM-related topics. I was an active member of the school community, organizing and participating in multiple school events as well as the school’s home visit program, serving as the program’s site coordinator for an academic year. During the 2013-2014 school year, the school shifted to a STEM-focused academy in hopes of preparing students for STEM-related professions. This change included regularly scheduled STEM blocks during the week, and a new STEM coordinator for the school to provide additional supports for the teachers in this new endeavor.

During my career as an elementary school teacher, I primarily worked with diverse student populations, which included a high percentage of Hispanic students. Since 2010, the percentage of students who identified as Hispanic at the school where I taught has varied between 64 to 67 percent of the total student population (State Department of Education, 2018). Many of these students came from homes where the primary language was Spanish and when enrolling in the school system, these students were identified as English language learners. My planning and instruction constantly involved utilizing best practices to support my language learning students.

I began my doctoral program during my third year as a classroom teacher and after two years of teaching full-time and completing coursework, I made the decision to leave the classroom and take a graduate assistant position at the university. While I was no longer a full-time teacher, I still regularly participated in student-based activities, both at my old school and the university. Because of my experience and the relationships I
built with my students who belonged to the Hispanic community, I was drawn to conducting research that focused on effective teaching practices that support students who are language learners.

I was afforded the opportunity to assist a professor in my department with her robotics program and with my teaching background, along with my STEM-teaching experience, I was immediately attracted to the research topic of robotics as a vehicle to support language acquisition, specifically how robotics can help students acquire academic vocabulary. Thus, the evolution of the research questions for my dissertation came to fruition, leading to this current study.

Setting

This study was conducted over the course of eight weeks at a local school, which acted as the community-based location for the LEGO® robotics program. The program consisted of a total of 38 60-minute sessions, with an initial meet-and-greet prior to the start of the eight-week program and a participant showcase on the last day (Appendix A). Sessions were held in a large room, with table work stations for students who worked in groups of three to six. Each group was assigned a laptop, provided by the school for the summer, which were set up with the needed LEGO® software prior to the start of the program.

The robot. Students engaged with LEGO® MINDSTORMS® EV3 robot kits, which gave participants the opportunity to build, program, and command a robot in a hands-on and engaging way (LEGO® Education, 2017). Kits included LEGO® bricks, motors, sensors, and both printed and digital directions for assembling and programming their chosen robot design (Figure 3.2).
The EV3 Intelligent Brick served as the brain of the robot and is described on the LEGO® MINDSTORMS® website as “a compact and powerful programmable computer that makes it possible to control motors and collect sensor feedback using the intuitive icon-based programming and data logging software” (LEGO® Education, 2017). By utilizing icon-based programming in the software on which the students programmed...
their robots, non-native speakers and language learners were able to still engage with the robotics program even while not being fluent in the primary language.

During each session, all students participating in the robotics program engaged with the LEGO MINDSTORM® EV3 robot kits. At the start of the hour, students divided into their groups and worked together as they followed the provided instructions to assemble the LEGO® robots. Groups gathered the necessary materials (e.g., LEGO MINDSTORMS® EV3 robot core set, additional LEGO® pieces, pliers, etc.) and convened at their assigned work station. Students asked for assistance in locating materials and some clarification questions, but overall, groups were self-directed. After each group finished constructing their robot, they began working on their group laptop to complete the programming component of the program, using the LEGO® MINDSTORMS® Education EV3 software and programming app. The user-friendly software had students determine and allocate the appropriate speed and direction for their robot to travel. In their groups, the students problem-solved and determined how to complete each task.

Ten minutes before the end of the hour, students collected their materials and cleaned their work stations, and completed their robotics journal entries for the day. All materials, including robotics kits and journals, were returned to the designated storage area.

**The challenges.** While working in their small groups, students built and programmed a robot with the goal of completing challenges associated with the *FIRST* LEGO® League (2017b) annual competition. The theme for the *FIRST* LEGO® League (FLL) competition is released in August. Due to the timing of this study, students
engaged with FLL’s previous competition theme of hydrodynamics. The hydrodynamics theme gave the students a purpose for their engagement with the LEGO® challenges; rather than merely building and completing basic programming with their robot, students were given an additional component to help guide their inquiry.

For the hydrodynamic challenges, students programmed their robots to complete tasks such as Fountain, where students triggered a lever to initiate the fountain, and Pipe Addition, where students maneuvered a solitary pipe to connect with another pipe-piece in the target area (FIRST LEGO® League, 2017a). Again, while actual water or hydrodynamics were not used directly with the robots, the theme added an additional element for students to consider while participating in the LEGO® robotics program. Although students in this study did not compete in the official competition, they showcased their robots at the conclusion of the summer program for their families, teachers, and other community members. In addition to the competition theme, the FLL Core Values (Table 3.2) were also promoted, which aligned with the constructionism (Papert, 1993) and interaction hypothesis (Long, 1996) framework that guided this study.

Table 3.1
*FIRST LEGO® League Core Values*

<table>
<thead>
<tr>
<th>Core Values (FIRST LEGO® League, 2017b)</th>
<th>We are a team.</th>
<th>We do the work to find solution with guidance from our coaches and mentors.</th>
</tr>
</thead>
<tbody>
<tr>
<td>We know our coaches and mentors don’t have all the answers; we learn together.</td>
<td>We honor the spirit of friendly competition.</td>
<td></td>
</tr>
<tr>
<td>What we discover is more important that what we win.</td>
<td>We share our experiences with others.</td>
<td></td>
</tr>
<tr>
<td>We display Gracious Professionalism® and Coopetition® in everything we do.</td>
<td>We have FUN!</td>
<td></td>
</tr>
</tbody>
</table>
The project. In addition to building and programming, students conducted a research project in their small groups, which aligned with the FLL theme of hydrodynamics. Aligning with the theme and providing an additional thread for inquiry, each group decided individually if they wanted to research the issue of water quality or water quantity. Once each group chose an issue, they identified a specific problem related to that issue (e.g., water quality in third world countries) and researched solutions for that problem (e.g., providing filtration systems for households). Beginning the second week of the program, groups followed an alternating research and building schedule, with each group being allotted 20-25 minutes, twice a week, to focus on research for their chosen hydrodynamics-related topic (Appendix A).

For research, students were assigned an individual laptop, once again provided by the school for the summer program, on which they could freely conduct research using online resources. Students took notes for their chosen topic in their individual robotics journals and, once finished with researching, each group put together an informational poster, which they displayed and presented at the robotics showcase. Informational poster templates (Appendix B) were displayed around the room for all groups to reference and guide them in assembling their notes on their chosen topic. The templates also had prompts, such as “What is water quality/quantity,” “What is the problem,” and “What can we do to make a change,” which assisted students as they conducted their research.

Role of the Researcher

During the study, the researcher acted as a teacher for the program, facilitating each session; however, the researcher limited the teacher-like actions she enacted. For
example, where teachers would traditionally be more inclined to provide specific feedback regarding students’ writing, such as spelling and grammar corrections, the researcher simply encouraged students to write or draw in their robotics journals regardless of their spelling abilities. During each session, the researcher interacted with the students, asking open-ended questions regarding what the students were doing during that day’s activities. Interacting with the students utilized participant-observations (Yin, 2014), which provided an inside perspective of how the students engaged with literacy and academic vocabulary in the robotics program. The researcher also established routines with the students, including session start-up and wrap-up procedures, to help each session run smoothly and allow more time for the students to focus on their program goals and work with their robots.

**Participants**

A total of 26 students participated in the community-based program, ranging in age from eight to fourteen, from which four focal students were selected. Purposeful selection (Maxwell, 2005) was used to determine the four focal students and considered the following demographics: age, gender, grade level, race/ethnicity, and program attendance (Table 3.3). Additionally, information regarding participants’ home lives, including language background and proficiency, was obtained through in-person one-on-one interviews with the participants (Appendix C) and was used in the purposeful selection process. Per Maxwell, (2005), conducting purposeful selection using differing criteria, such as that identified above, captures “the heterogeneity in the population” (p. 89). In this case, selecting four participants who varied by age, gender, grade level, race/ethnicity, and language background and proficiency, allowed for a more adequate
representation of “the entire range of variation” within the population of students who participated in the eight-week robotics program (p. 89). Also, choosing four focal students allowed for a more in-depth analysis of the data in relation to the research questions that guided this study (Creswell, 2013). All four focal students self-identified as multilingual and had no prior experience with the LEGO® robotics program.

Table 3.2
Participant Demographics

<table>
<thead>
<tr>
<th>Student Pseudonym</th>
<th>Age</th>
<th>Grade</th>
<th>Gender</th>
<th>Race/Ethnicity</th>
<th>Multilingual?</th>
<th>Program Attendance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eric</td>
<td>10</td>
<td>5th</td>
<td>Male</td>
<td>Hispanic</td>
<td>Yes</td>
<td>37/38</td>
</tr>
<tr>
<td>Isabella</td>
<td>11</td>
<td>6th</td>
<td>Female</td>
<td>Hispanic</td>
<td>Yes</td>
<td>35/38</td>
</tr>
<tr>
<td>Carla</td>
<td>10</td>
<td>5th</td>
<td>Female</td>
<td>Hispanic</td>
<td>Yes</td>
<td>31/38</td>
</tr>
<tr>
<td>Ximena</td>
<td>10</td>
<td>5th</td>
<td>Female</td>
<td>Hispanic</td>
<td>Yes</td>
<td>31/38</td>
</tr>
</tbody>
</table>

Participants primarily came from a single school in a school district located in a western U.S. state to participate in the community-based LEGO® robotics program. The school district is comprised of 107 schools and has over 65,000 students, almost 20% of whom have been identified as English learners (U.S. Department of Education, Institute of Education Sciences, 2016). Two middle-school participants, who were siblings of other program participants, engaged in the program as well, however were not selected as one of the focal students. While not an intentional choice when selecting the focal students, the four participants that were chosen happened to belong to the same group. The factor that contributed to this was these four students had higher program attendance in comparison to other program participants.

While four students were the focus for this study, all students interacted with one another as they constructed and programmed their robots. Interactions for the four focal
students were not limited solely to one another; the focal students regularly interacted with other students in the program. Allowing the focal students to interact with all program participants provided them additional opportunities to engage with language, gather various inputs, and construct their own understandings of academic vocabulary.

**Eric.** Eric was the only male student selected as one of the four focal students. Of the 26 total participants, six students were male, while the remaining 20 were female; therefore, selecting one male focal student was representative of the overall group. In his initial interview, Eric shared that his family was from Mexico, he had one older sister, and that Spanish was the primary language spoken at home. He also shared that he liked playing soccer and video games, and in the following school year he was going to be his school’s vice president. When asked about his prior experiences with LEGO® products, he said he was not a big fan of traditional LEGO® bricks, but was looking forward to the electronics-related components associated with the robotics program.

During the summer program, Eric had consistent attendance and actively participated in robot construction and programming. He emerged as a leader within his group, often instructing other students on what steps to take in order to complete the given task. He actively engaged in research, excitedly sharing findings with his groupmates as well as the researcher and other program participants. Eric was a strong collaborator and regularly supported others.

**Isabella.** Isabella was the oldest of the four focal students and transitioning to middle school at the end of the summer program. In her initial interview, she shared that some of her family was from Mexico, but most were from the United States. She also shared that English and Spanish were both spoken in the home, especially with her older
relatives, such as aunts and uncles. Isabella was an only child; however, talked about how she was very close with her extended family, frequently spending time with her cousins afterschool and on the weekends. When asked about her experiences with LEGO® products, she said she had played with LEGO® kits during those times spent with her family.

Isabella also had consistent attendance during the program and supported her group with constructing their robot. At times, she ended up being more social and wanted to talk about other topics with her friends, but would re-engage when her groupmates needed help. At the robotics showcase, held on the final day of the summer program, Isabella was the most vocal in explaining what she and her group accomplished in building, programming, and research. She actively answered questions from her family and others who attended the showcase.

**Carla.** Of the four focal students, Carla was one of two female fifth graders. During her initial interview, she shared that she was the youngest of three children, with an older brother and an older sister. She stated that she spoke three languages: English, Spanish, and Esperanto, the latter, she described, as a language that combines all other languages. Carla said she was familiar with robotics, because her brother, a soon-to-be college freshman planning to major in engineering, frequently used technology to build lasers and robots.

Carla had consistent program attendance and actively participated with her group in building and programming. She was also highly engaged with the research project, admitting that she enjoyed writing and learning about new topics. She would assist her
groupmates in locating online resources and accessing the appropriate information for their group’s chosen topic.

**Ximena.** Ximena was the other fifth-grade female selected as one of the focal students. From her initial interview, it became apparent that Ximena was more reserved in comparison to the other focal students; however, when in the more social setting of the group work, she was active in supporting her groupmates. Her initial interview revealed that she had an older brother, three sisters, and her mom provided childcare for many families in their neighborhood, so she regularly had other children in her life. Her parents only spoke Spanish, while Ximena was a fluent Spanish speaker and becoming proficient in English. Ximena shared that she knew what LEGO® products were, but did not really play with them on her own.

Ximena, too, had good program attendance, and in her group and throughout the summer program, she was the biggest helper. She regularly volunteered to complete tasks in her group as well as assisted other students and the researcher with pack up at the end of each session. At times, Ximena took on tasks that other students were not keen on completing, such as retrieving parts for the robot and cleaning up the group work station at the end of the session, but she was eager to provide help wherever and whenever she could.

**Data Sources and Data Collection Procedures**

Data were collected during all robotics sessions and included videotaped sessions, student interviews, and student artifacts.

**Videotaped sessions.** Each session during the robotics program included students working in small groups as well as completing some individual tasks. Of the 38
60-minute robotics sessions, 37 were recorded. The final session, which culminated in the robotics showcase, was not recorded due to lack of parent permissions. Video recording took place in the large room and utilized four video cameras connected to wireless microphones, with each camera focusing on one group of students. Microphones were placed at student work stations to better capture audio and were unobtrusive to the students. Additionally, anecdotal notes were taken by the researcher during each robotics session, with these notes being the sole data from the robotics showcase. The videotaped sessions and corresponding transcripts as well as the anecdotal notes provided a documented look into the use of the phenomenon of robotics within a real-world context.

**Student interviews.** Interviews were conducted both individually and in small groups. Individual student interviews were conducted during the first and last weeks of the program, with three to five students being interviewed each day, and each interview lasting approximately three to five minutes. Individual interviews (Appendix C) were performed one-on-one by the researcher in the hallway outside the large, community room, separate from other program participants. Each student participant was interviewed to ensure students did not feel excluded or isolated. For the four focal students, the initial interviews provided additional background information for each student as well as their prior experiences with LEGO® products and robotics. The concluding interviews provided further insight to the students' takeaways from the program, along with examples of their verbal use of academic vocabulary. Informal small group interviews (Appendix D) were conducted at the end of each week and showed how students verbally used academic language while interacting with each other.
**Student artifacts.** Each student was provided a robotics journal on the first day of the program, which they used during each session, with daily writing prompts provided by the researcher (Appendix A). Students utilized their journals at their discretion while interacting in small groups; they were encouraged, but not required, to make notes or observations while working with the robot kits and conducting their research. The students were, however, required to journal for the last five minutes of each robotics session, responding to the daily writing prompt. The robotics journals provided evidence of students’ written use of academic language.

In addition to their notes and responses to the writing prompts, students were asked to define robotics-related academic vocabulary at the beginning and end of the eight-week program (Appendix E). A total of 20 vocabulary terms were chosen and included a mixture of tier-two and tier-three vocabulary (i.e., seven tier-two words and 13 tier-three words). Students were allowed to write or draw their understandings of the provided terms in their robotics journal. This activity exhibited the depth of students’ understandings for the robotics-related academic vocabulary both prior to and after engaging with the robotics kits.

