

DIALOGIC INTRA-ACTIONS OF YOUNG CHILDREN AND ROBOTIC MANIPULATIVES

by

SUNG EUN JUNG

(Under the Direction of Kyunghwa Lee)

ABSTRACT

This dissertation study explores the dialogic and intra-active engagement of young children, aged 4 to 6, with robotic manipulatives (BeeBots and Cubelets) in two early childhood robotics education programs, which were offered in a community learning center. Drawing on Bakhtin's (1981) dialogism and new materialist perspectives (Barad, 2007; Bennett, 2010), I examine how young children make sense of, respond to, and use the robotic manipulatives. Also, I investigate how the robotic manipulatives actively influence and shape the children's understanding of the robotic manipulatives and their expression of themselves. As an interpretive case study, I conduct a micro-analysis of video-recorded observation data with artifacts such as the children's engineer logs and lesson plans. The findings of this study present 1) a young child's agentic role in dialogically adopting and adapting the features of programmable robots (BeeBots), the methods of programming, and the perspectives of robots and programming, 2) two girls' gender tactics to negotiate with authoritative gender discourses that challenged their femininity and to position themselves as a powerful heroine and a competent robot builder by programming and building robots, and 3) the unexpected but agentic roles of robotic manipulatives in a young child's hands-on inquiry with/about robotic manipulatives (Cubelets) and the child's autotelic bodily engagement as a state of inquiry. This study emphasizes young

children's engagement with robotic manipulatives as inherently heteroglossic and dialogical to produce new meanings of robots/machines, controlling, building, and programming robots, rather than simply accepting the pre-determined meanings and intentions of teachers and manufacturers of the robotic manipulatives. Also, this study stresses the inter-dependent and co-dependent agency of young children and robotic manipulatives in mutually constructing and shaping their dialogic engagements. In addition, this study suggests paying attention to young children's autotelic and tacit embodied practices to respond to and to use the robotic manipulatives as their mode of inquiry.

INDEX WORDS: Robotic manipulatives; Robotics; Programming; Technology for young children; Gender tactics; Robot designing and building; Autotelic and tacit embodied practice; Inquiry with robotic manipulatives; Co-dependent agency between humans and non-humans

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CHAPTER 1

INTRODUCTION

Young children live and grow surrounded by others. Not only other humans but also things/objects can be an important part of their lives. There are always materials where young children are. Young children create connections not only with fellow humans but also with things and material environments. In this dissertation, I am interested in young children's relationships with robotic manipulatives.

The importance of things/objects is not a new idea in the field of early childhood education. The field has a strong tradition of recognizing the importance of young children's connections with things. Froebel's (1895) gifts, for example, emphasized how a direct and deep exploration of objects can be a way for young children to understand the abstract knowledge embedded in objects and the interconnectedness of the world the children belong to. Montessori (1964) believed that young children learn best from materials she termed "didactic" (p. 37). While stressing that the material environment is vital for children's learning, the Reggio Emilia approach paid attention to creating material environments that could serve as a third teacher (Malaguzzi, 1998). Many early childhood classrooms are filled with a variety of materials, including blocks, puzzles, balls, beads, colored papers, crayons, scissors, and so on.

The development of new technology has brought changes into the material environments of children's homes and the early childhood classroom (Sharkins, Newton, Albaiz, & Ernest, 2016). Today's children are considered "digital natives" (Prensky, 2001, p.1) who are growing up with technology, such as computers, video games, cameras, and cell phones (Furlong &

Davies, 2012). New devices, such as computers, iPads, smart boards, and document cameras, have become tools for supporting teachers' instruction and young children's activities in early childhood classrooms (Couse & Chen, 2010; Flewitt, Messer, & Kucirkova, 2015; Palaiologou, 2016).

Robots are an example of both a new technology and a contemporary object. Robots are non-human things that have mechanical bodies (the tangible hardware) and autonomous systems (the invisible software) to carry out a complex series of actions (the detectable behaviors, such as walking) (Virnes, 2012). Considering these distinct features, robots have been gradually shaping contemporary life. Although they don't necessarily have humanoid bodies, robot vacuum cleaners, surgical robots, carebots for the elderly, and self-driving cars are several examples of robots in modern life (Fischinger et al., 2016; Gallagher, Nåden, & Karterud, 2016; Howard & Dai, 2014; Taylor, Menciassi, Fichtinger, Fiorini, & Dario, 2016).

In the context of early childhood education, young children have been introduced to educational robots or robotic manipulatives in recent years. Different types of educational robots have different appearances, structures (hardware), systems (software), and functions (behavioral outcomes) (Hughes & Hughes, 2016; Virnes, 2012). Teachers or curriculum developers can choose and use robotic manipulatives that match their instructional objectives, according to the different features. In an early childhood robotics project that I participated in¹, our research team also used robotic manipulatives for teaching young children about programming (with BeeBots) and robot building (with Cubelets)². Through this project, I experienced that the robotic manipulatives had power to draw young children's attention, as some researchers have argued (Bers, 2008; Petre & Price, 2004).

¹ I further explain this early childhood robotics project in the methodology section.

² I describe these two types of robotic manipulatives in detail in the methodology section.

However, the participating children did not necessarily approach the robotic manipulatives in pre-determined ways or use them for prescribed purposes. The young children were active in entering into a relationship with the unfamiliar things, continuously attempting to do something with them. Ackermann (2013) shared a similar observation about how young children engage with programmable robots:

To many [young children], undoing a creature [a robot] to see what's inside is not the point. Nor are they particularly keen on building or programming a bot. Instead, they spend much time finessing their dance with a creature and, in doing, they experience the pros and cons of shared or distributed control. The purpose is to converse rather than construct, to bond rather than rule, and to feel connected rather than in charge. (p. 143)

Ackerman found that the children were interested in communicating with the programmable robots and developing a bond with them, not mastering and ruling them. I observed that young children's engagement with robotic manipulatives could take various forms and produce different meanings in connection to the children's lives. Just as young children's exploration of blocks or balls has meanings for them beyond mere cognitive mastery, their engagement with robotic manipulatives can be understood as social and cultural practices in their specific contexts.

I believe that looking deeply into young children's engagement with robotic manipulatives can lead us to think about what it means for young children to be agentive human beings in relation to machines/things/technology, what humans' relationships with non-human things look like, how children communicate with non-human things, and how their relationship with non-human things broadens or constrains their lives. To this end, early childhood educators need to consider in what ways the education of young children can support their relationships with non-human things and meet their needs.

In this dissertation, I pay attention to young children's engagement with robotic manipulatives from a sociocultural perspective (e.g., Bakhtin, 1981) and a new materialist perspective (e.g., Barad, 2007; Bennett, 2010). I regard the robotic manipulatives as new and innovative things/technology in young children's lives, rather than treating them only as instructional tools for Science, Technology, Engineering, and Mathematics (STEM) education. In doing so, I explore robotics as a pedagogical approach rather than as content for mastery. I focus on young children's points of view, their interests, and their attempts at engaging with robotic manipulatives, while pursuing the following research questions:

- 1) When young children engage with robotic manipulatives, what do they attempt to do with them?
- 2) When young children encounter a new type of thing/technology, how do they make sense of, respond to, and use the thing/technology?

With these questions, I attempt to understand how the children's engagement with the robotic manipulatives can provide them with opportunities to construct personal beliefs, values, and ideas of themselves and their worlds.

Literature Review

In the field of early childhood robotics education, how did the existing literature view young children's engagement with robotic manipulatives and what did the researchers discuss? To answer these questions, I searched four databases for existing literature: ERIC (Educational Resources Information Center), Science Direct, Springer Link, and Google. I utilized search keywords, such as educational robots, robotics kits, robotics, robotics education for young children, and kindergarten. As for the years of publications, I limited my search to the previous 10 years—between 2006 and 2017. At the end of my search, I identified and reviewed 47

empirical studies. In addition, I included Georgia pre-k and kindergarten standards (Georgia Department of Education, 2008a, 2008b) and the statement of the National Association for the Education of Young Children ([NAEYC], 2012) to review how early childhood education practices have dealt with robotics. I focused on the topics and key questions of the existing studies and analyzed them as themes. In the following sections, I group the existing literature into three themes that I identified: (a) robotic manipulatives for STEM teaching and learning, (b) robotic manipulatives as changing technological environments, and (c) robotic manipulatives for diverse learners.

Robotic Manipulatives for STEM Teaching and Learning

The first theme, represented in the majority of the studies, dealt with young children's engagement with robotic manipulatives in relation to STEM teaching and learning (Gadzickowski, 2018; Lindsay & Hounsell, 2017; Sullivan, Ber, & Mihm, 2017; Sullivan & Heffernan, 2016). Among the searched empirical studies, more than half of the reviewed studies have connected the benefits and outcomes of robotics education to STEM education. This line of research is interested in understanding how young children's engagement with robotic manipulatives serves their learning and how robotics functions as an academic discipline. The studies in this line highlighted not only the types of robotic manipulatives but also the features of robotics education curricula. Robotic manipulatives were considered effective tools to motivate young children to learn STEM. Besides, young children's engagement with the robotic manipulatives was perceived as involvement with STEM-related skills, concepts, and dispositions. By referring to STEM education, this line of research was concerned with the interdisciplinary nature of robotics education curricula. These studies were based on the premise that young children's engagement with robotic manipulatives and robotics education curricula shared common features with STEM

education (e.g., application of the engineering design process, a real context-based problem-solving activity, teamwork, and an interdisciplinary approach) (Benitti & Spolaôr, 2017).

In fact, there has been an ongoing debate on how to define STEM education and how to position robotics in connection with STEM education (Bybee, 2010; Johnson, 2003). Regarding young children's engagement with robotic manipulatives and the relationship of robotic manipulatives with STEM, the existing studies tended to take two different stances. On the one hand, robotics education was perceived as a sub-discipline of STEM education. On the other hand, young children's engagement with robotic manipulatives was treated as a distinct and independent field of robotics with some shared content with STEM education. In this dissertation study, I do not differentiate between STEM education and robotics education.

It is noticeable, however, that this line of research focused on the positive and effective learning outcomes of robotics education (e.g., Cacco & Moro, 2014; Datteri, Zecca, Laudisa, & Castiglioni, 2013; Chambers, Carbonaro, & Murray, 2008; Highfield, 2010; McDonald & Howell, 2013; Wei, Hung, Lee, & Chen, 2011). The studies were basically concerned with (a) what STEM-related components (e.g., concept, skills, and disposition) young children achieved and (b) to what extent children were able to gain STEM competency through their engagement with the robotic manipulatives. These studies were heavily outcome-oriented. For example, Table 1 specifies the learning outcomes of young children's engagement with the robotic manipulatives and the robotics curricula that all of the searched studies reported.

Table 1

Domains and Content for Young Children's Engagement with Robotic Manipulatives and Robotics Education Curricular

Domain	Sub-domain	Content
Knowledge (Concepts)	Subject-Oriented Knowledge	• Science • Physics • Computer science • Mathematics • Geometry (Spatiality) • Literacy
	Knowledge of Robots	• Physical parts of robots • Functions of parts of robots • Basic components of different robots • Different morphologies of robots • Different purposes of using robots • Definition of robots • History of robots
	Systems of Robots	• Rules of adaptive behaviors of robots • Artificial autonomous decision-making systems
	Computational Concepts	• Abstraction of commands (or symbols) • Sequencing • Corresponding • Repeated loop • Parameters (Numbers parameters & Sensor parameters)
Practices (Skills)	Programming	• Analyzing • Planning • Sequencing • Debugging (Trouble-shooting) • Control flow • Conditional branching
	Construction of Robots	• Design • Building • Balance • Stability • Control
	Cognitive Skills	• Analyzing • Classification • Prediction • Reasoning • Meta-cognition (reflection)
	Problem-Solving Process	• Identifying a problem → Exploring information and creating ideas → Making a decision / Selecting the best idea → Building and testing the idea → Evaluating the results
	Engineering Design Process	• Identifying a problem → Researching the problem → Developing possible solutions → Selecting a promising solution → Building a prototype → Testing and evaluating the prototype → Redesigning as needed
	Scientific Methods (Scientific Inquiry Skills)	• Observing and identifying a question → Formulating explanatory hypotheses → Testing the hypotheses → Evaluating hypotheses in light of the observed results and knowledge (evidence) → Communicating with others.

Attitude (Disposition)	Intra-Personal Attitude	• Initiative Engagements • Satisfaction • Familiarity with technology • Self-efficacy • Endurance • Flexibility
	Inter-Personal Attitude	• Collaboration • Cooperation • Communication • Conflict resolution

In addition, this line of research stressed young children's ages. The studies paid attention to the extent to which young children, including preschool and kindergarten children, were able to learn computational thinking, the programming process, the engineering design process, and the problem-solving process (e.g., Bers, Flannery, Kazakoff, & Sullivan, 2014; Kazakoff & Bers, 2014; Somyürek, 2014; Strawhacker & Bers, 2015; Sullivan & Bers, 2016b; Sullivan, Ber, & Mihm, 2017). Bers and her colleagues are key scholars in this area. For example, Bers, Flannery, Kazakoff, and Sullivan (2014) implemented the TangibleK Robotics Project which employed commercially available robotics construction kits and 20 hours of curriculum. Their study assessed young children's achievement in computational thinking in the following four aspects: (1) debugging, (2) correspondence, (3) sequencing, and (4) control flow. They presented quantitative evidence that kindergarten children were able to develop higher levels of computational thinking (e.g., understanding control flow instruction and a conditional control flow with parameters) by building and programming robots. They defined control flow as the situation where "programmers can control the order in which a robot follows the instructions" (p. 150). Their curriculum introduced the children's control flow instructions and a conditional control flow with parameters. As an example of control flow instruction, the children experienced giving repeated instructions to their robots to keep the robots moving forward. Next, the children used a light sensor (a parameter) to give a new instruction to the robots to move forward and then stop, if the environment was dark. This was the example of the conditional

control flow with parameters. Their results highlighted that even kindergarteners were able to understand and perform a high level of control flow. However, the authors acknowledged that the children needed more adult support and time to learn conditional instructions and sensor parameters.

A recent study by Sullivan and Bers (2016b) also quantitatively compared the achievements of three different age groups of children (pre-K, K, 2nd-grade) in the following aspects: (1) robotics knowledge (e.g., different parts of the robot and their functions) and (2) programming knowledge (e.g., easy sequencing with the different conditional commands, easy repeat loops with sensor parameters, and hard repeat loops with sensor parameters). Interestingly, the results of this study showed that all ages of children performed equally well even on the advanced programming tasks with the KIWI robotics kit. However, the authors reported that the pre-k children needed to learn at a slower pace, with repetitive experiences, and with one-on-one adult assistance.

Given that few studies on robotics education in general have paid attention to young children as learners, I think that the outcome-oriented studies can contribute to raising the awareness of young children's intellectual capabilities. In addition, these studies may help clarify developmentally appropriate expectations for the robotics curriculum. However, the outcome-focused research literature tended to highlight the technological traits of the robotic manipulatives and the expected outcomes of the robotics curricula rather than the participating children's characteristics, ways, and needs to engage with the robotic manipulatives and in the curriculum.