**Limitations**

While this study adds to the existing research on the use of robotics in educational settings, particularly in conjunction with literacy, there were still limitations that must be identified. Foremost, when obtaining permissions and consent for students to participate in this study, the researcher initially had planned to recruit parents of the participants as well to provide additional insights to the students’ home languages. During the recruitment phase, there were a number of parents who were concerned about their
participation, and upon further examination what emerged was the parents’ concern about the term *research*, which, when translated into Spanish, is *investigación*. Taking into consideration the current climate on immigrants in the United States, parents were concerned that if they participated, their residency in the U.S. could be jeopardized. The researcher worked with translators to ensure that families knew participation in the study would not be tied in any way to immigration. Parents agreed to allow their child to participate, but were still hesitant of their own participation; therefore, it was ultimately decided to focus solely on the student participants and not pursue parent participation.

Additional limitations included the timing and duration of the program. Being held in the summer made the program optional for students to attend and resulted in low attendance at certain points during the eight weeks. For example, families had scheduled trips for the Fourth of July holiday, which fell on a Wednesday and resulted in fewer students coming to the program during that week. Also, with the program lasting eight weeks, there were students who began to lose interest in robotics midway through. This included students no longer attending sessions or coming, but distracting others who were trying to work on their robot and research. While these limitations were present, overall, the students who attended a majority of the sessions and remained engaged with the tasks were productive and able to achieve their goals in the robotics program.

**Data Analysis**

Data analysis were conducted in multiple phases to answer each research questions: (1) how do early adolescent students who are language learners engage with literacy during an eight-week LEGO® robotics program; (2) how do early adolescent students who are language learners develop and apply academic vocabulary during an
eight-week LEGO® robotics program; and (3) what are early adolescent students’ understandings of robotics-related academic vocabulary at the beginning and end of an eight-week LEGO® robotics program? The following sections describe the data analysis process for each individual research question.

Research question one. The primary data sources used in analysis for the first research question were the video recordings and corresponding transcripts that included the four focal students, the focal students’ robotics journals and informational group poster, and the researcher’s observational notes. The first cycle of data analysis focused on reviewing the identified data sources freely in order to get a feel for what was occurring during the robotics sessions (Corbin & Strauss, 2008). The data sources were reviewed based on the day in which they occurred; for example, the video recording, transcript, observational notes, and student robotics journal entries for session three were reviewed collectively to provide focus on that given day.

Next, the data were reviewed and openly coded to identify concepts that displayed how the four focal students engaged with literacy during the robotics program. For the purpose of this study, literacy was defined as, “The ability to identify, understand, interpret, create, compute, and communicate using visual, audible, and digital materials across disciplines and in any context” (ILA, 2019). Axial coding – the collapsing of key terms and concepts into main categories and themes – occurred concurrently with the open coding process. As described by Corbin and Strauss (2008), when researchers review and analyze data, they automatically begin to make connections between concepts, resulting in categories and themes. Again, the data sources were analyzed collectively by day. Initial concepts, categories and themes, and evidence from the data
were recorded in a table throughout the data analysis process for the first research question (Appendix F).

**Research question two.** For the second research question, data were analyzed in two phases. First, data were analyzed following the same process used for research questions one; however, instead of literacy, a focus was placed on how the four focal students engaged with academic vocabulary. Open and axial codes were recorded in a table (Appendix F), along with examples from the data.

Next, data were analyzed using a predetermined coding scheme, shaped by Beck, McKeown, and Kucan’s (2002) Three Tier Model for academic vocabulary and the Corpus of Contemporary American English (Table 3.3), to provide a deeper look into the specific vocabulary used by the focal students. Selected transcripts were entered into the Word and Phrase feature connected to the COCA database and color codes were produced in relation to the three levels of academic vocabulary (Figure 3.3). Transcripts chosen for the Words and Phrases feature were: (1) the focal students’ writing prompt responses; (2) student written research notes; and (3) one video transcript with the focal students from each week of the program. The first two data sources provided a look into the students’ written use of academic vocabulary and the third data source focused on their verbal use. After coding was completed using COCA, transcripts were re-analyzed to determine which levels of academic vocabulary were most frequently used by the students.
Academic Vocabulary Coding Scheme

<table>
<thead>
<tr>
<th>Tier 1: Basic Words</th>
<th>Low-frequency Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 2: General Academic/Multi-meaning Words</td>
<td>Medium-frequency Words</td>
</tr>
<tr>
<td>Tier 3: Specific Content Words</td>
<td>Domain-specific/Academic Words</td>
</tr>
</tbody>
</table>

Research question three. Data analysis for research question three focused on the students’ robotics-related vocabulary definitions they completed in their journals at the beginning and end of the eight-week program. The students’ definitions were analyzed to determine their depth of understanding for the provided terms. Semiotics was used to examine how students made meaning of the academic vocabulary through various means, including written word, drawings, and gestures (Siegel, 2006). Video recordings of the students completing this task were revisited to determine other factors.
that may have impacted their definitions, including physical gestures, talking with other students, and referencing other resources.

**Theoretical integration.** After completing data analysis, the overarching concepts and categories were revisited in regard to their relationship to the theoretical framework that guided this study – constructionism (Papert, 1993) and interaction hypothesis (Long, 1996). The act of constructing a physical product – the LEGO® MINDSTORMS® robot – was central in the students’ written and verbal communication that occurred throughout the program. Additionally, the students participated in verbal communication daily with their peers, providing multitudes of interactions for students to develop both informal and academic language.

**Summary**

Through qualitative methods, this case study, shaped by Papert’s (1993) theory of constructionism and Long’s (1996) interaction hypothesis for language acquisition, provided further insights into the use of robotics in education and, more specifically, robotics’ potential to promote literacy and academic vocabulary development. Conducted at a community-based location, a total of 26 students participated in the eight-week summer robotics program, of which four focal students were selected to provide a deeper data analysis to answers the three research questions that guided this study.
Chapter 4

Findings

Over the course of eight weeks, 26 students, ranging in age from eight to fourteen, participated in a summer robotics program. Of those 26 students, four focal students were chosen to provide an in-depth analysis of the data in relation to the purpose of this study. In this chapter, data are presented to show how the four focal students engaged with literacy during the robotics program as well as the students’ development and application of academic vocabulary, answering the following research questions:

- How do early adolescent students who are language learners engage with literacy during an eight-week LEGO® robotics program?
- How do early adolescent students who are language learners develop and apply academic vocabulary during an eight-week LEGO® robotics program?
- What are early adolescent students’ understandings of robotics-related academic vocabulary at the beginning and end of an eight-week LEGO® robotics program?

During the program, students’ engagement with literacy combined into three main themes: (1) informational texts; (2) writing; and (3) dialogue. In the data, examples of the focal students’ interpretation and comprehension of multimodal informational texts, including the students’ use of discipline-specific concepts and knowledge, emerged, collapsing into the overall theme of informational texts. Next, the students’ engagement with both informal and formal forms of written communication appeared, resulting in the theme of writing. Finally, the active participation by the students in social forms as well
as their application of discipline-specific concepts in verbal communication appeared, which developed the theme of *dialogue*. These themes aligned with the definition of literacy as applied within the context of this study.

Within these themes were also examples of the students’ development and application of academic vocabulary. Data showed how the students were exposed to, comprehended, and conducted research with academic vocabulary in *informational texts*, along with how the focal students incorporated varied levels of academic vocabulary in *writing*. Also, video recordings and transcripts illustrated how the students verbally incorporated academic vocabulary as they communicated with others in the robotics program, and how the students used *dialogue* to negotiate meaning of new vocabulary.

Additionally, the students’ recorded definitions of robotics-related vocabulary, completed at the beginning and end of the eight-week program, reflected minor changes in the students’ overall understandings of those specific terms.

**Finding 1: Students’ Engagement with Literacy**

The following sections describe how the four focal students engaged with literacy, within the themes of informational texts, writing, and dialogue. First, data illustrating how the focal students accessed and utilized informational texts is discussed, followed by an analysis of how the students used writing within the constructs of the robotics program. Lastly, data demonstrating the students’ engagement with verbal communication in relation to robotics is presented.

**Informational Texts.** As detailed in the Common Core State Standards for English Language Arts (National Governor’s Association/Council of Chief State School Officers [NGA/CCSSO], 2010), students are required to access and comprehend a greater
percentage of informational texts as they progress through the K-12 system. During the robotics program, the focal students engaged with numerous forms of informational texts, including the robot building and programming directions, and the various resources the students accessed while conducting research for their topic of water quantity. Additionally, the students used a number of multimodal texts to learn more about their chosen topic on water quantity, such as informational videos and text features.

**Book robot instructions.** The first informational text the students engaged with during the robotics program was the instructions for building what the researcher and students referred to as the “book robot.” These are the standard instructions that come with the LEGO® MINDSTORMS® EV3 robot kit (Figure 4.1), which the researcher scanned and uploaded to the computers for easier student access. The instructions are considered a visual text, because there are no written terms in the step-by-step directions; however, the instructions still required the students to negotiate the meanings of the images in order to comprehend each step.

*Figure 4.1 Example from LEGO® MINDSTORMS® EV3 robot instruction book (LEGO® Group, 2015).*
About halfway through the program, the focal students decided they wanted to try building a new, more challenging robot. They were given a link through the LEGO® education website, where they perused the new robot options, ultimately deciding to build a dog robot (Figure 4.2). Again, the directions for the new robot required the students to access their prior knowledge and other literacy strategies to engage with and comprehend a visual informational text.

![Figure 4.2 Example of robot dog instructions (left) and the focal students’ final project (right) (LEGO® Group, 2018).](image)

While at first glance the visual text, robot building instructions may appear easy, the difficulty in comprehension increases as the instructions start focusing on combining each individual component; if the pieces are not properly connected, the robot will not work. The final product made by the students showed they were able to engage with and comprehend this expository text. Other informational texts the students worked with were the digital texts they found during their research.
**Research with multimodal texts.** To begin researching, the students started by simply typing “water quantity” into the default search engine on their assigned laptop. Referring to the initial information that appeared in his search results, Eric read that there were different types of water on Earth, narrowing down to fresh water and salt water. He continued reading that there was “1.386 billion…water in the world,” which he proceeded to write in his research notes (Figure 4.3).

![Figure 4.3 Eric engaging with multimodal texts. This image shows Eric referencing a piece of informational text on water quantity.](image)

As the students continued their research, they began utilizing specific informational text features, such as maps, graphs, and charts, to access and compile additional facts on water quantity. Upon discovering a map of the United States that contained information on how much water each state wastes, the students began discussing this information, comparing it to what they had learned so far. After this discussion, they determined the map contained older information and proceeded to brainstorm other terms and phrases to enter into the search engine to narrow down results to specific states, which is illustrated in the following transcript.
Alex: I don’t know what else to… Oh wait, I found a map that’s pretty cool. Hold up, hold up. [Gestures to Isabella and Eric] Come over here.

[Eric and Isabella huddle around Alex’s computer]

Alex: What state is that?

Eric: Which one?

[Alex points to the map on the screen]

Alex: That state wastes more water than the entire United States. Hold up, let me search up… Look how much water we waste. Out of the entire United States.

Isabella: No, we’re down. 30 something. [Referring to the research results on her laptop screen].

Alex: Oh man, we waste a lot of water.

Eric: No. This [map] is from 2000 to 2015.

Isabella: That’s why you have to…

[Alex and Carla start typing new search entries]


Alex: And 2018.

[Alex and Carla begin typing on their laptops to continue researching]

Eric: I’m getting my notebook.

Employing informational text features, a map in this specific case, proved to be fruitful in supporting the focal students’ research and led to discovering new facts about the amount of water wasted by various U.S. states (Figure 4.4).
The discussions of the focal students’ use of the robot instructions and research with multimodal texts illustrates how the students engaged with different forms of informational texts. They actively employed various comprehension strategies in order to understand distinct formats, including the visual step-by-step instructions and informational text features, such as maps and graphs. In turn, they contextualized this information and showed their comprehension of the material through correctly building their robot as well as by adding facts to their notes and informational poster through writing.

**Writing.** Throughout the robotics program, students were provided various opportunities to engage with writing, primarily in their individual robotics journals. For the purpose of this study, writing, at its most basic level, was defined as a process of graphically recording language using letters and other symbols (ILA, 2019). In this program, writing took shape in the forms of student responses to daily writing prompts, such as, “What did you accomplish today? What are your goals for tomorrow?”, as well as note-taking during the research portion of the robotics sessions. Research was student-led and aligned with the focal students’ chosen topic of water quantity, which
corresponded with the FLL theme of hydrodynamics, as discussed in the previous chapter. Lastly, the students compiled and wrote their facts about water quantity on and informational poster, created by the group and presented at the robotics showcase.

*Writing prompt responses.* Starting on day one, each session ended with the students being given an open-ended writing prompt to answer in their robotics journals. The purpose of the writing prompts was to support the students as they constructed and programmed their robots. Student responses were informal, meaning there were no expectations in regards to standard writing conventions, such as spelling or grammar. Each focal student completed the daily writing responses and their writings varied in length, content, and style. Three of the four focal students wrote their responses as a stream-of-consciousness (Figure 4.5), while one student wrote in a more bulleted-style (Figure 4.6). The individual responses for each focal student showed how that student utilized this writing to support his or her participation in the robotics program.
Figure 4.5. Robotics journal examples. This figure shows informal journal prompt responses from Carla (top), Eric (middle), and Ximena (bottom).
Figure 4.6 Robotics journal comparison. This figure shows excerpts from Isabella’s robotics journal from the beginning of the program (left) and the end (right).

**Eric.** Eric’s responses to the daily writing prompts were specific and directly answered the questions asked for that given day. Examples of Eric’s writing are shared in Figure 4.7. As shown, his entries were typically short and at times incomplete sentences, and did not always employ correct grammar or syntax. He did, however, address what he and his group accomplished with regard to building and programming their robot, and once the group began their mini-research project, he included facts about their topic of water quantity as well. Since Eric attended 37 out of 38 sessions, his
writing prompt responses provide a clear outline of what his group did throughout the eight-week robotics program.

<table>
<thead>
<tr>
<th>Date</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/12/18</td>
<td>today we started on part three! my goal is to finish part three and start part four</td>
</tr>
<tr>
<td>6/13/18</td>
<td>today we are working on part six and are goals is to finish part six and seven</td>
</tr>
<tr>
<td>6/15/18</td>
<td>today we are program the robot to talk/my goal is to program more thing on the robot</td>
</tr>
<tr>
<td></td>
<td>we finish a challenge today.</td>
</tr>
<tr>
<td></td>
<td>today we made the robot go straight and not limp</td>
</tr>
<tr>
<td></td>
<td>what we have been successful is to patate patate patahing</td>
</tr>
<tr>
<td></td>
<td>we finish a challenge today we started on the expansion</td>
</tr>
<tr>
<td></td>
<td>pack</td>
</tr>
<tr>
<td></td>
<td>we started in a new set! we learned the average of water in 117 million lake is 187,362,100,000</td>
</tr>
</tbody>
</table>

*Figure 4.7* Eric’s Writing Prompt Responses. This figure shows excerpts from Eric’s robotics journal.

_Ximena_. Ximena’s writing responses answered the day’s questions and were also short, but she regularly followed writing conventions, such as using capitals when required and proper punctuations. As illustrated in Figure 4.8, she attempted to correct mistakes she made when writing, primarily with spelling. This editing, however, did not appear to inhibit her participation in completing the daily writing responses. She, too, wrote about not only what her group did with their robot, but what she learned through research as well. One thing Ximena included in all her journal entries was the date on which she wrote that entry; the other three focal students included the date with their entries at the beginning of the program, but began leaving it out as the program progressed. While including the date may seem small, this piece of data is an important
component when engaged with a sequential activity, because it is marker for milestones when completing a given task.