One noticeable commonality that I found in the outcome-oriented studies was that they reported on young children's intrapersonal and interpersonal attitudes. Although those areas were

not the main topics of the studies, the researchers mentioned those effects as unexpected but impressive findings (e.g., Bennie, Corbett, & Palo, 2018; Cacco & Moro, 2014; Hwang & Wu, 2014; McDonald & Howell, 2012; Wei, Hung, Lee, & Chen, 2011; Zaharija, Mladenovic, & Boljat, 2015). Nonetheless, the majority of the studies on robotics education has continued to place more emphasis on the cognitive domain than on the affective domain.

Robotic Manipulatives as Changing Technological Environments

As the second theme, a few studies on early childhood robotics education have considered robotic manipulatives as technological environments that are parts of young children's lives. The rationale for paying attention to children's technological environments is based on the logic that as life environments change, children's ways of living must change as well. Simply put, changes in technological environments are understood as social and cultural changes in children's lives. Therefore, interactive technology-enriched environments are assumed to transform young children's ways of thinking, communicating with others, making decisions, and living. In this context, the field of early childhood education has started focusing on different types of technologies as environments, including interactive media (e.g., apps, software programs, digital materials, e-books, Internet), in order to better support young children to grow up as competent and capable individuals in their changing environments.

This line of research is interested in understanding how young children explore and make sense of their technological environments and how they adjust themselves to the new environments. In this context, some researchers paid attention to young children's conceptualization of educational robots (e.g., Levy & Mioduser, 2010; Mioduser & Kuperman, 2012; Mioduser, Levy, & Talis, 2009; Slangen, Van Keulen, & Gravemeijer, 2011; Spektor-Precel & Mioduser, 2015).

Compared to other types of educational technologies and movable toys, educational robots have distinct features. Many educational robots appear to have animated human-like or creature-like appearances, such as snowman-like Keepon robots (Kozima, Michalowski, & Nakagawa, 2009), an alligator-like LEGO WeDo (Romero & Dupont, 2016), and a humanoid QRIO robot (Tanaka & Suzuki, 2005). At the same time, their animated behaviors (e.g., following hands, avoiding obstacles) can be controlled by a human. Focusing on the features of educational robots (e.g., the tangible hardware, invisible software, and detectable behaviors), the existing studies assumed that reasoning about robots' behaviors and systems played a significant role in young children's understanding of their relationship with the robots (Ackermann, 2013). For this reason, by zooming in on young children's encounters with robots, these studies investigated young children's reasoning about the robot's systems or how they conceptualized the robots' systems and behaviors. For example, in the study by Mioduser and Kuperman (2012), kindergarten children participated in constructing and programming robots. The findings of this study showed that kindergarten children mostly took an engineering perspective (i.e., children use technological language) to understand and explain the robots' behaviors (e.g., pushing a ball, moving around). However, during story-based tasks or under natural situations like conversations with the robots, young children tended to use more anthropomorphic language (e.g. describing robots' behaviors as human-like volition and emotions). The study demonstrated that young children's anthropomorphic perspectives changed into technological perspectives as they dealt with complex robot programming and building tasks.

This line of research is worth noticing in that it was the first to value young children's own perspectives on robots. From young children's points of view, their engagement with the robotic manipulatives may be an encounter with unfamiliar artifacts. Thus, I think these studies

contributed to deepening our understanding of children's ways of understanding robots' behaviors and their interactions with the robots. In addition, these studies suggested a different way to interpret young children's anthropomorphic views of robots beyond developmentalism. For example, researchers appreciated the hybrid nature of young children's reasoning about robots – having both anthropomorphic and technological perspectives on robots and switching the two perspectives – as a more mature cybernetic view (Ackermann, 1991), not a lack of rational thinking ability.

For early childhood education practice, there has been discussion of how pre-kindergarten (pre-k) and kindergarten classrooms can provide young children with appropriate opportunities for exploring different technologies. For example, Georgia pre-k and kindergarten standards (Georgia Department of Education, 2008a, 2008b) and the statement of the NAEYC (2012) defined new technologies as a broad range of digital devices, such as tablets, interactive whiteboards, electronic toys, e-book readers, and mobile devices. Technology was explicitly mentioned in the Georgia Early Learning and Development Standards (GELDS) (Georgia Department of Early Care and Learning, 2013). Similarly, the GELDS also expected 4- to 5-year-old children to “explore the uses of technology and understand its role in the environment” (p. 86). These documents emphasized the appropriate use of technology in early childhood settings. They take a cautious perspective on the adoption of technology and consider whether the employment of new technologies is pedagogically appropriate for young children.

In fact, the field of early childhood education has been cautious and warned that young children's engagement with technology should not deprive them of opportunities for holistic development (Johnson, 2016). In particular, NAEYC (2012) stated, “Above all, the use of technology tools and interactive media should not harm children . . . Technology and media

should never be used in ways that are emotionally damaging, physically harmful, disrespectful, degrading, dangerous, exploitative, or intimidating to children” (p. 5). NAEYC specified possible negative impacts of young children’s engagements with technology on health (e.g., eye, obesity, and toxins), cognitive developmental delays, and psychological side effects (e.g., media addiction and lack of attachments with people). The organization also emphasized that young children’s engagement with technology should not “replace activities such as creative play, real-life exploration, physical activity, outdoor experiences, conversation, and social interactions that are important for children’s development” (p. 5). In this way, young children’s engagement with technology is depicted as a potential threat to creativity and to real-life and physical experiences. In this context, while acknowledging that the appropriate use of technology can enhance children’s learning, the attractiveness of technology has been regarded as a dangerous force.

Robotic Manipulatives for Diverse Learners

The last theme that I identified was relevant to using robotic manipulatives as a means to support diverse learners. In this line of research, three groups of children received attention, including girls, children with special needs, and children from low-income families. I explain the studies relevant to each group next.

First, a few studies suggested that engaging girls with robotic manipulatives is an effective strategy for broadening girls’ participation in STEM areas. In the field of robotics education, one of the most frequently mentioned advantages of using robotic manipulatives is its attractive and interactive power to draw girls’ interests to STEM learning (Gomoll, Hmelo-Silver, Šabanović, & Francisco, 2016; Hartmann, Wiesner, & Wiesner-Steiner, 2007; Sullivan, Keith, & Wilson, 2016). Researchers have argued that programming experiences can help girls challenge gender stereotypes about STEM (Master, Cheryan, Moscatelli, & Meltzoff, 2017).

Surprisingly, there were only two empirical studies concerned with girls' engagement with robotic manipulatives and their academic achievement (e.g., Sullivan, 2016; Sullivan & Bers, 2016a). For example, Sullivan and Bers (2016a) were concerned with the gender differences in kindergarten children's robotics learning. Their quantitative results indicated that boys had a higher mean score than girls on more than half of the tasks related to programming. However, few of these differences were statistically significant. Therefore, the authors claimed that both girls and boys were able to have successful learning experiences, in particular when they were exposed to robotics and programming as early as kindergarten.

This line of research seems critical to bringing the important issue of gender inequity to the surface and to refute gender stereotypes in STEM learning. Nonetheless, the way in which gender was treated only as a biological distinction (boys versus girls) could be a limitation of these studies. In these studies, gender was presented as basic demographic information. I think that further explanations of gender aspects (e.g., boys' and girls' gender norms, explicit/implicit social and cultural contexts of the gendered behavior) need to be explored when trying to understand girls' engagement with the robotic manipulatives. Given the male dominance of STEM professions (Glass, Sessler, Levitte, & Michelmore, 2013) and the impact of gender stereotypes on girls' achievement in STEM fields (Cheryan, Siy, Vichayapai, Drury, & Kim, 2011; Shapiro & Williams, 2012), girls' engagement with the robotic manipulatives needs to be investigated from the social and cultural perspectives.

Second, some researchers in special education have explored the use of robotic manipulatives for the education of young children with special needs, such as Autism Spectrum Disorder (ASD). This line of research tended to take a clinical/therapeutic approach by utilizing Socially Assistive Robotics (SAR) designed to demonstrate behaviors (e.g., eye contact, facial

expression, body gestures) appropriate for social interactions (e.g., Barakova et al., 2015; Costa, Lehmann, Dautenhahn, Robins, & Soares, 2015; Costescu, Vanderborght, & David, 2015; Duquette, Michaud, & Mercier, 2008; Feil-Seifer & Matarić, 2009; Ranatunga et al., 2012; Srinivasan et al., 2015; Tartaro & Cassell, 2008; Wainer, Ferrari, Dautenhahn, & Robins, 2010; Warren, et al., 2015). Improving the social skills and attention of the children with ASD was the main focus in the SAR studies.

NAEYC (2012) recommended that the integration of technology in early childhood education should be responsive and flexible in order for young children with special needs to be independent technology users and learners. However, the studies using clinical approaches to robotic manipulatives tended to examine the child-robot interaction in settings outside of the regular classroom, such as laboratories. Thus, these studies were limited in their ability to consider pedagogical strategies for adopting the robots for the children in classrooms. Most of all, the studies with the clinical approach tended to have deficit views on the children with special needs and neglected these children's unique strengths.

Lastly, children from low-income families were mentioned in the literature. However, there was no empirical research on these children's engagement with robotic manipulatives or their participation in the robotics curricula. While emphasizing the necessity of the technological environment, NAEYC (2012) stated a concern about differences in children from different economic backgrounds. The organization recognized that young children from economically disadvantaged families have limited access to the latest technologies, which might cause gaps in these children's technology skills and digital literacy, compared to their peers from affluent families. As an alternative, NAEYC stated that early childhood education programs need to support children's access to different types of technology by providing technological experiences

in early education settings. Yet, the organization did not explain specific ways of doing this.

Surprisingly, it was difficult to find research literature focusing on young children with different cultural, racial, ethnic, and linguistic backgrounds in robotics education. In only one study that I found, Libman (2011) implemented a robotics education program for kindergarten children in a Jewish school by employing CHERP – the hybrid tangible programmable robots. By examining the children’s descriptions of their robots and their programming of the robots, this study showed that robotic manipulatives could be an appropriate means for the children to express their Jewish identity. Considering the increasing numbers of children from diverse backgrounds and calls for equity in STEM fields, more studies need to examine the role of race, culture, ethnicity, language, socioeconomic class, prior experiences, and other socially defined markers in children’s engagement with robotic manipulatives.

Gaps in the Literature

From the review of literature, I identified several gaps in the existing literature on young children’s engagement with robotic manipulatives. I discuss these gaps and the ways in which I address them in my study.

First, the existing literature – in particular, the studies focusing on STEM-related teaching and learning – stresses the effect of robotic manipulatives on young children. Although the studies in this line have helped us understand how the robotic manipulatives influence young children’s thinking and behavior, these studies tend to neglect how young children shape the way they use robotic manipulatives. The same was observed in the literature discussing the negative effects of technology on young children. These considered the unidirectional influence of the robotic manipulatives on young children based on the deterministic view of technology, which assumes that “technology itself exercises causal influence on human’s social practice” (Bimber,

1994, p. 83). I argue that young children's engagement with robotic manipulatives should be explored as mutual and bidirectional interactions.

Considering this directionality is important because young children's agency has been ignored in the deterministic frame. Young children are not passive receivers of external influences. As Adair (2014) conceptualized children's agency, young children have the ability "to influence what and how something is learned in order to expand capabilities" (p. 217). Framed by constructivism (Piaget, 1973), existing studies shed light on the fact that young children are capable learners in using robotic manipulatives for learning. However, the study recognized young children's capabilities only in the predetermined ways of using robots or robotic manipulatives and for the prescribed content of learning. In relationships with others and non-human things, young children can actively negotiate with, choose, or resist against the given influences (Buckingham, 2013; Carroll, Howard, Vetere, Peck, & Murphy, 2002; Lynch, 2015; Sefton-Green, 2004). Also, as the new materialist perspective (e.g., Barad, 2007; Bennett, 2010) emphasizes, children and non-human things can mutually act upon, change, shape, construct each other.

Second, much of the research literature considers the features of robotic manipulatives or the robotics education curricula but neglects the social, cultural, and historical contexts in which children are situated. Without the consideration of these contexts, the proposed causality—between robotic manipulatives and changes in children's performance—can be a hasty interpretation or a fragmentary claim. Graue and Walsh (1988) argued, "Children cannot possibly remain untouched by their contexts. Just as their contexts are shaped by their presence, children and their contexts mutually constitute each other" (p. 8). Young children's engagement with robotic manipulatives is a social and cultural phenomenon in which their local and large

contexts are embedded and nested together. I consider that young children's behaviors of touching, using, playing with, and exploring robotic manipulatives are not only a physical/cognitive practice but also a discursive/ideological one.

Paying attention to children's contexts may help us see how their engagement with robotic manipulatives is situated in and connected to what they already know, what they are interested in, and what they value. In addition, children's contexts may provide us with ways to see what unique and personal meanings they construct about themselves and their worlds through their engagement with robotic manipulatives. In the existing literature, the meanings of young children's engagement with robotic manipulatives were not determined by the children themselves, but by others, such as educators, researchers, robot designers, or policymakers. The given meanings mirror the future-oriented, social, and economic values imposed by others rather than the present-centered and personal meanings constructed by children themselves. I believe that seeing the contextual connection between children's local and larger worlds may help us see personalized and context-specific meanings of children's engagement with robotic manipulatives.

In this dissertation I attempt to close the aforementioned gaps in the existing literature on early childhood robotics education by (a) considering the mutual influences between young children and robotic manipulatives, (b) referring to local and large contexts wherein the young children are situated, and (c) extending meanings of children's engagement with robotic manipulatives beyond the prescribed learning outcome determined by adults.

Methodology

An Interpretive Case Study

This study is a qualitative case study rooted in the interpretive paradigm. The interpretivist paradigm focuses on the socially constructed meanings of phenomena that a participant constructs in a context where s/he is situated (Glesne, 2011). From the interpretive tradition, young children's engagement with the programmable robots can be read and interpreted differently, depending on the specific contexts in which s/he interacts with the robots (Graue & Walsh, 1998). The interpretive case study is suitable for this dissertation study, which attempts to understand the focal children's ways of engaging with the programmable robots from their perspectives.

I used a case study to explore "how the social phenomenon works" (Yin, 2018, p. 3). For a case study, Yin (2018) suggested defining and limiting the case to be investigated. In defining the case to be examined for this dissertation study, I chose four children as focal children. In Chapters 2, 3, and 4, I will explain the focal child or children of each chapter and how I selected them in detail.

Stake (1995) explained that the case study is not for sampling. Yin (1989) also articulated that the goal of the case study is to expand and make an "analytic generalization" (p. 21), not a "statistical generalization" (p. 21). In this dissertation study, I am not trying to generalize the cases of the focal children's engagement with the robotic manipulatives to other children. Instead, I intend to provide thick descriptions of their engagement with robotic manipulatives in the ordinary context (Stake, 1995; Yin & Davis, 2007) of the robotics education programs in order to expand our understanding of the children's ways to respond to and make sense of the robotic manipulatives.

Settings

This case study was situated in a series of robotics education programs for young children, which was designed and provided as a team research project led by my academic advisor, Dr. Kyunghwa Lee. For this dissertation study, I focused on data collected from two robotics education programs from the larger research project: A Summer Robotics Camp and a Saturday A. L. T. (Art, Literacy, and Technology) program (see Table 2). These two robotics education programs were provided at a community learning center, which was located in a town in Georgia where working-class African American and Latino American families were highly populated.