Figure 4.8 Ximena's Writing Prompt Responses. This figure shows excerpts from Ximena's robotics journal.

Carla. Similarly, Carla’s responses also directly answered the daily writing prompts, which she periodically incorporated into her journal entry, as seen in Figure 4.9. However, when compared to the other three focal students, Carla’s entries were significantly longer and included more detail in regard to what was accomplished or learned on a given day. Additionally, Carla not only addressed what her group did, she talked about what she individually contributed for the day. Her responses became slightly shorter about halfway throughout the program, but still had enough specific details to exhibit a strong image of the day’s occurrences. At times she would also incorporate slang in her writing, such as “cuz,” or describe her feelings in relation to a task, like, “I hope we do it right.” When read in conjunction with Eric and Ximena’s
journal entries, Carla’s writing adds further insights about and paints a clearer picture of the eight-week robotics program.

Figure 4.9 Carla’s Writing Prompt Responses. This figure shows excerpts from Carla's robotics journal.

**Isabella.** Isabella’s writing, while similar content-wise to the other three focal students, followed a more bulleted-style, but became choppier and vaguer towards the end of the eight-week program (Figure 4.10). She frequently wrote in incomplete sentences, sometimes single-word responses, and incorporated slang (e.g., “IDK”). While she did answer the writing prompts, even if in just one word, there were times she strayed off topic, like seen in Figure 4.10 where she writes that their group’s dog robot lost a tooth, to which she replied, “I was the tooth fairy.” Isabella’s writing painted a more ambiguous picture of what she accomplished during each robotics session, and how much she participated in the constructing and programming of her group’s robot.
Overall, the writing examples from each of the four focal students show the variability in how the students used informal writing to support their progress and participation during the robotics program. Within their written entries, the students did incorporate various levels of academic vocabulary, which is further discussed in finding two. In addition to informal writing, the students utilized their robotics journals for note taking purposes during the research portion of the robotics program.

**Student research notes.** Beginning the second week of the program, groups followed an alternating research and building schedule, with each group being allotted 30 minutes, twice a week, to focus on research for their chosen hydrodynamics-related topic. During research, students took notes on information they felt was important and wanted
to include on their group informational poster, which they presented to their families and other invited guests at the robotics showcase held on the last day of the program. For researching purposes, students were given access to various informational books as well as laptops, which they could use to freely search and access online resources. Of these two main modes of research, the students primarily used the online sources they found to compile their notes and assemble their informational poster. When engaging with the online resources, three practices emerged: (1) when reading online texts, students predominantly copied information into their notes word-for-word; (2) when using digital sources, such as videos, students paraphrased information to the best of their abilities; and (3) students incorporated pictorial representations (e.g., pie charts) to record information.

Direct copying. Ximena primarily copied all her notes on water quantity from the sources she accessed (Figure 4.11). This copying was apparent when comparing the spelling in her notes on water quantity to her responses to the daily informal writing prompts (Figure 4.8). For example, the first sentence Ximena wrote in her notes is grammatically and syntactically correct (e.g., “People need 8 ounce glasses, which equals about 2 liters, or half a gallon of water.”), whereas her informal writing typically contained syntax and spelling errors (e.g., “Today we acplish is finishing building our robot. Tomorrow out goal is programing.”). While relying heavily on the words of others, in this case the original author of the accessed source, Ximena still engaged with writing to recall new information on her group’s chosen research topic.
Paraphrasing. In contrast, Eric compiled many of his notes in his own words (Figure 4.12). His paraphrasing was clear through his consistent use of spelling “their” in place of “there,” the latter being grammatically correct in the context of his notes; if merely copying notes, grammatical errors like this would not be present. Additionally, when writing the states that are running out of water in his research notes, another student told Eric to copy her notes, passing over her robotics journal, to which Eric replied, “No,
I don’t want to copy.” Consequently, he did use the correct abbreviation of “km³,” which is less likely to be in a fifth-grade student’s repertoire and could reflect intermittent copying from the accessed resources; however, he made the conscious choice to include this in his written notes, indicating some metacognition in his notetaking.

![Research notes](image)

*Figure 4.12* Eric robotics journal research notes.

**Pictorial notetaking.** In addition to using the written word to collect their research notes on water quantity, two of the focal students chose to include pictorial
supports, specifically in the form of pie charts (Figure 4.13). Isabella and Carla not only wrote out part of their notes in sentence form, they also recorded numerical data in pie charts. It is unclear what Carla’s pie chart represents, due her lack of incorporating labels; however, Isabella’s chart is clear in that it had appropriate labels for each piece of the chart and its corresponding percentages (e.g., “Water Waster Chart,” “Outdoors – 50%,” “Toilets – 10%”).

*Figure 4.13 Pictorial Research Notes. This figure includes pictorial examples of Isabella's (top) and Carla's (bottom) research notes.*
The research notes examples present the different ways the four focal students used writing for the purpose of recording information. As the students continued following the alternating researching and building schedule, by week six of the program, they had completed and collected enough research and notes to begin creating their group informational poster.

*Group informational poster.* While the robotics journal excerpts showed how the focal students’ note-taking writing styles varied, the informational poster revealed that the students were able to collect and compile their thoughts in a comprehensible manner (Figure 4.14). The students used one of the informational poster templates (Appendix B) that was displayed to assemble their notes on water quantity in a comprehensible manner. The focal students chose to include the following components in their poster: (1) a definition for water quantity; (2) causes of the problem; (3) where and what places this occurs most in; (4) the effect on people living in those areas; (5) what individuals can do to solve the problem; and (6) fun facts.
Figure 4.14 Focal students group informational poster.

The focal students chose to list their facts on the poster using a bulleted format and included pie graphs, modeled after the ones used in Isabella and Carla’s robotics journals, to support their research on water quantity. The graphs were labeled to provide additional clarification. The poster shows a transition in the students’ thinking, from individually to globally; initially, the students focused on writing notes in order for
themselves to be able to understand the information, then moved to using writing to put together facts in such a way that others could comprehend.

For example, Isabella included a pie chart in her individual research notes, which focused on causes for water waste (e.g., toilets, showers, and sprinklers). That specific graph was not included on the group poster; however, the group chose to share other information using a pie chart format to provide visual support for their information (e.g., a pie chart identifying the percentages of the different types of water – fresh water, ocean water, lake water, fresh frozen water). Another example of the focal students’ collaborative writing was comparing their research notes to see which facts were repeated. Video recordings showed how the students conversed with one another to negotiate which facts were most important and needed to be included on the final poster (e.g., “68.7% of the fresh water on Earth is trapped in glaciers” and “take less showers” as a solution to the problem of water quantity).

The combination of informal writing, notetaking, and publishing a group poster, by way of their initial engagement with various informational texts, illustrated how writing proved to be a valuable literacy tool for the students during the robotics program. The final area of literacy to be discussed that the students engaged with was that of verbal communication, or more simply put: dialogue.

**Dialogue.** While reviewing the data, the theme of dialogue was pronounced, largely due to the amount of conversation students engaged with on a daily basis during the program. Discussions occurred at varying degrees of participation; meaning, students talked with one another focusing on the robotics project, in addition to off-topic chats. Within their groups, students conversed as they built and programmed their robots and
while they conducted their research for their chosen topic. The focal students also interacted with other students in the program, engaging in dialogue as they assisted other groups with their building and programming. On the final day of the summer program, families and friends were invited to a robotics showcase, where the focal students shared with various guests their informational poster and their robot, which resulted in a more formal use of dialogue by the students.

*Small group collaboration and conversation.* In their group, the four focal students actively communicated with one another. There were times when the group would talk about topics other than those related to robotics and the research project; however, when focused on a specific task, the students partook in productive conversations. The following transcript excerpt exemplifies how the focal students communicated with one another to complete a given task, which was to program their robot to follow a given path (Appendix G). The transcript includes an additional student, Alex, who was also a member of the same group as the focal students, but whom was not chosen to be a focal participant due to leaving halfway through the robotics program.

Ximena: Okay, that’s good.
Alex: Yup, push it in.
Eric: Got it.
Alex: Okay, now we got it.

[move to floor to test robot]

Isabella: More.
Carla: A little more.
Eric: 100 percent.
Carla: We’d have to make it -100. It’s negative. Or never mind, never mind. Let’s try this. Maybe that’ll be a little bit…

Ximena: What number?

Eric: I don’t know.

Alex: Just a little more. Like ten more. Go like ten more

Ximena: It’s at 90, it’s at 94.

Alex: Actually, I think that’s what we need.

Isabella: I don’t know. I honestly don’t know.

Alex: Let’s try it. Hold on. Don’t want you to drop it again.

[testing robot]

Alex: We made it touch it! That’s it!

Eric: Make it 100%

Carla: Don’t make it 100. Make it like…99.

Ximena: -99. Write it down.

In the excerpt, three group members noted they needed to increase the speed and directionality of their robot program, with Eric stating it needed to be increased to, “100 percent.” Carla added to her group mates’ points that this number needed to be negative in order to accommodate for directionality. As the students continued to negotiate and test their programming code, they concluded that the number did indeed need to be negative; however, it also needed to be less than 100. Ximena ends by asserting they need to write this down for future reference.

In addition to using conversation to collaborate in constructing and programming their robot, the students discussed new information regarding their research topic as they
learned interesting facts. One example was the students’ discussion on reusing different types of water. Upon discovering that the amount of fresh water in the world, which they noted was the only type of water safe for human consumption, was running out, they started exploring some innovative solutions researchers have proposed.

Eric: Ok. So, I’m pretty sure whenever you, like…washing your hands, you’re basically…and going to the bathroom…you’re basically wasting water.

Alex: But what if you have dirty hands? You really want to drink dirty water?

Eric: [thinking] Good point.

Alex: That’s a good point, right? And, it’s like, just, wasting toilet water. That would be weird.

Eric: Well, that’s… that’s…

Alex: [interjecting] Did you guys know that there are people who are trying to recycle… Oh wait, I think you know about this [gestures to Eric].

Isabella: Toilet paper?

Alex: No. Toilet water. Like, taking out all the pee…

Eric: [long sound of disgust]

Alex: Cuz soon they’re gonna…like…know, but like, to the point where it actually turns, like, good. Like, drinkable.

Eric: Drinkable?!

Alex: But it won’t have any taste. It’ll taste just like regular water. You want poo water?

Eric: [while making crying/laughing sounds] No!
While certainly a comical discussion, this interchange shows how the students engaged in conversation as they began making connections between new information they learned through research and parts of their everyday life.

Both transcripts also illustrate how these students felt safe with one another in their smaller group and took risks, such as stating, “I don’t know,” in the first excerpt when attempting to program the robot. In the second example, the students discussed a topic that might normally not be condoned in a regular classroom, but certainly relates to the hydrodynamics theme and purpose for their research project. Providing an open forum within their groups to converse as they pleased allowed the students to express themselves freely, which proved to be productive. All the within-group conversations culminated in the more formal presentation by the focal students at the robotics showcase.

**Robotics showcase presentation.** At the showcase, the students formally presented their informational poster to their families and friends, along with their completed robot and corresponding programming. To present their research, the students primarily read straight off their informational poster; however, they did engage in some informal dialogue as guests asked them questions about their poster and robot. While videos and transcripts were unavailable from the robotics showcase due to lack of parent participation over concerns with IRB paperwork impacting any government or immigration status, the researcher’s observational notes from the evening reflected how the students were able to effectively use dialogue to elaborate on their work during the program.
While presenting her poster to her family, Isabella was able to answer questions posed by her mother and aunt about how much water people waste on a daily basis. She also explained how the suggestions made by her group to conserve water, such as taking shorter showers, can be something everybody can do because it only takes one person to start making a difference. Afterward, she showcased the group’s robot and explained the “tricks” they programmed their robot dog to do, including “chasing its tail” and “scratching its butt on the carpet.” Again, a comical example, however, this conversation demonstrated the creativity the students had in applying everyday knowledge into their robot programming and their ability to communicate this creativity in a clear manner to others who were not everyday participants of the robotics program.

The various avenues of dialogue engaged in by the students showed how providing a forum in which individuals can freely converse in can stimulate a productive environment. While there were occasional off-topic conversations, overall, the students stayed focused on completing the FLL robot challenges and their group research project. In addition to writing and communication, the robotics program also promoted the students’ access to, use of, and engagement with informational texts.

The examples shared in Finding 1 demonstrate how the four focal students engaged with literacy, as a whole, during the eight-week robotics program. This engagement included working with various forms of informational texts, utilizing writing to record ideas and facts, and participating in purposeful dialogue to complete a given task. The next section will discuss examples from the data that answer the second research question and present the students’ development and application of academic vocabulary.
Finding 2: Students’ Development and Application of Academic Vocabulary

Within the themes presented in Finding 1, examples of how the students developed and applied academic vocabulary during the LEGO® robotics program were also evident. Both Beck, McKeown, and Kucan’s (2002) Three Tier Model for academic vocabulary and the Corpus of Contemporary English (COCA; Davies, 2012) were utilized to identify the type of academic vocabulary used by the four focal students within their writing as well as verbal communications. Transcripts of video recordings that included the focal students’ participation in group conversations and examples of their writing were entered into the Words and Phrases feature of COCA, which identified the various types and levels of academic vocabulary employed by the students.

The following sections are organized using the same three themes described in Finding 1; however, focus is placed on the academic vocabulary present in the data. Ways in which the themes interrelate with one another are incorporated throughout the discussion as well. The written application of academic vocabulary by the students will be explored, followed by an examination of their verbal application. First, a discussion of the students’ exposure to academic vocabulary in various contexts, particularly domain-specific words, will be presented.

Informational Texts. As addressed in Finding 1, the students accessed various informational texts during their participation in the eight-week robotics program. Different levels of academic vocabulary were present in these multimodal texts. Through their engagement with these texts, the focal students were exposed to academic language within appropriate contexts, which led to further research and exploration with newly acquired general- and domain-specific academic vocabulary. Additionally, the
multimodal texts required the students to employ varying strategies in order to comprehend the material.

Comprehending visual informational texts. Although the robot instructions were classified as a visual text, the focal students were still required to negotiate the meanings of the images. An example of the visual text instructions the focal students used to construct their robot dog can be seen on the computer screen in Figure 4.15. This step required the students to attach the dog’s eyes to the body of the robot. The image merely showed the eyes on the robot and did not provide additional instructions on how to ensure the eyes would stay attached. As Eric attempted to attach the eyes, he repeatedly looked over the robot body and back at the instructions to comprehend how the eye would connect. While watching the video recording for this session, Eric can be heard making puzzled noises and vocalizing a questionable, “Okay?” After multiple attempts, he finally exclaimed, “I got it. I got it. I got it.” showing he was able to negotiate and comprehend this step in the visual text instructions.

Figure 4.15 Example of visual text robot instructions.
Figure 4.16 and the corresponding transcript represents another example of the students negotiating the meaning of the visual text instructions through conversation.

Figure 4.16 Eric and Ximena interpreting the visual text robot instructions.

[Another program participant asks Eric and Ximena what they are doing]

Eric: We’re building a dog.

[Eric and Ximena return to the instructions]

Eric: We need a black T.

Ximena: It’s this one [referring to robot kit insert]

Eric: There. A black T.

[Looking back at instructions and attempting to attach the new pieces]

Eric: Wait a minute… Ah, like that. Okay, okay.

Ximena: What’s next?

Eric: One small yellow. I need a coin. A yellow coin.

[Ximena looks for the piece]

[Ximena hands Eric a yellow piece and a grey piece]

Eric: No. I was just telling you what the names were.