Table 2

Research Settings

	Setting	Period	Day
1	Summer Robotics Camp	June 2 – June 13, 2014	10 days (Two hours per day)
2	Saturday A.L.T. (Art, Literacy, and Technology) Program	August 30 – November 15, 2014	11 days (Two hours per day)

As summarized in Table 2, the Summer Robotics Camp took place for two hours per day, Monday through Friday, for two weeks. A total of 11 children, who ranged in age from 4 to 7, were recruited to participate in this Summer Robotics Camp. This intensive summer camp included two different robotics classes: a BeeBot class and a Cubelets class. The robotics classes had structured activities with specific learning objectives and content about robotics in accordance with the types of robotic manipulatives that were used. The robotics classes were

divided into two small groups of children (four to seven in each group) according to the children's ages. Each group participated in both robotics classes.

The Saturday A.L.T. program was held in the fall semester after the Summer Robotics Camp. Although this Saturday program still had two robotics classes (the BeeBot class and the Cubelets class), it was a more child-led and less-structured program than the Summer Robotics Camp. The robotics activities were planned and set up by our research team with different materials (e.g., flashlights, blocks, puppets, colored paper, Lego blocks, etc.). The children were able to choose the robotics classes and determine when and how to engage in the classes. We also allowed the children to suggest their own ideas to modify the planned activities or to use different materials available in the classroom. Through a new recruitment process, a total of 21 children ranging in age from 4 to 7 participated in this program. However, unlike the Summer Robotics Camp, the rates of the children's participation in the Saturday program fluctuated. On average, six to seven children attended each week.

I chose data from the Summer Robotics Camp because this camp was the participating children's first experience to engage with robotic manipulatives and learn about robotics. The activities provided during this camp were guided by specific instructional goals and content designed by our research team. Therefore, the Summer Robotics Camp provided me with a rich source of data for examining the focal children's initial responses to, interests in, and understanding of the robotic manipulatives. I also used the data from the Saturday A.L.T. program because this program allowed me to see how the focal children's ways of engaging with the robotic manipulatives had evolved. Furthermore, the data from the Saturday A.L.T. program helped me see the focal children in a different context due to its less-structured, free play-based curriculum.

Robotic Manipulatives

As mentioned earlier, our research team used two robotic manipulatives: BeeBots and Cubelets. BeeBots (© Terrapin Software) are a programmable robot for young children to use. Children can control the movements and actions of the bee-shaped robots by pushing command buttons (e.g., Forward, Backward, Left, Right) (see Figure 1). As a coding language, the directional arrows function as visual commands. BeeBots can move according to the sequential commands that users input.

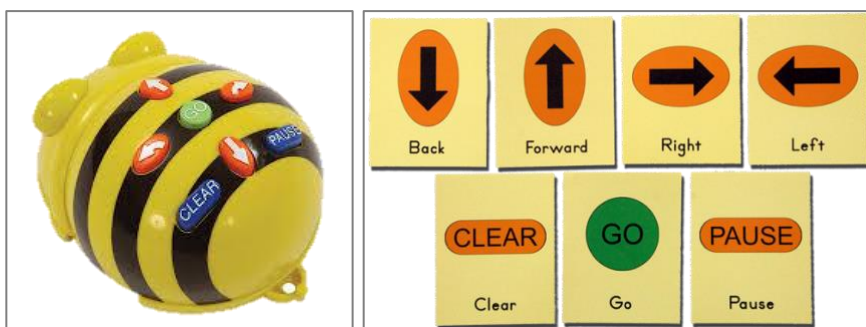


Figure 1. A BeeBot (left) and command cards (right).

Cubelets (© Modular Robotics) are magnetic robotic blocks enabling children to design and build their robots while learning about sensors, actuators introduced as actors, and their causal relationships. For this project, we used three types of Cubelets, including sensors, actors, and a battery. Figure 2 shows one example of each type of Cubelets. For example, a Drive Actor is a type of actor Cubelet which has a motor and roller wheels. An Distance Sensor is a type of sensor Cubelet which can detect nearby objects and how far it is from the objects. The battery provide the energy to make Cubelets robots carry out behaviors. The executive behaviors of Cubelets change depending on the type of actors.



Figure 2. Drive Actor (left), Distance Sensor (middle), and battery (right).

The Role of the Researcher

For this dissertation study, my role as a researcher was somewhat different from the typical participant-observer in other qualitative research studies (Schwandt, 2007). Along with other researchers on the research team, including my academic advisor and graduate student colleagues, I was a co-designer of the curricula of the two robotics education programs and involved in running the programs. During the Summer Robotics Camp, I led and taught the BeeBots class. For the Saturday A.L.T. Program, I was still in charge of the BeeBot class as a teacher. However, considering the less-structured and more child-led nature of the program, I participated in the children's activities by providing them with necessary materials, facilitating their activities, and performing the role of an active play partner, rather than directly teaching them.

The Video Method

Because this dissertation study focused on young children's engagement with robotic manipulatives, I needed a research method that could produce data on the children's bodily and non-verbal behaviors and materials. Video data was useful for this dissertation study by allowing me to capture and analyze not only young children's verbal utterances but also their non-verbal behaviors in engaging with the robotic manipulatives. Also, using video enabled me to pay

attention to physical and material traits of the robotic manipulatives and the material environments of the research settings.

Video-recorded data was generated in both research settings. In the Summer Robotics Camp, three videographers helped to generate video-recorded data. The videographers were two doctoral students (Su Yun Choi and Jaehee Kon) and one visiting scholar (Dr. Joeeun Oh). In collaboration with the research team, the videographers set up four video cameras. They took charge of recording all daily routines of the Summer Robotics camp, including snack and free play times. Referring to lesson plans for each day, the videographers identified in which rooms of the community learning center they had to set up cameras and determined the appropriate proximities between the video cameras and the children. They used tripods to generate high quality video-recordings. In addition, while videotaping, they flexibly adjusted the location, height, angle, and frame of the video cameras in order to follow and capture the participant children's facial expressions, movement to different locations, and behaviors in handling the robotic manipulatives.

In the Saturday A.L.T program, the members of our research team (my academic advisor Kyunghwa Lee, Eunji Cho, and I) acted as videographers while simultaneously facilitating the child-led activities. Before the Saturday program began and the children arrived, we set up three video cameras in each classroom: one camera in the BeeBots classroom, another camera in the Cubelets classroom, and another in the living room where children had snacks and free play time. Because we were engaged in the children's activities as teachers and facilitators, it was difficult for us to check the video-recordings and to focus on videotaping. Thus, we set up the cameras in the corner of each room and fixed the wide frames of the cameras in order to capture the whole room.

The research team generated the following amounts of video data in the Summer Robotics Camp and the Saturday A.L.T program (see Table 3).

Table 3

The Amounts of Video-Recorded Data

Class	Summer 2014	Fall 2014
BeeBots Class	12 hours 21 mins	6 hours 27 mins
Cubelets Class	24 hours 59 mins	5 hours 6 mins
Total hours	37 hours 20 mins	11 hours 33 mins

In each finding chapter, I present different research questions and focal children. I selected different data sets according to the research questions and the focal children. I will explain specifically which video data set I focused on and analyzed for each finding.

Microanalysis of Video Data

I used the following analytical process to conduct a microanalysis of the video data (see Figure 3). Video-recorded data allowed me to implement an iterative analytic process by revisiting the same data several times (Jacobs, Kawanaka, & Stigler, 1999).