[Ximena puts back the grey piece]

Eric: Ok, so now… [begins attempting to connect new pieces]

[Eric and Ximena repeatedly look at the computer to clarify the instructions]

Eric: Ok, I need a slug. I need a slug and a small blue. I’m calling this a slug.

now [pointing to a specific piece on robot]

[Ximena hands Eric the pieces].

Eric: Thank you.

In comprehending these instructions, Eric chose to describe the pieces in a manner that he and his groupmates could understand. For his descriptions, he used general- and domain-specific vocabulary, such as “yellow,” “blue,” “grey,” and “coin.”

These two examples illustrated how the students comprehended the visual text in order to successfully assemble their robot. The difference between the two examples are internal versus collaborative interpretations of the instructions. Within Figure 4.15, Eric negotiated his understanding of the text internally, while in Figure 4.16, Eric and Ximena outwardly worked together in order to understand each instructional step. In their open collaboration, it was possible to see the academic vocabulary used in order to comprehended the text, as shown in the transcript excerpt, whereas with Eric’s internal comprehension, his use of academic vocabulary to interpret the visual text was not apparent. However, seeing how Eric used various tiered vocabulary to describe to
Ximena the pieces needed in order to complete the given step, it may be assumed he used academic vocabulary metacognitively for his personal interpretation.

In addition to the academic vocabulary employed by the focal students in order to comprehend the visual informational text, the students had additional opportunities to engage with academic language as they conducted research for their informational poster that aligned with the FLL theme of hydrodynamics.

**Exposure to academic vocabulary in context.** As the students engaged with multimodal informational texts during their research on water quantity, they were exposed to general- and domain-specific academic vocabulary within appropriate contexts. Figures 4.17 and 4.18 show three of the four focal students engaged with two different computers containing various information on water quantity based on the phrases entered into the search engines by the students. During session 21 and their designated research time, Eric, Carla, and Ximena accessed different online resources from their initial search of, “How can we stop water from being wasted?” For his research, Eric focused on the immediate search results listed below the search engine box (Figure 4.17). Examples include “5 easy ways to conserve water at home starting right now,” “Turn off the faucet when you brush your teeth,” and “Water your yard in the morning or evening.” While these sentences only appeared in the initial results, they still included academic vocabulary in context, such as “faucet,” “brush,” and “conserve.”
In contrast, Carla and Ximena collaborated to explore individual result options by clicking on links they thought would be most informative (Figure 4.18), such as “25
Things You Can Do to Prevent Water Waste” (Maui County, 2018). Examples of suggestions Carla and Ximena found were, “Check your toilet for leaks,” “Install water-saving shower heads or flow restrictors,” and “Plant drought-resistant trees and plants that need less watering.” These three sentences alone contain eight domain-specific academic vocabulary words (e.g., “toilet,” “leaks,” “install,” “restrictors,” and “drought-resistant”) and provided the two focal students context to support their understanding of what these terms mean. From these exposures to academic vocabulary within specific contexts, the focal students were led to conducting further research and exploring new resources with that specific vocabulary.

*Exploration with academic vocabulary.* Using the previous examples that discussed Eric, Carla, and Ximena’s exposure to academic vocabulary within context, the three focal students took some of the new terms they encountered and used them to conduct additional research. The realization of using academic vocabulary terms and phrases for researching purposes came to light during session 21, as seen in the following transcript. In the excerpt, the academic vocabulary the students used for researching purposes are highlighted using the green (general-academic terms) and yellow (domain-specific terms) coding-scheme.

Carla: What am I supposed to write?

Eric: Uh, whatever the things… [gestures to informational poster template]. Those are things we can put on our poster.

[The students look around at the different template options]

Carla: We can do that one or that one. [gestures to two different posters]

Eric: So, in the top or on the bottom, we can do our title and our team name.
Ximena: What should be our title?

Eric: This is why water…

Carla: Quantity?

Eric: This is… You know what, I’m just gonna search up best titles.

Carla: This is how water quantity is wasted.

Eric: This is how… No, this is how… No… let me just search this up really quick.

Eric: [while typing] How… can… we… stop… water… being… wasted.

[Each student is looking at their individual laptop]

Eric: Ok, so how ‘bout this? [turns computer to Carla and Ximena] This is… this is how we can stop water being wasted. Is that good Carla? Does that sound good to you?

Carla: Wait, what?

Eric: Does it sound good? The title.

Carla: What title?

Eric: How can we stop water… This is how we can stop water being wasted.

Then we can tell them about the water quantity. Like, how… We could tell, like what’s causing… water being wasted. We can just look at that [gestures to informational poster template] and get topics.

Carla: And then we could search it up!

In the video, Carla’s tone when she exclaimed, “And then we could search it up,” was energized, as if she had just discovered the secret to the group’s researching success.

Looking at her, the expressions on Eric and Ximena’s faces agreed that this new practice
would be beneficial to their continued research on water quantity. Later in that same session, the following dialogue occurred.

Carla: [reading Eric’s screen and typing on her computer] How can we stop water being wasted?

Eric: How can we stop water being wasted?

Carla: [reading her computer screen] I think a thing that we can do. We can use this… [points to screen and reads] ‘Save water in the kitchen.’ ‘Save water outside.’ We can use that.

Eric: [referring back to and reading informational poster template] ‘What’s causing water to be wasted?’ ‘Who are those affected?’ ‘Quality.’ Oh, no. ‘Quantity.’

Carla: [researching on laptop] Let’s see if these are the same. [begins to read screen] No, these are different. Ok, so here it says different stuff.

[Eric, Carla, and Ximena silently conduct individual research]

Eric: [talking aloud to his group mates] Ok. So, do any of you guys wonder…

Whenever you flush the toilet…water comes back and that comes out of the sewer. But there’s something in the toilet, that…there’s something in the toilet that cleans…it’s like a filter for, like, drinkable. faucet water. Because faucet water comes out of the sewers. So, there’s something, like that, that makes the water, like, drinkable. Like a filter. But it’s not a filter.

[While Eric is talking, Carla begins researching what he is talking about]
Carla: Ok, here it is. [looking at screen] Okay, you were right! [begins reading screen] Everything that’s, that’s in the toilet or shower or washer… flows down that drain…and into the sew…sew…

Eric: Sewers.

Carla: Sewers. No, it says something else. Sewage?

Eric: Sewage.

Carla: Sewage?

Eric: Let me see. [looks at Carla’s screen] Where?

Carla: Right here. [points]

Eric: Sewage.

Carla: [continues reading] Sewage pipes connected to your copper…

The middle of this transcript, where Eric begins talking about water in the toilet and how it comes from the sewers, is a clear example of how the students used the academic vocabulary they encountered during research to conduct additional research (e.g., “quantity,” “toilet,” “sewers,” “faucet,” and “drinkable”). As Eric is sharing his thoughts, Carla types some of the key words he says into her search engine, which results in her finding and confirming the facts that Eric has been talking about. This exploration caused a ripple effect of academic vocabulary that led the focal students to additional information on their chosen topics of water quantity.

The focal students’ engagement with informal texts provided them additional opportunities to work with various-leveled academic vocabulary. The visual text robot instructions required the students to apply academic language in order to be able to comprehend the steps in correctly building their robot dog. Moreover, the mini-research
project exposed the students to academic language within specific contexts as well as led to further exploration on their chosen topic of water quantity by using academic vocabulary they encountered in their research. The academic vocabulary used for comprehension and research purposes were also transferred to the students’ written applications.

**Writing.** For Finding 2, a focus on general-academic versus domain-specific words was used to analyze how the students applied academic vocabulary in their writing. Once again, writing was divided into the informal writing students completed when responding to the daily writing prompts and the students’ research notes. On surface level, it appeared the focal students used a great amount of general- and domain-specific academic words, but through data analysis, it was not apparent whether or not the students were just applying these terms due to encountering them during the program, particularly within the various informational texts employed for research, or had full understanding of these types of words.

**Informal writing responses.** Revisiting the students’ informal writing responses from their robotics journals, the focal students did incorporate academic vocabulary in their writing. Figures 4.19 and 4.20 share excerpts from the focal students’ robotics journals and highlight their use of general-academic words and domain-specific words. Although it appeared the students used more domain-specific academic vocabulary in their informal writing (Figure 4.20), two things must be noted: (1) the words are variations of the same term, such as “accomplish” and “accomplishing”; and (2) words such as “challenges” and “accomplish” were written out with the day’s writing prompt, which the students could reference and incorporate into their writing. When just looking
at the frequency of general-academic versus domain-specific words, the students included general-academic words more frequently in their informal writing responses (e.g., “goal,” “learned,” “challenge,” and “finish”). Similar results appeared in the students’ informal research notes as well.

\[Figure 4.19\] General-academic words. This image highlights the general-academic words used by the focal students in their informal writing.
Informal research notes. Looking at the students’ research notes, it was apparent when students were copying versus paraphrasing information from the resources they
used. Figures 4.21 and 4.22 show a page from each of the focal students’ research notes, all containing similar content. When reading through the research notes, Carla and Ximena have the exact same definition written for the word *quantity*: “Quantity means the amount or number of a material or immaterial thing not usually estimated by spatial measurement.” The students having the same wording for their definitions proves that these students directly copied their notes, rather than rephrasing the definition for *quantity* in their own words.

*Figure 4.21* Carla’s (left) and Ximena’s (right) Research Notes. This image highlights the general-academic and domain-specific words found in Carla’s and Ximena’s notes.
Figure 4.22 Eric’s (left) and Isabella’s (right) Research Notes. This image highlights the general-academic and domain-specific words found in Eric’s and Isabella’s notes.

The students’ copied notes provide a less accurate presentation of their understandings and use of academic vocabulary as compared to their informal writing responses. When the students wrote their writing prompt responses, they applied tiered academic vocabulary on their own, which demonstrated their transfer of understanding for those terms (e.g., “We accomplish[ed] the robot to go straight and come back and what [we’re] gonna accomplish tomorrow is to make the robot go a perfect square. [Or] a bad square, but we will try.”). When merely copying academic vocabulary into their informal research notes, it is unclear what their depth of understanding for those
academic terms are (e.g., “Quantity means the amount or number of a material or immaterial thing not usually estimated by spatial measurement.”).

While the students’ writing examples showed a more skewed use of their academic vocabulary, they still were afforded opportunities to develop and apply their understandings of these types of words through writing. For domain-specific words, the students were more or less just exposed to the words and used the same structure of that exposure in their writing, as seen in their copying direct quotes. As for general-academic words, the students used those more regularly on the students’ own terms and with their own, original application. Comparable results can be seen in the students’ verbal use of these two levels of academic vocabulary.

**Dialogue.** As addressed in Finding 1, students in the program engaged in various types of dialogue, including conversations focusing on the given task and chats about off-topic events. Throughout these communications, the students employed different levels of academic vocabulary, both involuntary and intentionally. Additionally, the dialogue exchanges had by the students provided opportunities to negotiate meanings of lesser or unknown words.

**Involuntary use of academic language.** As students began engaging in dialogue from the first day of the program, they inadvertently used academic language and tiered vocabulary in their conversations. The following excerpt comes from the first day the focal students began building their book robot, which was session two of the program. Using the green and yellow color coding applied to the students’ writing examples, the transcript illustrates the great amount of high frequency, tier-one terms the students used and the small amount of general- and domain-specific academic vocabulary.
Alex: We need one that has like a little…One that has a little circle.

Eric: Let me see it.

Alex: We need one that has a little thing on the back.

Eric: It looks like…

Isabella: Oh, it’s a grey?

Alex: It’s supposed to be… Yeah, or longer. This needs to be longer. I guess that’s it.

Isabella: It’s on. [referring to the MINDSTORMS® intelligent brick]

Alex: What the, what the heck? Where does this show? Oh, that one. That did not look like it.

Eric: Ok, what do you guys need?

Carla: And then we’re gonna need…

Alex: This is… Ok, ok. What else do we need? We need a black three circle. A black three… We need one of these. It’s one of these. It’s 1:1. We need a 1:1.

Isabella: Did I make it light up or was it already like that?

Alex: You made it light up, I think. I don’t know. I messed around a little and never got…

Carla: Is there any more?

Eric: Guys, I think we have more boxes… Yeah, we have more bags [grabbing bags of parts from the robot kit]

Alex: Yeah… guy… we messed this one up. [begin taking apart the piece they just made].
Isabella: Guys, there’s more in here. [pulling more bags from the robot kit].

Eric: Okay, we need the thing.

[Isabella, Eric, and Carla search for pieces in the kit]

Isabella: It’s just the size of it. [looking at the robot instructions]

Alex: It’s just the size. We need a 1:1. Yeah, it needs to be this size. Ok, where do I put it? Where’s the 1:1? Ok, 1:1. The 1:1, where the heck did this 1:1 go? Where does the 1:1 go? Hold on. Something went wrong. [looking closely at the instructions]. Oh, that’s the…that’s why. So, we didn’t need one of these. Sorry. Ok, we need one tiny blue. One tiny blue. Thanks. One tiny blue. Like an angle, almost a ninety-degree angle.

Almost a ninety.

Carla: Like that.

[Continuing building]

Alex: What is this? What contraption have we made? Ok, ok. We need another… ok, we need one of these. It’s like a square. We need a square.

Eric: Okay, I got it.

Alex: [as Carla and Eric look for parts] We need two blue, we need two short blues and one, and one… Ok, she already got ‘em. Got it. Okay. We need two, two sort of clip… They look like clips. No, they’re supposed to look… No, they’re supposed to look… Yeah, we need one more of these.

By the middle of the program, the students’ use of language in their conversations naturally switched to including more general- and domain-specific vocabulary. The next
transcript comes from session 18 and, while the students spent less time talking and more time building, an increase in the use of more domain-specific vocabulary can be seen.

Alex: There’s nothing else on there.

Eric: Dude, a contraption.

Alex: We already built that part. [referring to the directions]

Eric: I know.

Alex: We need another motor.

Isabella: We need another motor?

Eric: Hold it. There we go.

[Carla hands Eric the other motor]

Eric: Gracias. Thank you very much. [Looks back at the directions]. A three centimeter, a three centimeter long…yeah, I think that’s it. I think that’s fine.

Isabella: And a small one? A small one? [grabs a small connector]

Eric: Big one.

Isabella: [looking back at the instructions] That’s a big one.

[Eric assembling the parts]

Eric: Okay. We have to do the exact same thing, but this one is just…different.

   Nope.

[Continuing building]

Eric: Oh. I almost lost a part.

Alex: Is this one it? I think I found it. Yeah, it’s this one.
Comparing the two transcripts from session two and session 18, the students used more general-academic vocabulary to describe LEGO® pieces they needed, such as “tiny,” “blue,” and “short,” towards the beginning of the robotics program. By session 18, they started using more domain-specific terms, such as “centimeter” and “motor.” The use of this vocabulary was the students’ involuntary choice, because the robotics program was predominantly student-led and there was no prompting from the researcher or other mentors to use higher-tiered vocabulary.

**Intentional incorporation of academic vocabulary.** Intentional use of academic vocabulary predominantly occurred when the students were presenting or explaining to others specific aspects of the robotics program. For example, when asked by the researcher if the focal students would like to practice what they would say to guests at the robotics showcase about their informational poster on water quantity, the following exchange occurred.

[Unrolling their poster]
Researcher: So, what are you going to talk about?
Isabella: I don’t know.
Researcher: What did you write about?
Isabella: Water **quantity**.
Researcher: What did you learn?
Isabella: Water **quantity**.
Researcher: What about water quantity?
Isabella: That there’s water…
Eric: That there’s different… Water is getting wasted by the day and every hour. And we’re saying…we researched about it and a lot of water is getting wasted in different continents. Well that’s what me and Alex learned. That how much water is getting wasted by the day and every hour and in the year. I think I showed you some of them. And [our state] was one of the states that used the most water in one year.

Isabella: [referring back to the group poster] I’m going to write that one.

While there was some prompting from the researcher to promote this communication, Isabella and Eric both consciously used the correct academic vocabulary for the context of this conversation (i.e., “quantity,” “wasted,” “learned,” “write,” and “continents”). They showed their understandings for these terms by using the words correctly when verbally presenting their information for their research.

This intentional use of academic vocabulary also occurred at the robotics showcase when the students presented their robot and poster to their friends, family, and other guests. As previously mentioned, no videos were taken at the showcase due to lack of permissions for parent participation; however, observational notes captured Isabella’s ability to correctly describe the difference between “water quantity” and “water quality” – “quantity” and “quality” both being tiered vocabulary terms. As Isabella read her group’s informational poster (Figure 4.10) she elaborated on ways to conserve water, such as, “you can take less showers,” and, “don’t leave the water on when you’re not using it.” When asked why they researched about water, Isabella explained how the topic of “water quantity” related to the FLL theme of “hydrodynamics.”
Additionally, the robotics showcase required the focal students to explain to their parents and other family members how they were able to make their robot dog do tricks, by describing what “programming” was and the software they used to make their robot move. This also included the students’ capabilities to explain directionality in relation to the numerical values they entered into the software (e.g., +100 to move straight, -100 to move backwards). In order to approach this level of comprehension and ability to intentionally use correct academic vocabulary for explanation purposes, the students worked with one another to negotiate meaning and understanding of unknown vocabulary through group conversation.

**Negotiating meaning through conversation.** During the robotics program, especially towards the beginning, the focal students had to work together in order to support each other’s understandings of the program. For example, as the focal students’ group began programming their book robot during the second week of the program, they had to figure out how to make their robot move in a specific direction. As illustrated in the excerpt below, the focal students, plus an additional program participant, used dialogue in order to negotiate the meaning of the negative number’s purpose for their robot’s program.

Ximena: Okay, that’s good.
Alex: Yup, push it in.
Eric: Got it.
Alex: Okay, now we got it.
[move to floor to test robot]
Isabella: More.
Carla: A little more.

Eric: 100 percent.

Carla: We’d have to make it -100. It’s negative. Or never mind, never mind. Let’s try this. Maybe that’ll be a little bit…

Ximena: What number?

Eric: I don’t know.

Alex: Just a little more. Like ten more. Go like ten more

Ximena: It’s at 90, it’s at 94.

Alex: Actually, I think that’s what we need.

Isabella: I don’t know. I honestly don’t know.

Alex: Let’s try it. Hold on. Don’t want you to drop it again.

[testing robot]

Alex: We made it touch it! That’s it!

Eric: Make it 100%

Carla: Don’t make it 100. Make it like…99.

Ximena: -99. Write it down.

This example, while more conceptual in regards to what a “negative 100” means within the context of the robotics program, displays how the students used dialogue in order to come to an agreeable definition.

A more specific example of using dialogue to negotiate the meaning of new vocabulary came when the students began conducting their mini-research project. The program participants were introduced to the mini-research project, where they had to decide, in their groups, whether they wanted to research water quality or quantity.
Alex: Which do you want to do? Quality or quantity?

Eric: Water quality?

Ximena: What’s that?

Alex: How good water is or how much water there is?

Eric: Everyone who wants to do quality, say aye.

[No hands are raised]

Alex: Who wants to do quantity instead?

Eric: Do you know what quantity is?

Alex: How much.


[Alex begins typing on laptop]

Isabella: Quantity?

Eric: Quantity.

Isabella: Quantity. That’s fun to say.

Alex: [reading the computer screen] Here it is. ‘The amount or number of material.’

Eric: Amount. So how much.

Isabella: That’s pretty much the same thing.

Eric: Quality sounds a lot more difficult because, there’s like many types of...

Alex: Quantity, just look it up. And you’ve got that much water in the world.

Eric: Ok, let’s do that one.

In the example, while the students did use their laptop to clarify the definition for quantity that Alex shared with the group, they predominantly conversed with one another
in order to grasp the meaning and difference between “quality” and “quantity.” After Alex read the definition for “quantity” from the computer, Eric restates, “Amount. So how much,” to which Isabella replies, “That’s pretty much the same thing.” This exchange shows the negotiations made by the focal students to come to a final decision on their definition for quantity, leading to their ultimate decision to research water quantity for their research project and begin engaging with informational texts.

Data for Finding 2 further portrays how the robotics program supported the focal students’ development and application of academic vocabulary, through informational texts, writing, and dialogue. As the students worked with various forms of informational texts, they were afforded opportunities to both develop and apply their understandings of academic vocabulary. Whereas the students’ informal writing for the daily writing prompts and their research notes, along with their verbal communications with one another of building and presenting their informational poster, centered more on the application of their acquired vocabulary. The final finding for this study specifically examines the students’ understandings for robotics-related vocabulary, comparing the students’ definitions from the beginning to the end of the robotics program.

**Finding 3: Students’ Understandings of Robotics-Related Academic Vocabulary**

To better understand the four focal students’ depth of knowledge of academic vocabulary, the students defined robotics-related terms (Appendix E) at the beginning and end of the eight-week program in their individual journals. Finding 3 presents the students’ definitions for some of the terms; students were not required to define all 20 terms, they were simply asked to define as many as they could in the allotted time. Each
of the four focal students’ definitions will be described individually, followed by a comprehensive look at all four students’ entries.

**Eric.** For his definitions completed at the start of the eight-week robotics program, Eric completed four out of the 20 total words: (1) angle; (2) code; (3) degrees; and (4) design. He primarily used images to define each term, as seen in the top image of Figure 4.22. The images he produced for each of the terms were accurate, aligning with one of the multiple definitions possible for each term. At the end of the program, Eric wrote out 12 of the 20 terms in his journal; however, he only provided a definition for one (e.g., “code – a code is a series of number[s] or words”).

With “code” being the only term Eric provided and pre- and post-definition for, this was the sole piece of data that was used to compare his understandings for academic vocabulary (Figure 4.22). His initial definition, “give a three digits code,” with his image of three boxes, aligns with his post-definition, showing that participation in the robotics program did not necessarily contribute to his development of understanding for this term. Still, Eric did include more terms in his journal when he went to completed his post-definitions (e.g., “axles,” “connectors,” “gear,” “gyro”), and through review of the video recordings, it appeared he left for the day prior to being able to complete all his definitions. In comparison to his pre-definitions, with his adding more terms to his list, it may be assumed that he began to develop understandings for these additional terms, with anticipation of defining them, but was unable to record his definitions in his robotics journal due to being picked up from that day’s session early.
Ximena. Similar to Eric, Ximena defined six out of the 20 total robotics vocabulary at the beginning of the program (i.e., “angle,” “bend,” “beam,” “code,” “degrees,” and “design”), and three at the end (i.e., “angle,” “axel,” and “beam”). She also used images to support her definitions, as seen in Figure 4.23. Ximena’s definitions were acceptable in relation to the possible definitions for each term. Of her total
definitions, two terms had pre and post definitions (i.e., “angle” and “beam”), and two more terms were added to her post-definitions list (i.e., “axle” and “ball joints”).

![Figure 4.24. Ximena's pre (top) and post (bottom) definitions for robotics-related vocabulary.](image)

No changes can be seen in her pre and post definitions for “beam,” which she attributed to its use in gymnastics. On the other hand, comparing her definitions for “angle,” Ximena included more detail in her post-definition as well as other domain-specific vocabulary – “like a shape…and it’s like a degree. Like 45° is a right angle.” While a right angle is actually 90-degrees, she still incorporated the words “degree” and
“right angle” into her definition. This incorporation illustrated a connection between what she and her group engaged in during the robotics program, including research, robot construction, and group dialogue, and the understanding Ximena formed for the term “angle” by the end of the program.

Carla. Of the four focal students, Carla recorded the most pre- and post-definitions for the robotics-related academic vocabulary (Figure 4.24). For her pre-definitions, Carla listed 10 of the 20 total terms, but only defined eight of those words: (1) angle; (2) ball joints; (3) beam; (4) bend; (5) connectors; (6) code; (7) degrees; and (8) design. She used a combination of sentences and images to define the eight vocabulary terms. When completing her post-definitions, she labeled the journal page at the top with, “I [know] these words.” She listed 16 out of 20 terms, defining 11 of those words, and, again, used sentences for her definitions, but little image support. Like Eric and Ximena, both her pre- and post-definitions aligned with one of the possible definitions for each term. Of the 11 post-terms she defined, eight were words she provided a pre-definition for.
Angle - an angle is a *shape* or a *90 degree angle*. Axes - ball joints - a ball joint is a magnet that connects. Beam - a beam is a box that a robot can move on. Bend - when you try to pick something up then you bend. Connectors - when you connect wires together. Code - when you type the robot to do stuff. Degrees - when a robot touches something it lets it go. Design - when you make something. Duration -

I now these words

Angle - Angle means like a shape or a 90 degree angle. Axes - ball joints - when a magnet gets together and connect. Beam - were we go and do gymnastics and bend on. Bend - when you go down and get something. Connectors - when you connect wires together. Code - when you tell your robot what to do. Degrees - when you touch something and it is horser design - when you decorate something that is horses. Duration -

Gears -

Peg -

Power - your robot needs energy to get power. Programming - when you tell your robot to do something. Robot - when you have something around.
Comparing her pre- and post-definitions, four words had the same definition (e.g., “ball joints,” “bend,” “code,” and “degrees”), three contained slight differences (e.g., “beams,” “connectors,” and “design”), and one changed (e.g., “angle”). Carla’s pre and post definitions are presented in Table 4.1. Looking at her definitions for “beams,” “connectors,” and “design,” slight changes between her definitions are present, such as “robot” being used in her pre-definition for “beams” and “we” in her post or the switch from “make” to “decorate” in the definition for “design.” With the seven words that had little to no changes in their definitions, it may be assumed that Carla’s participation in the robotics program did not affect her understandings.

Table 4.1
*Carla’s Pre and Post Definitions for Robotics-Related Vocabulary*

<table>
<thead>
<tr>
<th>Robotics-Related Vocabulary</th>
<th>Pre-Definition</th>
<th>Post-Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>“An angle is a line”</td>
<td>“Angle means like a shape or a [90°] degree angle”</td>
</tr>
<tr>
<td>Ball Joints</td>
<td>“A ball joint is a magnet together”</td>
<td>“When a magnet gets together and connects”</td>
</tr>
<tr>
<td>Beams</td>
<td>“A bea[m] is a box that a robot make[s] tricks on”</td>
<td>“[Where] we go and do gymnastics and land on soft things”</td>
</tr>
<tr>
<td>Bend</td>
<td>“When you try to pick something up then you bend”</td>
<td>“When you go down and get something”</td>
</tr>
<tr>
<td>Connectors</td>
<td>“When you connect a wire or a straw together”</td>
<td>“When you connect wires together”</td>
</tr>
<tr>
<td>Code</td>
<td>“When you type the robot to do stuff”</td>
<td>“When you tell your robot what to do”</td>
</tr>
<tr>
<td>Degrees</td>
<td>“When a robot touch something it tells if [it’s] cold or hot”</td>
<td>“When you touch something and if [it’s] hot or cold”</td>
</tr>
<tr>
<td>Design</td>
<td>“When you make something”</td>
<td>“When you decorate something that is [pretty]”</td>
</tr>
</tbody>
</table>

Conversely, Carla’s definition for “angle” did evolve, with her post-definition including more specific content information (e.g., “like a shape or a 90-degree angle”).
This change could be contributed to her participation in the program. Additionally, she added three more terms to her post-definitions journal entry – “power,” “programming,” and “rotate” – one term having a more general definition (e.g., “rotate”) and two terms being defined in direct relation to the robotics program (e.g., “power” and “programming”). In her definitions for “power” and “programming,” Carla uses the word “robot,” showing she had made a connection between these terms and her engagement with the robot her and her group constructed.

**Isabella.** Unlike the other three focal students, Isabella only recorded definitions for the robotics-related vocabulary at the beginning of the program (Figure 4.25). She did not attend the session during which the students completed their post-definitions in their journals. For her pre-definitions, she listed and defined 14 of the 20 words, and her definitions illustrated she came into the robotics program with a strong vocabulary background; however, her definitions were more general and applicable to various settings, not just robotics.
Figure 4.26. Isabella’s pre-definitions for robotics-related vocabulary.

While there is not a journal entry providing a written comparison for Isabella’s definitions, after reviewing video recordings and transcripts from the last week of the program, there were occurrences where she exhibited new understandings for the robotics-related vocabulary. For example, in their preparation for the robotics showcase, Eric was testing the “tricks” his group had programmed their robot dog to do. He was having trouble finding the program for “chasing its tail,” and asked Isabella, “Do you
remember how to make it [the robot] go around and around? Like, chase its tail or something?” Her response was, “Go around? It’s programmed on there.” Her use of the word “program” in her answer, within this context, shows she had developed the understanding that to make a robot move, it needs to be programmed. He pre-definition for “program” was, “that helps with plans,” which is broader and more applicable to various settings. Although the pre and post definition examples are from two different mediums – written versus verbal – a shift in Isabella’s understanding of this word is perceptible.

Overall, data for Finding 3 revealed minor changes in the four focal students’ understandings of robotics-related vocabulary from the beginning of the eight-week program to the end. Rather, engagement with robotics introduced the students to new vocabulary, which they began to recognize and attribute to this vocabulary’s use within the particular context of robotics. The students’ capacity to acknowledge this new vocabulary is evident in their including new terms in their post-definition journal entries. While definitions were not provided for all the post-terms listed, the students did make the decision to include these terms in their lists, indicating some metacognition on the part of each focal student.

**Summary**

The data presented in this chapter illustrated how the four focal students engaged with literacy, and developed and applied academic vocabulary, primarily through: (1) acquiring and accessing multimodal informational texts; (2) employing informal and formal writing practices; and (3) partaking in conversational and constructive dialogue. While the students’ pre and post definition journal entries did not show large changes in
their understandings and acquisition of new vocabulary, there were still minor variations present.
Chapter 5

Discussion

The purpose of this qualitative case study was to further explore the use of robotics in educational settings, with regard to literacy and, more specifically, academic vocabulary. Employing the theories of constructionism (Papert, 1993) and the interaction hypothesis for language acquisition (Long, 1996), the following questions that guided this study were addressed:

- How do early adolescent students who are language learners engage with literacy during an eight-week LEGO® robotics program?
- How do early adolescent students who are language learners develop and apply academic vocabulary during an eight-week LEGO® robotics program?
- What are early adolescent students’ understandings of robotics-related academic vocabulary at the beginning and end of an eight-week LEGO® robotics program?

Previous chapters presented relevant literature that discussed the increase use of robotics within the field of education (Barak & Assal, 2018; Eguchi, 2016), with particular attention to their use in STEM-related subject areas (Mitnik et al., 2008; Sullivan, 2008; Whittier & Robinson, 2007; Williams et al., 2007). Additionally, works on foundational theories in language acquisition (Krashen, 1982, 1983, 1985; Lantolf, 1994; Skinner, 1957; Schumann, 1978a, 1978b; Swain, 1985, 1995), along with literature on academic vocabulary instruction with language learners (Lesaux et al., 2014; Sibold, 2011; Townsend et al., 2012; Wilson et al., 2016) were reviewed. The review of the
relevant literature established the purpose for this study, confirming the need for research on the use of robotics in relation to other subject-areas, such as literacy, and its promise to support the learning of language learners.

Chapter 4 presented the findings from this study, as related to the four focal students’ (a) overall engagement with literacy, (b) development and application of academic vocabulary, and (c) understandings of robotics-related terms. The data was organized by themes on how the students engaged with, and developed and applied academic vocabulary through informational text, writing, and dialogue. In general, the eight-week robotics program supported minor changes in the focal students’ understandings of robotics-related academic vocabulary.