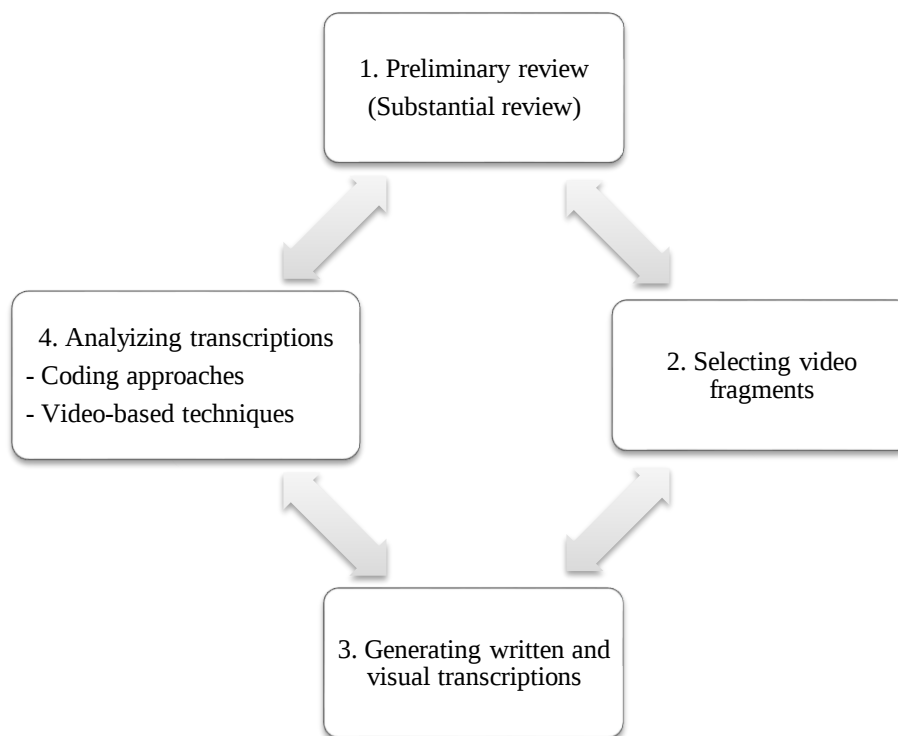


Figure 3. The procedure for microanalysis of the video-recorded data.

In the first step, I conducted a preliminary review of all video data presented in Table 3. My preliminary review of the video data had two purposes. First, I attempted to produce simple descriptions and classifications from the entire body of raw data (Heath, Hindmarsh, & Luff, 2011). As Appendix A shows, I watched the video data and recorded the fundamental elements of each video file (e.g., date, day, the title of video files, the focal child in the video, the robotic manipulatives used in the video, the goals of the daily lessons). In the Saturday A.L.T program, we did not provide teacher-led instructions but followed child-led and initiated activities. For this reason, I did not record the lesson goals for videos of those classes. Because our research team produced a vast amount of video data, this preliminary review was helpful for me to navigate and figure out basic and contextual information about the data. Second, my preliminary review helped me to identify and summarize distinct characteristics and behavior patterns of the focal children. For example, considering the research questions for this dissertation study, I reviewed

what the focal children attempted to do with the robotic manipulatives and summarized their actions (see the last columns of Appendix A). By analyzing what the focal children actually did with the robotics manipulatives, I could recognize what kinds of unexpected events occurred in each encounter between the focal child and the robotic manipulatives. Also, this review was helpful for me to extract a relevant video data set that connected with the research questions and the theoretical frameworks.

In the second step, I selected video data from the entire set of video data based on the preliminary review results. This was a data reduction process that allowed me to organize the data into manageable chunks and identify representative and relevant data samples. As a researcher, I had to reduce the original body of data in comprehensible, useful, and systemically organized ways (Smagorinsky, 2008). The principles that I used to eliminate video data or select data as representative and relevant were as follows:

- 1) I re-organized the preliminary data according to each focal child. In this process, I excluded data that involved only other participant children without the focal child.
- 2) With the data on each focal child, I arranged the data in time sequences (e.g., dates and times of each day) and according to the type of robotics class (BeeBots class versus Cubelets class), and I selected video data showing the focal child's repeated behaviors in responding to and using the robotic manipulatives.
- 3) With the data on each focal child, I excluded the data that showed the focal children following teacher-led instructions. For example, if a video segment showed a focal child successfully programming a BeeBot to go along a given route, I excluded the video segment from my analysis. This was not because the child's compliance with the teacher-led instruction was meaningless. However, considering the purpose of and

questions for this dissertation study, that type of data did not effectively show what the focal child attempted to do with the programmable robots. Thus, in this process, I focused on and selected video segments that demonstrated the focal child's attempts to engage with the robotic manipulatives as well as showing unexpected events that occurred.

In the third step, I created written and visual transcriptions of selected video data. In this process, I watched the video segments over and over to generate detailed descriptions of the video data. Also, considering that the video data contained both visual and auditory information, I attempted to make transcriptions involving both written descriptions and screenshot images corresponding to the written descriptions. I found it helpful to describe the children's non-verbal behaviors and the physical characteristics of the material environments. In particular, I added photos of artifacts (e.g., engineering logs and drawings) into the transcriptions. Appendix B shows examples of a written and visual transcription. Concentrating on each focal child, I generated the following amounts of transcriptions:

- Carlos (the focal child for Chapter 2): a 62-page transcription (9292 words)
- Silvia (a focal child for Chapter 3): a 25-page transcription (1693 words)
- Lucia (a focal child for Chapter 3): a 74-page transcription (7668 words)
- Keon (the focal child for Chapter 4): a 47-page transcription (3745 words)

In the last step, I analyzed the transcriptions by employing coding methods and video-based techniques. While reading the transcription line-by-line, I used different coding approaches (e.g. process coding and external coding) depending on the specific research questions of each finding chapter. I will explain in detail what specific coding methods and what codes/themes I used in the methods sections of each finding chapter. The combination of coding

approaches and video techniques helped me to conduct a detailed microanalysis of each video segment.

I employed three video-based techniques. First, I analyzed the video segments by speeding up and slowing down the playback while muting the audio. This helped me to pay more attention to the children's bodily behaviors. Also, in the sped-up mode, the constant changes in the robotic manipulatives and material environment were more visible. Thus, watching the video at the faster pace helped me to recognize robotic manipulatives and other materials (e.g., blocks) as vibrant and active elements of the scenes, not static and passive ones. Also, sped-up video segments showed different series of engagements between the children and the robotic manipulatives as continuing and evolving events, not separate and one-time events.

Second, I employed the reframing technique that Hayashi and Tobin (2015) used in their study. For analyzing embodied aspects of teaching, Hayashi and Tobin employed the technique of freezing a shot from video data, zooming, and re-centering the shot. They found that this strategy was useful to analyze bodily techniques and details that they had neglected in their previous analysis. I used this reframing technique to analyze details of the children's behaviors (e.g., gaze shifts, facial expressions, and finger movements) and small traits of the robotic manipulatives (e.g., the holes of the BeeBots and the switch of the battery Cubelets). In doing the reframing technique, I first screenshotted the scenes from the video segments and zoomed in on the scenes. The zooming shots provided close-up, detailed versions of images; thus, they helped me to catch aspects of the scenes that I might have missed otherwise.

Last, considering the new materialist framework, one of the theoretical frameworks of this dissertation study, I attempted to develop a visual technique that artfully abstracted the existing scenes to erase the distinction between humans and non-humans. For example, when I

analyzed a scene in which a boy touched and manipulated Cubelets, I attempted to analyze how the human actor (the child) and the nonhuman actants (the Cubelets) were entangled together as an ontological unit and exerted mutual influence on each other. To do so, I outlined the image of a boy engaging with the Cubelets, blurred the area inside the outline, and created a fusion of the boy and the Cubelets. This re-editing technique helped me to de-familiarize my understanding of how the children interacted with the robotic manipulatives and materials and revealed a radically different perception of what was happening in the scene.

Organization of the Dissertation

In this chapter, I introduced the overall purpose and research questions of this dissertation study. I also discussed the three themes and gaps in the existing literature on early childhood robotics education. I organized the remaining chapters of this dissertation as three finding chapters and a conclusion chapter. The three finding chapters contain their own research questions, theoretical framework, methods, and implications.