This chapter further discusses these major findings as related to Papert’s (1993) theory of constructionism and Long’s (1996) interaction hypothesis for language acquisition. Also included are discussions of these findings in relation to the existing literature on the use of robotics in educational settings as well as the importance of academic language and vocabulary instruction, particularly for language learners. Finally, this chapter concludes by addressing implications for practice in regards to using robotics to teach literacy and academic vocabulary to language learners, and suggestions for future research.

**Robotics and Informational Texts**

During the eight-week robotics program, the students engaged with various multimodal informational texts; an important element in the ELA CCSS standards for upper-grade students (NGA/CCSSO, 2010). This included the visual text robot instructions and the resources the students found during their self-directed research for
their chosen topic of water quantity, which aligned with the FLL LEGO® robotics challenge theme of hydrodynamics. Providing a topic aligned with the engaging activity of robotics as well as giving the students the opportunity to present this information to others, both within the program and to invited guests at the robotics showcase, provided them additional motivation to conduct research (Beschorner & Hall, 2017; Moss, 2005; Pappas, 1991).

Through research, the focal students were exposed to academic vocabulary within a formal use of language (Townsend, 2009). Meaning, the informational texts the students worked with employed academic language and vocabulary in a manner necessary for the given discourse; in this case the scientific topic of water quantity. Numerous scholars have noted the importance of providing students with multiple exposures to academic vocabulary within various contexts (Baker et al., 2014; Blachowicz et al., 2006; Townsend, 2009). While the focal students had incidental exposure – no additional instruction to support depth of knowledge development – to the academic vocabulary within these various texts (Loftus-Rattan, Mitchell, & Coyne, 2016), the exposure still added to the multiple exposures needed for students to develop understandings for academic terms. Additionally, the informational text features (e.g., graphs, labels, captions, and diagrams) provided an alternative medium for the students to use to help develop their academic vocabulary understandings (Beschorner & Hall, 2017).

In regards to the visual text robot instructions, these visual supports acted as another means for the students to understand academic vocabulary. A long-standing practice in supporting the learning of language learners is the incorporation of visual
aides to reinforce meaning (August, Artzi, & Barr, 2016; August, Branum-Martin, Cardenas-Hagan, & Francis, 2009; Baker et al., 2014). With informational texts, language learners often encounter barriers in the forms of text complexity and word recognition of advanced vocabulary (Lesaux et al., 2014). By not including the written word, the barrier of having to decode written text and contextualize academic language was removed from the robot instructions. The focal students were successful in interpreting and implementing the visual robotics manual steps, using their pre-existing academic vocabulary knowledge to comprehend this informational text.

The informational texts the students worked with in this study varied in substance and style; however, they upheld the need for upper-elementary students to engage with and comprehend more informational texts, as detailed in the CCSS (NGA/CCSSO, 2010). Due to the multimodal features of these texts, the students who identified as language learners, were given multiple exposures to academic vocabulary within texts (Baker et al., 2014; Blachowicz et al., 2006; Townsend, 2009) and able to employ different strategies in order to access and understand the information being shared (August et al., 2009; Beschorner & Hall, 2017; Lesaux et al., 2014). The opportunities to engage with the informational texts were further enhanced through the students’ use of writing within the robotics program.

**Robotics and Writing**

Framed by the work of Papert (1993), the eight-week robotics program employed constructionism for students to build knowledge as they engaged with and constructed their LEGO® MINDSTORMS® robots. A vehicle in which the students were able to further construct their newly acquired knowledge was writing. Building and
programming a LEGO® robot gave the focal students a purpose for writing. When students have a specific purpose to write, they are more engaged with the task-at-hand as well as have a reason to participate in this form of communication (Graham & Perin, 2007). During the eight weeks, students were afforded daily opportunities to engage with informal writing.

Informal writing took shape in the forms of journal responses to provided writing prompts and individual student research notes. The informal responses to the daily writing prompts allowed students to engage with writing without the constraints of formal writing expectations (Graham & Harris, 2005). By removing the formal writing conventions component, students were encouraged to merely write for the sake of writing. In their written entries, the focal students incorporated tiered academic vocabulary and, while limited, this incorporation of vocabulary showed the students’ attempt to apply these terms in written communication. As discussed by Brun-Mercer and Zimmerman (2015), while learners may recognize academic words receptively, to use those words productively takes “time and practice” (p. 132). The daily informal writing responses provided the students with additional practice to aid their vocabulary development and application.

In addition to the focal students’ writing prompt responses, their individual research notes also afforded additional practice for using academic vocabulary in writing. Beschorner and Hall (2017) noted the significance of writing informational text in that it, “provides a platform for students to use traditional and digital literacies in meaningful ways throughout the process of researching, note-taking, writing, revising, and sharing” (p. 597). As the students conducted research on their chosen topic of water quantity, they
compiled notes in their individual robotics journals, which demonstrated their application of their individual understandings for the academic vocabulary they encountered. Even the students who copied their research notes from the accessed resources established surface-level understandings for those terms by being exposed to the words in context (August, Artzi, Barr, & Francis, 2018). The students’ individual notes were then transferred to the group’s informational poster, which acted as the formal, or published, writing the students partook in during the robotics program. This information was then shared with others, primarily at the robotics showcase, held on the last day of the program.

According to Brun-Mercer and Zimmerman (2015), writing “requires productive knowledge of words that are high frequency, those used only in academic settings, and those that are technical terms for particular disciplines” (p. 132). The eight-week robotics program afforded participants numerous opportunities to apply their knowledge of high-frequency as well as general- and domain-specific academic vocabulary through various forms of writing, as illustrated in the works of the four focal students. Additionally, the focal students were able to share their writing, in the form of their group informational poster, to their family and others, providing purpose for their participation in this form of communication (Graham & Perin, 2007). In order to share their posters and aspects of the robotics program, the students also had to engage with dialogue; a component of literacy that program participants partook in on a daily basis.

**Robotics and Dialogue**

Aligning with previous research on robotics in education, there was a high level of engagement among the students during the eight-week program (Barak & Zadok,
The interest students had in the common goal of building, programming, and completing FLL challenges promoted active communication within the groups and among the program participants (Papert, 1993; Papert & Harel, 1991). Within the social forms of communication carried out by the students, different levels of academic vocabulary were incorporated based on the need for that language in conjunction with the purpose for the conversation.

According to Long (1996) the interactions between native and non-native speakers, even those had during informal conversations, support language acquisition. During the program, the focal students regularly engaged in dialogue with individuals who were at varying degrees of English proficiency. As the students conversed with one another while constructing their robot and conducting research, they were able to negotiate academic language via input and output (Mackey, 1999). Examples include how the focal students used tiered academic vocabulary to describe pieces needed for building (i.e., output) as well as discussing with each other the definition for water quantity (i.e., input). The face-to-face group interactions allowed these language-learning students to negotiate meaning through verbal communication (Long, 1996) and make connections between vocabulary, their prior knowledge, and their experiences (Sibold, 2011).

Also, the discourse elicited throughout the program promoted talk in a low-stress environment (Wilson et al., 2016). The low-stress setting is evidenced in student statements reflecting risk-taking, such as, “I don’t know,” and, “Let’s try it.” The small groups played an important role in the students’ participation in dialogue, as noted by Wilson and colleagues (2016) who highlighted that students who are language learners
are less likely to engage in communication within larger groups. Working in small
groups of three to six students took away the anxiety commonly felt by individuals when
having to speak to large groups of people. Even at the robotics showcase, students
presented to their families on a smaller basis versus having each group present to the
larger crowd.

The eight-week robotics program elicited many opportunities and encouraged
students to engage in dialogue. Focusing on constructing a LEGO® MINDSTORMS®
robot and conducting research on a topic correlated to the FLL theme of hydrodynamics,
gave the students a more specific content to discuss (Baker et al., 2014; Wilson et al.,
2016). Through verbal communication, the students were able to learn from one another
and employ academic vocabulary (Baker et al., 2014). Lastly, the high engagement and
entertainment level of robotics built a low-stress environment for the participants to
communicate in (Wilson et al., 2016). Between the themes of informational texts,
writing, and dialogue, overall, the robotics program showed great potential in promoting
literacy and academic vocabulary development.

**Implications for Practice**

First a foremost, the robotics program aligned with the existing literature in that
participants were greatly engaged with the task of building and programming LEGO®
MINDSTORMS® robots (Barak & Zadok, 2009; Mitnik et al., 2008; Sullivan, 2008).
The eight-week program carried out in this study afforded the participants exposure to
academic vocabulary in various contexts, purpose to participate in informal and formal
writing, and opportunity to engage in and negotiate meaning through dialogue. However,
the program did lack in providing explicit vocabulary instruction to support students’ depth of knowledge for academic terms.

Although the students were exposed to and had opportunities to develop understandings for the various-leveled academic vocabulary they encountered, purposeful instruction for that vocabulary was absent. Since this program was community-based and primarily student-led, opportunities for direct instruction were not taken nor scheduled by the researcher. As recommended by multiple academic vocabulary scholars (e.g., Baker et al., 2014; Blachowicz et al., 2006; Nagy et al., 2012; Townsend et al., 2012; Wilson et al., 2016), for students to fully acquire vocabulary, both understandings and usage, educators must select and provide purposeful instruction, in addition to opportunities to engage with vocabulary. This is even more significant with language learning students. While the robotics program provided ample chances for students to engage with vocabulary in text, writing, and verbal communication, future use of robotics to support literacy and academic vocabulary elicits the need to include focused vocabulary instruction.

Considering the work of Baker and colleagues (2014), the incorporation and extension of the four following recommendations would be beneficial in enhancing vocabulary instruction within educational robotics programs: (1) intense instruction of vocabulary word sets; (2) integration of oral and written language instruction; (3) regular and structured opportunities to develop writing skills; and (4) small-group interventions for struggling students.

**Intense instruction of vocabulary word sets.** A first step in approaching explicit and purposeful vocabulary instruction is selecting a small set of academic
vocabulary words that students are likely to encounter in various texts (Baker et al., 2014; Lesaux et al., 2014). Baker et al. (2014) suggest selecting an “engaging piece of informational text” that contains the pre-identified academic vocabulary to introduce the terms and begin intense instruction (p. 14). For purpose of the robotics program, this text could revolve around robotics in general or tie specifically to the given theme for the annual FLL competition (e.g., hydrodynamics).

In regards to choosing specific vocabulary for instruction, researchers suggest choosing words that are (a) essential for comprehension of the chosen text, (b) used frequently in the text, (c) probable to appear in other contexts, (d) applied by multiple meanings, (e) manipulated by affixes, and (f) possible cross-language cognates (August et al., 2009; Baker et al., 2014; Carlo et al., 2004; Lesaux, Kieffer, Faller, & Kelley, 2010). Brun-Mercer and Zimmerman (2015) noted the importance of instructors pointing out examples of academic vocabulary in texts to show students appropriate uses of those terms. Additionally, teaching students “word-learning strategies” is beneficial in equipping them with tools to figure out the meaning of words independently (Baker et al., 2014, p. 21). Example strategies include graphic organizers and word maps.

One suggestion from Baker and colleagues (2014) that the robotics program did implement was using multimodal avenues to help students develop and apply their understandings for the academic vocabulary, including writing, speaking, and listening. While specific vocabulary words were not explicitly taught as part of the robotics program in this study, students were afforded many opportunities to engage with written and oral communication.
Integration of oral and written language instruction. Building on the previous recommendations, Baker et al. (2014) endorsed the integration of oral and written instruction and content-area teaching. Wilson and colleagues (2016) also advocated for increased and enhanced speaking opportunities for language learners in safe, low-stress environments. Additional strategies to use in conjunction with increased oral and written practice is the incorporation of “videos, visuals, and graphic organizers” to help students grasp the specific content (Baker et al., 2014, p. 6). Due to the abstractness and complexity of general- and content-specific vocabulary (Sibold, 2011), it is imperative for teachers to equip learners with multiple strategies they can independently use and be successful in comprehending academic content (August et al., 2009; Baker et al., 2014; Brown, Ryoo, & Rodriguez, 2010).

While the robotics program did not provide oral and written instruction, it did promote the students’ engagement in oral and written communication, with regard to the content of robotics and water quantity. Baker and collaborators (2014) also recommended providing students with constructive feedback as they engage with and practice their oral and written language with the pre-chosen academic vocabulary. This feedback could be incorporated into the robotics program via weekly check-ins with each group of roboticists and responding to student robotics journal entries.

Regular and structured opportunities to develop writing skills. Next, Baker et al. (2014) suggested routinely providing students structured opportunities to engage with writing by, “providing writing assignments that are anchored in content and focused on developing academic language” (p. 48). This practice may be more suitable for classroom-based instruction; however, within the community-based robotics program,
students still participated in daily writing, which they found purposeful due to the writing’s relationship with the robotics program. To further build students’ writing skills, offering “language-based supports,” such as graphic organizers or writing frames, can help language learners better understand formal writing conventions, which they can later incorporate into their independent writing (p. 49).

Another practice to further support students’ writing is providing small-group opportunities to confer about writing (Baker et al., 2014; Lesaux et al., 2014; Kim et al, 2011). Just as verbally discussing content is beneficial for students in building understandings for that specific subject-area, so is talking about various aspects of writing. Finally, Baker et al. (2014) suggested teachers must provide frequent, constructive feedback on student writing. The incorporation of this recommendation, and to what degree, should be discretionary, based on the environment built within the robotics program. For example, this study was conducted as a community-based program during the summer and was primarily student-led; therefore, employing structured feedback on academic vocabulary use in writing may have hindered the students’ participation in writing as well as in the program overall.

Overall, Brun-Mercer and Zimmerman (2015) noted that, “Effective writing entails not only knowing a lot of words, but knowing them well” (p. 132). Therefore, affording learners multiple opportunities to partake in writing not only allows students to develop writing skills, but further build understandings of academic vocabulary through written application.

**Small-group interventions for struggling students.** Baker and colleagues’ (2014) final recommendation was identifying students who were still struggling with
acquiring academic vocabulary and providing personalized instruction through small-group interventions. Steps for conducting small-group interventions included: (1) using assessments to provide additional information in identifying students who are struggling; (2) designing individualized instruction for each group; (3) implementing instruction to groups of three to five students; (4) incorporating instruction for foundational reading skills when necessary; and (5) providing regular opportunities for students to practice and review new skills and information.

It must be noted that, employing this recommendation would depend on the purpose for the robotics program. For this study, the eight-week program was carried out to research the qualitative-natured questions of how students engaged with literacy as well as developed academic vocabulary during the program. It was not the goal for students to come out of the program with explicit knowledge of a set number of vocabulary terms. However, if educators do choose to implement a robotics program to support students’ development of understandings for specific vocabulary, then implementing small-group interventions would be beneficial for student success.

In sum, the implications for practice address ways in which to enhance robotics programs to purposefully support student academic vocabulary acquisition. The findings, and corresponding discussion, from this study show great potential in the inclusion of robotics in education settings to enhance non-STEM subject areas, such as literacy.

**Suggestions for Future Research**

While this study provided additional insights into the use of robotics in educational settings, specifically in relation to the subject-areas of literacy and academic vocabulary, future research denotes modifications to the implementation of robotics
programs to support literacy development. From this study, the researcher noted two promising suggestions to implement in future research: (1) incorporation of mentors; and (2) community versus classroom-based robotics program.

**Incorporation of mentors.** The use of mentors, particularly individuals older than the primary participants, has proved to be beneficial in supporting student success in various areas (DuBois, Holloway, Valentine, & Cooper, 2002; Ellis, Small-McGinley, & Hart, 1998). An established practice has been the use of mentors to support youth’s emotional and social development (DuBois et al., 2002), as seen in programs such as Big Brother Big Sisters of America (2019). Researchers have also begun to explore the role mentors play in student achievement (Angus & Hughes, 2017; Gordon, Iwamoto, Ward, Potts, & Boyd, 2009; Heppen, Zeiser, Holtzman, O’ Cummings, Christenson, & Pohl, 2018), including science-minded mentors to support student success in STEM-related subjects (Karp & Maloney, 2013; Nelson, Sabel, Forbes, Grandgenett, Tapprich, & Cutucahe, 2017).

During the robotics program, there were times when other adults, including parents, older siblings, and community volunteers, observed the students as they constructed their robots and conducted their research. Upon review of the video recordings, when the students were engaged with an older individual, they verbally produced higher levels of academic vocabulary, and expanded on their thoughts and understandings. From these few occurrences, the researcher noted the promise of including mentors as supervisors in robotics programs and the need for research on this program structure.
Community versus classroom-based robotics program. Another suggestion for future research is to compare the findings of a community-based robotics program to a classroom-based program. Conducting classroom-based research has become an essential area of inquiry considering the amount of time students spend in school (Alibali & Nathan, 2010; Lonergan & Cumming, 2017). School-based research comes with elements commonly associated with traditional classroom settings (Gallego, 2001), such as student learning outcomes, participants’ character, attitudes, and beliefs, and the social contexts within the environment (Brown & Rodgers, 2002; Chaudron, 1988; Hartwick, 2018). Additionally, classroom research helps bridge the gap between theory and practice (Gallego, 2001; Hartwick, 2018).

Community-based research, on the other hand, provides “unique teaching and learning opportunities,” different from those commonly had in classrooms and schools (Gallego, 2001, p. 314). Referencing the work of Gusfiled (1975), Chan and Farrington (2018) highlighted two definitions for the term community including (a) community as a geographical area and (b) community as a group of individuals that have a common relationship. When compared to classroom-based research, community-based research affords the opportunity to include others outside the geographic area of the school, increasing the diversity of the participants (Chan & Farrington, 2018). While this diversity necessitates the need for “multidisciplinary strategies to address complex challenges” (p. 130), community-based research can provide unique discoveries on the use of educational practices with different populations.

In this study, a community-based program was implemented, which was less structured than a classroom setting and gave students more autonomy over their role in
the program. Within the community-based program, the researcher took on the role of facilitator, rather than teacher, hence why opportunities for explicit vocabulary instruction were not taken. Considering the importance of active vocabulary instruction in supporting students’ development of deep understandings for academic terms, this led to the suggestion of conducting robotics program research in both a community- and classroom-based setting.

**Final Thoughts**

During this eight-week LEGO® robotics program, early-adolescent student participants were afforded numerous opportunities to engage with literacy as well as academic vocabulary, through informational texts, writing, and dialogue. Previous research highlights the use of robotics in promoting student (a) learning in STEM-related content areas, (b) inquiry- and collaborative-skills, and (c) overall engagement and motivation. This study addresses and supports the gap in the literature and need for additional research on the use of robotics in educational settings, with regard to non-STEM-related subject areas. The focus of this study was placed on literacy and, more specifically, academic vocabulary development. Robotics showed potential in promoting student development in these areas as students engaged in building a LEGO® MINDSTORMS® robot and, in turn, constructing their own knowledge (Papert, 1993; Papert & Harel, 1995). Additionally, the large involvement of verbal communication supported the input and output of language learners as they used dialogue to negotiate their understandings of academic language (Long, 1996). The incorporation of robotics in educational settings has great potential in enhancing more than just STEM-related
subject areas; robotics can be the vehicle that drives student literacy and vocabulary development forward.
References


# Appendix A

## Program Overview

<table>
<thead>
<tr>
<th>Week</th>
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### Initial Meet-and-Greet

- Researcher introduced program to participants and families (10 minutes)
- Researcher discussed research project (20-25 minutes)
- Students freely explored LEGO® MINDSTORM® EV3 robot kits (25-30 minutes)
- General Q&A conducted with participants and families (5-10 minutes)
- No Video Recordings
- No Robotics Journal Entry

### Holiday

60 minutes
Session 1 (Start of Week 1)

- Students randomly assigned to small groups (3-4 students)
  - Groups came up with group names (5 minutes)
- Students received robotics journal
  - Students wrote their name and group name on their journal
  - Individually, students completed pre definitions for robotics-related academic vocabulary identified by the researcher (15-20 minutes; Robotics-Related Vocabulary see Appendix C)
- Groups began working with LEGO® MINDSTORM® EV3 robot kits (15-20 minutes)
  - Each group was assigned a LEGO® MINDSTORM® EV3 robot kit
  - Groups reviewed the instruction book included with the kit and began construction of their robot
- Initial one-on-one student interviews (Interview Questions see Appendix B)
  - Interviews conducted while students completed their concept maps and began construction on their robots (3-5 minutes/interview)
- Session wrap-up (10-15 minutes)
  - Researcher explained clean-up procedures for each session:
    - At the end of every session, researcher will give wrap-up signal
    - Groups will clean up robotics station: put assembled pieces in a large Ziploc, return unused pieces to robot kit, fold up table cover, put all group materials in group storage bin
    - Students will write in robotics journals (5 minutes)
  - Groups then completed wrap-up procedures
- Robotics Journal Entry
  - Writing Prompt: What did you do today during robotics? What are your goals for tomorrow?
  - Students encouraged to include as much detail as possible, and instructed they may write and/or draw their journal entry.

Session 2

- Session start-up (10-15 minutes)
  - Researcher explained start-up procedures for each session:
    - As students finish their snack, they may start setting up their robotics station
    - Groups will set up robotics station: grab group storage bin, lay out table cover, take out Ziploc with assembled pieces, take out robot kit
    - Students will find where they left off in the instruction book and begin working on their robot
- Groups independently worked on constructing their robot (35-40 minutes)
  - During this time, researcher took observational/anecdotal notes when not continuing one-on-one interviews
- Initial one-on-one student interviews continued
Interviews conducted while students completed their concept maps and began construction on their robots (3-5 minutes/interview)

- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did you do today during robotics? Did you encounter any obstacles? If so, what? What are your goals for tomorrow?
  - Students encouraged to include as much detail as possible, and instructed they may write and/or draw their journal entry.

Session 3
- Session start-up (5 minutes)
- Groups independently worked on constructing their robot (45 minutes)
  - During this time, researcher took observational/anecdotal notes when not continuing one-on-one interviews
- Initial one-on-one student interviews continued
  - Interviews conducted while students completed their concept maps and began construction on their robots (3-5 minutes/interview)
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did you and your group do today during robotics? What are your goals for tomorrow?
  - Students encouraged to include as much detail as possible, and instructed they may write and/or draw their journal entry.

Session 4
- Before “Session start-up,” researcher explained program mini-research project (15 minutes):
  - Each group will choose to either research “water quality” or “water quantity” and determine a solution to their chosen problem
  - Groups will use books, text-sets, the internet, etc. to conduct their research
  - By the end of the program, each group will create an informative poster to share on Robotics Showcase night.
  - Today and tomorrow’s sessions (Sessions 4 and 5) will begin with research time
  - By the end of tomorrow’s session (Session 5) individual groups will need to choose their research project topic
  - Beginning next week (Session 7), groups will have an alternating schedule for research time:
    - Groups 1, 3, & 5 – Mondays and Wednesdays
    - Groups 2, 4, & 6 – Tuesdays and Thursdays
    - On groups’ assigned days, they will begin the day’s session with research time
- After explanation, individual groups brainstormed topic for mini-research project
- Session start-up (5 minutes)
- Groups independently worked on constructing their robot (30 minutes)
During this time, researcher took observational/anecdotal notes when not continuing one-on-one interviews

- Initial one-on-one student interviews continued
  - Interviews conducted while students completed their concept maps and began construction on their robots (3-5 minutes/interview)

- Session wrap-up (10 minutes)

- Robotics Journal Entry
  - Writing Prompt: What challenges have you and your group faced? How did you problem-solve those challenges?
  - Students encouraged to include as much detail as possible, and instructed they may write and/or draw their journal entry.

**Session 5**

- Research time (20 minutes)
  - In their groups, students:
    - Continued brainstorming their mini-research project
    - Discussed and decided if their group would research “water quality” or “water quantity”
    - Explored the provided books and text sets

- Session start-up (5 minutes)

- Groups independently worked on constructing their robot (25 minutes)
  - During this time, researcher took observational/anecdotal notes when not continuing one-on-one interviews

- Initial one-on-one student interviews continued
  - Interviews conducted while students completed their concept maps and began construction on their robots (3-5 minutes/interview)

- Session wrap-up (10 minutes)

- Robotics Journal Entry
  - Writing Prompt: What have you and your group accomplished this week? What are your goals for next week?
  - Students encouraged to include as much detail as possible, and instructed they may write and/or draw their journal entry.

**Session 6 (Start of Week 2)**

- Researcher reviewed previous week & introduced research time schedule:
  - Groups 1, 3, & 5 – Mondays and Wednesdays
  - Groups 2, 4, & 6 – Tuesdays and Thursdays

- Session start-up (5 minutes)

- Research time (20-25 minutes)
  - Groups 1, 3, & 5: researched chosen problem using book, text sets, the internet, and other resources
  - After 20 minutes of research time (signaled by the researcher), Groups 1, 3, & 5 began working on their robots (remaining 20-25 minutes)

- Group construction
Groups 2, 4, & 6 continued working on constructing their robot (40-45 minutes)

- During research time & group construction, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What problem did your group decide to research?

Session 7

- Session start-up (5 minutes)
- Research time (20-25 minutes)
  - Groups 2, 4, & 6: researched their chosen problem using book, text sets, the internet, and other resources
  - After 20 minutes of research time (signaled by the researcher), Groups 2, 4, & 6 began working on their robots (remaining 20-25 minutes)
- Group construction
  - Groups 1, 3, & 5 continued working on constructing their robot (40-45 minutes)
- During research time & group construction, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did you and your group do today during robotics? What are your goals for tomorrow?

Session 8

- Session start-up (5 minutes)
- Research time (20-25 minutes)
  - Groups 1, 3, & 5: researched chosen problem using book, text sets, the internet, and other resources
  - After 20 minutes of research time (signaled by the researcher), Groups 1, 3, & 5 began working on their robots (remaining 20-25 minutes)
- Group construction
  - Groups 2, 4, & 6 continued working on constructing their robot (40-45 minutes)
- During research time & group construction, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What have you learned in your research so far? What challenges have you faced this week?
Session 9
- Session start-up (5 minutes)
- Research time (20-25 minutes)
  - Groups 2, 4, & 6: researched their chosen problem using book, text sets, the internet, and other resources
  - After 20 minutes of research time (signaled by the researcher), Groups 2, 4, & 6 began working on their robots (remaining 20-25 minutes)
- Group construction
  - Groups 1, 3, & 5 continued working on constructing their robot (40-45 minutes)
- During research time & group construction, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What have you learned in your research so far? What challenges have you faced this week?

Session 10
- Session start-up (5 minutes)
- Groups independently worked on constructing their robot (45 minutes)
  - During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did you accomplish this week? What are your goals for next week?

Session 11 (Start of Week 3)
- Researcher reviewed previous week
  - Groups introduced to five different “Programming Challenges”: predetermined tracks designated on the floor by blue tape with arrows indicating directionality
- Session start-up (5 minutes)
- Research time rescheduled due to power outage
- Groups independently worked on constructing and/or programming their robot (45 minutes) – no research time
  - During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did you accomplish today? What challenges did you face? How did you overcome those challenges?
Session 12
- Session start-up (5 minutes)
- Research time (20-25 minutes)
  o Groups 2, 4, & 6: researched their chosen problem using book, text sets, the internet, and other resources
  o After 20 minutes of research time (signaled by the researcher), Groups 2, 4, & 6 began working on their robots (remaining 20-25 minutes)
- Group construction
  o Groups 1, 3, & 5 continued working on constructing and/or programming their robot (40-45 minutes)
- During research time & group construction/programming, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  o Writing Prompt: *What did you accomplish today? What challenges did you face? How did you overcome those challenges?*

Session 13
- Session start-up (5 minutes)
- Research time (20-25 minutes)
  o Groups 1, 3, & 5: researched chosen problem using book, text sets, the internet, and other resources
  o After 20 minutes of research time (signaled by the researcher), Groups 1, 3, & 5 began working on their robots (remaining 20-25 minutes)
- Group construction
  o Groups 2, 4, & 6 continued working on constructing and/or programming their robot (40-45 minutes)
- During research time & group construction/programming, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  o Writing Prompt: *Has your group been successful with programming? Why or why not? What have you learned during your research?*

Session 14
- Session start-up (5 minutes)
- Research time (20-25 minutes)
  o Groups 2, 4, & 6: researched their chosen problem using book, text sets, the internet, and other resources
  o After 20 minutes of research time (signaled by the researcher), Groups 2, 4, & 6 began working on their robots (remaining 20-25 minutes)
- Group construction
  o Groups 1, 3, & 5 continued working on constructing and/or programming their robot (40-45 minutes)
• During research time & group construction/programming, researcher took observational/anecdotal notes and informally interviewed students in their groups
• Session wrap-up (10 minutes)
• Robotics Journal Entry
  o Writing Prompt: Writing Prompt: Has your group been successful with programming? Why or why not? What have you learned during your research?

Session 15
• Session start-up (5 minutes)
• Research time (20-25 minutes)
  o Groups 1, 3, & 5: researched chosen problem using book, text sets, the internet, and other resources
  o After 20 minutes of research time (signaled by the researcher), Groups 1, 3, & 5 began working on their robots (remaining 20-25 minutes)
• Group construction
  o Groups 2, 4, & 6 continued working on constructing and/or programming their robot (40-45 minutes)
• During research time & group construction/programming, researcher took observational/anecdotal notes and informally interviewed students in their groups
• Session wrap-up (10 minutes)
• Robotics Journal Entry
  o Writing Prompt: Have you completed any of the programming challenges? If so, were you successful? Have you completed enough research to start your informational poster? What are your goals for next week?

Session 16 (Start of Week 4)
• Researcher reviewed previous week
  o Students provided with example informational posters and templates to follow
  o Only two days of research due to mid-week holiday
• Session start-up (5 minutes)
• Research time (20-25 minutes)
  o Groups 1, 3, & 5: researched chosen problem using book, text sets, the internet, and other resources
  o After 20 minutes of research time (signaled by the researcher), Groups 1, 3, & 5 began working on their robots (remaining 20-25 minutes)
• Group construction
  o Groups 2, 4, & 6 continued working on constructing and/or programming their robot (40-45 minutes)
• During research time & group construction/programming, researcher took observational/anecdotal notes and informally interviewed students in their groups
• Session wrap-up (10 minutes)
• Robotics Journal Entry
Writing Prompt: How many programming challenges have you completed? Is your group ready for the LEGO® Hydrodynamics challenges?

Session 17
- Session start-up (5 minutes)
- Research time (20-25 minutes)
  - Groups 2, 4, & 6: researched their chosen problem using book, text sets, the internet, and other resources
  - After 20 minutes of research time (signaled by the researcher), Groups 2, 4, & 6 began working on their robots (remaining 20-25 minutes)
- Group construction
  - Groups 1, 3, & 5 continued working on constructing and/or programming their robot (40-45 minutes)
- During research time & group construction/programming, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What are your goals for the LEGO® Hydrodynamics challenges? What is your team’s plan for the challenges?