In Chapter 2, I examine a 6-year-old boy's appropriation of programmable robots (BeeBots). Drawing on the notion of dialogism (Bakhtin, 1981), I will explore the boy's creative and playful usage of the robotic manipulatives. This chapter will show in what ways the boy used, transformed, and made sense of the programmable robots.

In Chapter 3, I explore a 5-year-old and a 6-year-old girls' gendered engagement with the programmable robots (BeeBots) and magnetic robotic blocks (Cubelets). Again, Drawing on Bakhtin's (1981) notion of dialogism, I will look at how the two girls negotiated gender discourses and performed their own femininity while engaging with the robotic manipulatives.

In Chapter 4, I investigate a 6-year-old boy's hands-on inquiry about/with the magnetic robotic blocks (Cubelets). Utilizing new materialists' perspectives (Barad, 2007; Bennett, 2010;

Taguchi, 2010), I will investigate features of material and bodily practices another 6-year-old boy experienced with the robotic manipulatives.

In Chapter 5, I summarize the findings and conclude with the implications of this study for practice and research in early childhood education.

CHAPTER 2

A YOUNG CHILD'S DIALOGIC APPROPRIATION OF PROGRAMMABLE ROBOTS

Introduction

Vignette 1: Video transcript 6/11/2014



Figure 4.1. Carlos (in the black and yellow striped shirt) and Samuel (in the gray and black striped shirt) input the commands to make BeeBots push one another.



Figure 4.2. Carlos links two BeeBots with a paper clip to make them pull each other.

It is on the 8th day of the 10-day Summer Robotics Camp. Carlos places three BeeBots on the floor all facing each other (see Figure 4.1.). Carlos and Samuel push the Forward button the same number of times for each of the BeeBots. Then, Carlos pushes the Go buttons of all the BeeBots at the same time to make them start to move. Carlos and Samuel observe how the BeeBots push and hit one another. The BeeBots randomly go in different directions. While observing the BeeBots, Carlos and Samuel look at each other's faces and laugh. Carlos says, "It's a BeeBot Battle!" to me, as I perform the role of a teacher in the BeeBot class. The boys repeat the BeeBot Battle several times.

As the BeeBots begin moving forward, Carlos and Samuel crawl to follow them. Then, Carlos finds a paper clip on the floor. He suggests that Samuel link two BeeBots by hooking them together with the paper clip to see which BeeBot will be strong enough to pull the other one (see Figure 4.2.). Carlos and Samuel have two

BeeBots and link them with the paper clip. Again, they give the same number of Forward and Go commands to the BeeBots. Then, they watch the BeeBots pull each other in opposite directions.

The above Vignette 1 provides examples of Carlos's series of BeeBot Battles. Carlos and his close friend Samuel used the programmable robots in a playful and creative manner.

Nevertheless, given that they were in a Summer Camp to learn about programming BeeBots, the boys' ways of using the manipulatives appeared to be off-task, just silly play or resistance or even failure to follow the instructions on how to properly operate the BeeBots by using the programming process they had been learning.

However, in this chapter, drawing on Bakhtin's (1981) dialogism, I reframe Carlos's BeeBot Battle as a dialogical appropriation of the programmable robots. In doing so, I argue that this dialogic appropriation of the manipulatives was actually a full and authentic engagement with the programmable robots in a way that allowed Carlos to play an active and agentive role in (a) transforming properties of the robots, (b) reshaping the rules of programming the robots, and (c) constructing his own concept of and perspective on the robots. I also demonstrate how Carlos's ways of understanding and engaging with the programmable robots went beyond mere adoption of the robots but rather took the forms of dialogue and parody.

Theoretical Framework

In examining the relationship between users and educational technology, the appropriation of educational technology has been defined as the process through which the users make technology their own by re-inventing, tweaking, and applying it to fit their needs and contexts (Bar, Weber, & Pisani, 2016; Carroll, Howard, Vetere, Peck, & Murphy, 2001; Flint & Turner, 2016; Papa & Papa, 1992). This process extends beyond mere adoption of the

technology according to its original design. Investigating how young children appropriate programmable robots can provide an insight into how their interaction with the robotic manipulatives changes and evolves from their original design and educational purposes (Flint & Turner, 2016). In addition, examining young children's appropriation helps us see the ways in which programmable robots can be incorporated into the early childhood curriculum in a manner that is responsive to children's interests and needs.

Expanding the concept of technological appropriation, I attempt to conceptualize Carlos's appropriation of the programmable robots through Bakhtin's (1981) dialogism. In what follows, I explain what I mean by dialogic appropriation of the programmable robots, drawing on Bakhtinian perspectives.

Dialogism

In describing his concept of dialogism, Bakhtin (1981) talked mostly about texts, utterances, and dialogue between humans. He did not directly talk about dialogue between people and things/objects. Then, how can I apply Bakhtin's perspective to interpret Carlos's engagement with the programmable robots?

Bakhtin viewed the nature of interactions as intrinsically heteroglossic and dialogic (Hayashi & Tobin, 2015). His dialogism is mainly concerned with the meanings of the interactions as constructed by the contexts of the interactions, not determined and fixed by the original intentions of the authors/speakers. In his book, *The Dialogic Imagination*, Bakhtin (1981) used the novel as a kind of metaphor to explain these points. Through dialogues among three positions (an author, a hero in a novel, and the reader), Bakhtin demonstrated that meaning is not determined exclusively by the author and transferred to the readers; rather, the meaning is

constructed and evolves through a dynamic dialogue among the author, the hero (a character in the novel), and the readers.

I apply Bakhtin's (1981) dialogism to Carlos's engagement with the programmable robots. Carlos can be considered the reader while the BeeBots take the position of the hero in a novel. Teachers and BeeBot designers can be in the position of authors. For Carlos, BeeBots were others' cultural artifacts, which were produced by designers and employed by our research team with the intention of guiding him and other children to learn programming and to think and act like scientists, engineers, and programmers. In this sense, the BeeBots were not neutral tools. In term of others' voices, the BeeBots were filled with different values, beliefs, and ideologies. Thus, the BeeBots were given to Carlos with specific purposes and intentions, and Carlos's engagement with the programmable robots could be seen as his dialogue with others' voices (e.g., different ideas, interests, intentions, goals, beliefs, and values).

Considering that Bakhtin focused on the nature of linguistic and discursive interactions, how can I use his ideas to interpret Carlos's bodily behaviors and interactions in his engagement with the programmable robots? Oh (2014) explained that Bakhtin's concept of dialogue was not limited to verbal utterances. Instead, he saw dialogue as taking various forms of communication, including speech, writing, and embodied actions, all making distinct meanings. Hayashi and Tobin (2015) also used Bakhtin's dialogism to think about young children's embodied interactions, suggesting that the Bakhtinian notion of language could be applied to bodily interactions. Where Bakhtin (1981) referred to heteroglossic and polyvocal aspects of the novel, Hayashi and Tobin coined the terms "heterocorporeal" and "polycorporeal" to describe similar aspects of bodily interactions (p. 83). Lee and Hassett (2017) also applied Bakhtin's framework to capture kindergarten children's non-verbal communications with sounds and gestures.

Drawing on these researchers' ideas, I consider Carlos's bodily and non-verbal engagement with the programmable robots a mode of dialogue.

Dialogic Appropriation

I think Bakhtin's (1981) notion of *appropriation* is useful to further explain Carlos's process of engaging with the programmable robots. Explaining the discourse in the novel, he pointed out that readers not only engage with others' voices but also appropriate them to construct their own. Bakhtin conceptualized others' voices as the authoritative discourses. They have their own points of view, values, beliefs, norms, and rules. Most of all, they maintain static forms and rigidity in their views and values and preclude dialogic relationships with other views. In this chapter, I interpreted the authoritative discourse as the codes for programming and engineering procedures, principles of robot programming processes, and values and rules of the robotics curricula.