Session 18
- Researcher introduced students to resources to support LEGO® Hydrodynamics challenges – students focused on programming for challenges
  - 2017 FLL Hydrodynamics Missions and Point Values – Mr. Hino: https://youtu.be/1Tjpnd6-P8M
- Session start-up (5 minutes)
- Groups independently worked on constructing and/or programming their robot (45 minutes)
  - During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What Hydrodynamics challenges will your group be attempting? How far has your group gotten on your informational poster?

Session 19
- Session start-up (5 minutes)
- Groups independently worked on constructing and/or programming their robot (45 minutes)
During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups

- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: *What did you accomplish this week? What are your goals for next week?*

**Session 20 (Start of Week 5)**
- Researcher reviewed previous week
- Session start-up (5 minutes)
- Research time (20-25 minutes)
  - Groups 1, 3, & 5: researched chosen problem using book, text sets, the internet, and other resources
  - After 20 minutes of research time (signaled by the researcher), Groups 1, 3, & 5 began working on their robots (remaining 20-25 minutes)
- Group construction
  - Groups 2, 4, & 6 continued working on constructing and/or programming their robot (40-45 minutes)
- During research time & group construction/programming, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: *What challenges did you encounter today? What are your goals for tomorrow?*

**Session 21**
- Session start-up (5 minutes)
- Research time (20-25 minutes)
  - Groups 2, 4, & 6: researched their chosen problem using book, text sets, the internet, and other resources
  - After 20 minutes of research time (signaled by the researcher), Groups 2, 4, & 6 began working on their robots (remaining 20-25 minutes)
- Group construction
  - Groups 1, 3, & 5 continued working on constructing and/or programming their robot (40-45 minutes)
- During research time & group construction/programming, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: *What challenges did you face? What are your goals for tomorrow?*
Session 22
- Session start-up (5 minutes)
- Research time (20-25 minutes)
  - Groups 1, 3, & 5: researched chosen problem using book, text sets, the internet, and other resources
  - After 20 minutes of research time (signaled by the researcher), Groups 1, 3, & 5 began working on their robots (remaining 20-25 minutes)
- Group construction
  - Groups 2, 4, & 6 continued working on constructing and/or programming their robot (40-45 minutes)
- During research time & group construction/programming, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: *How did you problem solve any challenges? What goals do you have?*

Session 23
- Session start-up (5 minutes)
- Research time (20-25 minutes)
  - Groups 2, 4, & 6: researched their chosen problem using book, text sets, the internet, and other resources
  - After 20 minutes of research time (signaled by the researcher), Groups 2, 4, & 6 began working on their robots (remaining 20-25 minutes)
- Group construction
  - Groups 1, 3, & 5 continued working on constructing and/or programming their robot (40-45 minutes)
- During research time & group construction/programming, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: *What did you do today? What are your goals for tomorrow?*

Session 24
- Researcher introduced students to additional resources to support LEGO® Hydrodynamics challenges
  - YouTube search using phrase: “2017 Hydrodynamics: Completing the…”
- Session start-up (5 minutes)
- Groups independently worked on constructing and/or programming their robot (45 minutes)
  - During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
• Robotics Journal Entry
  o Writing Prompt: What did you do this week? Did you encounter any obstacles? If so, what were they? What are your goals for next week?

Session 25 (Start of Week 6)
• Researcher reviewed previous week
  o Began LEGO® mat schedule – groups worked on the robotics mat during their allotted times
    ▪ Groups 1 & 4: First 15 minutes
    ▪ Groups 2 & 5: Second 15 minutes
    ▪ Groups 3 & 6: Third 15 minutes
• Session start-up (5 minutes)
• When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
  o During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
• Session wrap-up (10 minutes)
• Robotics Journal Entry
  o Writing Prompt: What did you accomplish today? What are your goals for tomorrow?

Session 26
• Session start-up (5 minutes)
• LEGO® Mat Schedule
  o Groups 1 & 4: First 15 minutes
  o Groups 2 & 5: Second 15 minutes
  o Groups 3 & 6: Third 15 minutes
• When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
  o During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
• Session wrap-up (10 minutes)
• Robotics Journal Entry
  o Writing Prompt: What did you accomplish today? What are your goals for tomorrow?

Session 27
• Session start-up (5 minutes)
• LEGO® Mat Schedule
  o Groups 1 & 4: First 15 minutes
  o Groups 2 & 5: Second 15 minutes
  o Groups 3 & 6: Third 15 minutes
• When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
  o During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
• Session wrap-up (10 minutes)
• Robotics Journal Entry
  o Writing Prompt: Did you complete any of the LEGO® challenges? What steps did you take to complete it?

Session 28
• Session start-up (5 minutes)
• LEGO® Mat Schedule
  o Groups 1 & 4: First 15 minutes
  o Groups 2 & 5: Second 15 minutes
  o Groups 3 & 6: Third 15 minutes
• When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
  o During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
• Session wrap-up (10 minutes)
• Robotics Journal Entry
  o Writing Prompt: Is your group ready for the Robotics Showcase? What do you need to do to get ready?

Session 29
• Session start-up (5 minutes)
• LEGO® Mat Schedule
  o Groups 1 & 4: First 15 minutes
  o Groups 2 & 5: Second 15 minutes
  o Groups 3 & 6: Third 15 minutes
• When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
  o During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
• Session wrap-up (10 minutes)
• Robotics Journal Entry
  o Writing Prompt: What did you accomplish this week? What are your goals for next week?
Session 30 (Start of Week 7)

- Researcher reviewed previous week
- Session start-up (5 minutes)
- LEGO® Mat Schedule
  - Groups 1 & 4: First 15 minutes
  - Groups 2 & 5: Second 15 minutes
  - Groups 3 & 6: Third 15 minutes
- When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
  - During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did your group accomplish today? What does your group need to do to prepare for the showcase? What are your goals for tomorrow?

Session 31

- Session start-up (5 minutes)
- LEGO® Mat Schedule
  - Groups 1 & 4: First 15 minutes
  - Groups 2 & 5: Second 15 minutes
  - Groups 3 & 6: Third 15 minutes
- When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
  - During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did your group accomplish today? What does your group need to do to prepare for the showcase? What are your goals for tomorrow?

Session 32

- Session start-up (5 minutes)
- LEGO® Mat Schedule
  - Groups 1 & 4: First 15 minutes
  - Groups 2 & 5: Second 15 minutes
  - Groups 3 & 6: Third 15 minutes
- When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups.

- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did your group accomplish today? What does your group need to do to prepare for the showcase? What are your goals for tomorrow?

Session 33
- Session start-up (5 minutes)
- LEGO® Mat Schedule
  - Groups 1 & 4: First 15 minutes
  - Groups 2 & 5: Second 15 minutes
  - Groups 3 & 6: Third 15 minutes
- When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
  - During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did your group accomplish today? What does your group need to do to prepare for the showcase? What are your goals for tomorrow?

Session 34
- Researcher discussed next week being the last week of the program
  - Robotics Showcase – the last day of the program; groups will showcase for their families and other invited guests what they accomplished during the robotics program
- Session start-up (5 minutes)
- LEGO® Mat Schedule
  - Groups 1 & 4: First 15 minutes
  - Groups 2 & 5: Second 15 minutes
  - Groups 3 & 6: Third 15 minutes
- When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
  - During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did you accomplish this week? What does your group need to do to prepare for the showcase? What are your goals for next week?
Session 35 (Start of Week 8)
- Researcher reviewed previous week & reminded students about this week being the last week of the program (5 minutes)
  - Robotics Showcase day will be at the end of the week
  - Groups start thinking about what to share with family and friends
  - Put finishing touches on informational posters
- Session start-up (5 minutes)
- LEGO® Mat Schedule
  - Groups 1 & 4: First 15 minutes
  - Groups 2 & 5: Second 15 minutes
  - Groups 3 & 6: Third 15 minutes
- When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
  - During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did your group accomplish today? What are your goals for tomorrow?

Session 36
- Session start-up (5 minutes)
- LEGO® Mat Schedule
  - Groups 1 & 4: First 15 minutes
  - Groups 2 & 5: Second 15 minutes
  - Groups 3 & 6: Third 15 minutes
- When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
  - During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did your group accomplish today? What are your goals for tomorrow?

Session 37
- Session start-up (5 minutes)
- LEGO® Mat Schedule
  - Groups 1 & 4: First 15 minutes
  - Groups 2 & 5: Second 15 minutes
  - Groups 3 & 6: Third 15 minutes
- When not assigned to robotics mat, groups worked on constructing and/or programming their robot as well as completing their informational posters (45 minutes)
  - During this time, researcher took observational/anecdotal notes and informally interviewed students in their groups
- Additionally, students completed post definitions for robotics-related academic vocabulary identified by the researcher (see Appendix C)
- Session wrap-up (10 minutes)
- Robotics Journal Entry
  - Writing Prompt: What did your group accomplish today? What are your goals for tomorrow?

Session 38
- Robotics Showcase
- Researcher welcomed participants, families, and friends, and discussed what the students did over the past 8 weeks (10 minutes)
- Students separated into their groups with their families and began showcasing what they did (40-45 minutes)
  - Each group assigned a time to showcase using the FLL competition mat and components
    - Group 1: First 6-8-minute slot
    - Group 2: Second 6-8-minute slot
    - Group 3: Third 6-8-minute slot
    - Group 4: Fourth 6-8-minute slot
    - Group 5: Fifth 6-8-minute slot
    - Group 6: Sixth 6-8-minute slot
  - Groups discussed their robot and how they constructed it
  - Groups shared their information poster
- No Video Recordings
Appendix B

Informational Poster Templates
**TOPIC**

What is water quality/quantity?

*Brief definition*

**FUN FACTS**

**WHAT CAUSES**

*Where is it most affected?*

*What place is this mostly at?*

*How does it affect those living there?*

**Picture**

**What can we do to make a change?**

*
Title

What is Water Quality?
- give a good definition describing what it is

Issues related to Water Quality + How/Who it Affect:

- issue #1
  - If you can find
  - Who does this affect? How?

- issue #2
  - Pictures about the
  - Who does this affect? How?

- issue #3
  - Issues inserted here!
  - Who does this affect? How?

Possible Solutions:
- are there possible solutions? What are those solutions?
  - Why is it important that we try and prevent or eliminate the issues?

Interesting Fact/Fun Fact:
- While researching your topic, was there something interesting that caught your attention? (talk about it here :)

* Brought to you by: Team Name *
Title: Water Quantity

What is water quantity?

Another Picture

What's the problem?

How can we solve this?

Put lots of Pictures!!!

*Explain the Pictures

FUN FACT: Water Quantity:

More

Some

Pictures!!!
Appendix C

Individual Student Interviews

Initial Interview Guiding Questions

1) What is your name?

2) How old are you?

3) What grade are you in?

4) What are some things I should know about you?
   a. Tell me about your family.
   b. Tell me about your home.
   c. Tell me about your school.

5) Have you ever played with LEGO® products before?
   a. Tell me about those times. What did you do?

6) Have you ever played with robots before?
   a. Tell me about those times when you’ve played with robots. What did you do?

7) What do you think we’ll be doing during our LEGO® robotics program?

Concluding Interview Guiding Questions

1) Tell me about your experiences during the summer robotics program.

2) What did you learn about during the program?

3) What did you enjoy most about the program?
Appendix D

Small Group Interviews

Weekly Interview Guiding Questions

1) Tell me about what you did this week.

2) Did you have any goals when you started working on your robot this week?
   a. Tell me more about those goals. Did you accomplish them?

3) Do you have any goals for next week?
   a. Tell me more about those goals.
Appendix E

Robotics-Related Academic Vocabulary

Directions: In your journal, write or draw your understanding for each vocabulary term listed below. Try your best with each term – it is ok to skip.

1. Angle
2. Axles
3. Ball Joints
4. Beam
5. Bend
6. Connectors
7. Code
8. Degrees
9. Design
10. Duration
11. Gears
12. Gyro
13. Peg
14. Power
15. Programming
16. Rotate
17. Seconds
18. Socket
19. Tone
20. Volume
Appendix F

Data Analysis Chart

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Initial Concepts</th>
<th>Evidence from the Data</th>
<th>Category/Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) How do early adolescent students who are language learners engage with LITERACY during an eight-week LEGO® robotics program?</td>
<td>Interpretation of visual and digital materials</td>
<td>Video Recordings &amp; Corresponding Transcripts - Book robot instructions - Multimodal research</td>
<td>Informational Texts</td>
</tr>
<tr>
<td>Literacy: “The ability to identify, understand, interpret, create, compute, and communicate using visual, audible, and digital materials across disciplines and in any context.”</td>
<td>Use of discipline-specific concepts/knowledge to interpret and comprehend digital materials</td>
<td>Video Recordings &amp; Corresponding Transcripts - Research with multimodal texts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Informal visual (written) communication to communicate understandings of robotics and research topic</td>
<td>Student Artifacts - Daily Writing Responses - Student Research Notes</td>
<td>Writing</td>
</tr>
<tr>
<td></td>
<td>Formal visual (written) communication to communicate understandings informational/nonfiction (discipline) topics</td>
<td>Student Artifacts - Student Research Notes - Group informational poster</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Social structures of audible (verbal) communication to share understandings and instruct on robot building</td>
<td>Video Recordings &amp; Corresponding Transcripts</td>
<td>Dialogue</td>
</tr>
<tr>
<td></td>
<td>Use of discipline-specific concepts to communicate in audible communications</td>
<td>Video Recordings &amp; Corresponding Transcripts - Prior Knowledge</td>
<td></td>
</tr>
</tbody>
</table>
(2) How do early adolescent students who are language learners develop and apply Academic Vocabulary during an eight-week LEGO® robotics program?

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>Materials Provided</th>
<th>Subject Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure to academic vocabulary within appropriate context</td>
<td>Video Recordings &amp; Corresponding Transcripts - Conducting research</td>
<td>Informational Texts</td>
</tr>
<tr>
<td>Conducting purposeful research using academic vocabulary</td>
<td>Video Recordings &amp; Corresponding Transcripts - Conducting research</td>
<td>Conducting research</td>
</tr>
<tr>
<td>Comprehending academic vocabulary through visual text</td>
<td>Video Recordings &amp; Corresponding Transcripts - Constructing robot</td>
<td>Constructing robot</td>
</tr>
<tr>
<td>Academic vocabulary used in writing prompt responses</td>
<td>Student Artifacts - Daily Writing Responses</td>
<td>Writing</td>
</tr>
<tr>
<td>Academic vocabulary used in research notes</td>
<td>Student Artifacts - Student Research Notes</td>
<td>Student Research Notes</td>
</tr>
<tr>
<td>Natural (unconscious) use of academic vocabulary in group communications</td>
<td>Video Recordings &amp; Corresponding Transcripts - Constructing robot</td>
<td>Dialogue</td>
</tr>
<tr>
<td>Purposeful use of academic vocabulary in group communications</td>
<td>Video Recordings &amp; Corresponding Transcripts - Constructing robot</td>
<td></td>
</tr>
<tr>
<td>Determining meaning of academic vocabulary through verbal communication</td>
<td>Video Recordings &amp; Corresponding Transcripts - Constructing robot</td>
<td></td>
</tr>
</tbody>
</table>
Appendix G

Robot Programming Paths

1) Start.
2) Go straight.
3) Stop.
4) Turn 180 degrees.
5) Go straight.
6) End.

Programming Path 1

1) Start.
2) Go straight.
3) Turn 90 degrees.
4) Go straight.
5) Turn 90 degrees.
6) Go straight.
7) End.

Programming Path 2

1) Start.
2) Go straight.
3) Turn 90 degrees.
4) Go straight.
5) Park in square.
6) End.

Programming Path 3

1) Start.
2) Go straight.
3) Stop.
4) Turn 360 degrees.
5) Go backwards.
6) End.

Programming Path 4