Yet, Bakhtin (1981) explained that readers can negotiate the given authoritative discourse and transform it into an internally persuasive discourse through appropriation. Bakhtin explained appropriation as follows:

The word in language is half someone else's. It becomes "one's own" only when the speaker populates it with his own intention, his own accent, when he appropriates the word, adapting it to his own semantic and expressive intention. (p. 293)

Relying on this quotation, I can read Carlos as not passively accepting the programmable robots and the authoritative discourses implied in them (e.g., the values and norms of programming and the given definition of robots). However, Carlos adapted the authoritative discourses on the BeeBots into his own internally persuasive discourse. This was a form of dialogic appropriation in which Carlos was able to negotiate and transform the authoritative discourse of the BeeBots in

a new way to construct his own ways, ideas, views, and values and to pursue his interests and purposes. Thus, Carlos's appropriation can be understood as a "retelling" (p. 389) in his own words, not as a passive "reciting" of the authoritative discourses on the BeeBots. In this sense, the notion of dialogic appropriation can help me capture Carlos's agentive and transformative practices to create something new in engaging with the programmable robots.

Parodies

In what ways do Carlos's appropriations of others' voices (authoritative discourses) on the programmable robots become the creation of new personal voices (internally persuasive discourses)? I attempted to answer this question with the notion of the *parody*. Parody can be a sub-category of dialogism (Simon, 1990). I think that parody can be a useful concept to explain how Carlos appropriated and stylized the programmable robots.

A parody refers to an imitation and exaggeration of the style and language of an author/speaker (Monemi, 2015). The predominant feature of the parody is its double-voicedness (Bakhtin, 1981). While engaging with an authoritative voice, the parody represents and exemplifies the original speaker's or author's style. At the same time, the voice doing the parody mocks and exaggerates the authoritative voice with "a derisive intonation" (Simon, 1990, p. 23). Thus, two different voices co-exist and even clash in the parody. The existence of the second voice in the parody can test and destabilize the authoritative discourse. It can broaden the original meanings and modes of the discourse and create new meanings and new forms of dialogue (Bartley, 2016).

Another important feature of the parody is its carnivalesque nature (Monemi, 2015) because it challenges and undermines the hierarchy and rigidity of authoritative voices. Moreover, the parody is ultimately about pro-social engagement. In other words, the parody is

not simply a challenge to and deconstruction of the dominant voices but an alternative way to engage with them. By crossing the boundaries of different viewpoints, the parody can create a dialogical moment and space in which different voices are mingled.

In engaging with the programmable robots, Carlos attempted to parody the robots and the language, perspectives, and values imbedded in the robots. Treating his ways to engage as a parody, I can capture what aspects of the robots Carlos parodied. This also allows me to identify how Carlos challenged and questioned the programmable robots given by teachers and the rigid rules for using them. I interpret Carlos's parody of the programmable robots as his distinct way to invert and deconstruct the distance and unfamiliarity of others' views on the robots and then to reconstruct his own meanings of them. In doing so, I see how Carlos's unofficial and unauthorized perspectives and practices take empowered positions in reshaping and reworking the meanings and rules of the programmable robots (Tarulli, 2002).

Drawing on Bakhtin's dialogism, the following two questions guided this chapter: (a) what aspects of the programmable robots did Carlos appropriate? and (b) in what ways did Carlos make sense of the programmable robots?

Methods

The Focal Child

I selected Carlos, a 6-year-old Latino American boy, as the focal child of this chapter because he was the only boy who participated in both the Summer Robotics Camp and the Saturday A.L.T. program. During the Summer Robotics Camp, he attended all sessions, except for one day. In the Saturday A.L.T. program, he attended four out of eleven days. Thus, focusing on Carlos allowed me to see the evolving nature of a child's engagement with the programmable robots. In addition, Carlos was very active not only in engaging in the teacher-led portions of the

BeeBot class but also in using the programmable robots for his own purposes. Therefore, I thought Carlos was a good case to pursue my research questions.

Data Sources and Data Analysis

For this chapter, I used a total of 18 hours and 48 minutes of video-recorded observation data that our research team collected during the BeeBot classes from the Summer Robotics Camp (12 hours and 21minutes) and the Saturday A.L.T. program (6 hours and 27 minutes). I also utilized artifacts, including the participating children's logs that our research team called *engineer logs*, photos of Carlos in the BeeBot classes, and lesson plans of the Summer Robotics Camp and the Saturday A.L.T. Program. These artifacts provided me with additional information related to the contexts in which Carlos was situated and the programmable robots were used.

For data analysis, I conducted a micro-analysis of the video data (Graue & Walsh, 1998; Heath, Luff, & Svensson, 2007). As Figure 3 in Chapter 1 presented, first, I briefly reviewed the entire collection of video recordings from the BeeBot classes, paying particular attention to Carlos's actions and encounters with the BeeBots. Then, during the second review, I transcribed all moments involving Carlos. I used an inductive coding approach to review the transcriptions along with other data (Saldana, 2013). Similar to the thematic approach, inductive analysis can be a fundamental feature of qualitative inquiry (Vaismoradi, Turunen, & Bondas, 2013). The inductive approach helped me effectively and systematically explore large amounts of different types of data and identify patterns and themes that emerged from the data.

For analyzing the transcription, I had two coding cycles. I conducted "process coding" (Saldana, 2013, p. 96) during the first coding cycle. Process coding can also be called action coding. Corbin and Strauss (2008) explained that this type of coding was appropriate for focusing on "ongoing action/interaction/emotion taken in response to situation, or problems,

often with the purpose of reaching a goal or handling a problem” (p.96-7). Process coding can help researchers focus on participants’ simple observable behaviors (e.g., watching, touching, moving) and more conceptual actions (e.g., negotiating, adapting, struggling). Process coding helped me identify what Carlos did with the programmable robots and generate codes for his actions, interactions, and responses. For the second cycle, I utilized “external coding” (Graue & Walsh, 1998, p. 163), drawing on Bakhtin’s (1981) dialogism. Graue and Walsh (1998) explained that external coding involves generating codes based on theoretical and conceptual frameworks. I examined and categorized the key codes generated by the first coding cycle (process coding) in relation to my theoretical frameworks (Blair, 2015). Table 4 presents examples of codes generated through the two cycles of coding.

Table 4

Examples of Codes

The First Cycle: Process Coding		The Second Cycle: External Coding
The Initial Codes	The Second Codes	The Third Codes
• Giving commands • Correcting errors • Following the BeeBots • Using other materials • Using hands • Naming the activity • Asking help from teachers/peers • Suggesting BeeBot Battles • Showing BeeBot Battles • Taking BeeBots from his peers • Explaining • Questioning	• Appropriating scientific and engineering language • Appropriating design • Appropriating concepts • Appropriating classroom rules • Appropriating the programming processes • Appropriating peer play • Appropriating media • Appropriating bodily usage • Appropriating ordinary toys	• Transgression • Mimicking • Challenging • Improvisation • Re-accentuation • Criticizing • Testing • Citation • Hybridity • Parody • Unofficial/local practice • Authoritative discourse • Internally persuasive discourse

Findings

For this chapter, I selected and focused on Carlos's series of BeeBot Battles as his dialogical appropriation of the programmable robots. Carlos dialogically adapted these battles to (a) re-accentuate the features of the programmable robots, (b) reshape the programming practice, and (c) parody the programmable robots to engage with different perspectives on the robots and programming. I explain each of these findings next.

Re-accentuating the Features of BeeBots

BeeBots are able to move. Whenever a BeeBot begins to move, its wheels go around and make machine- or robot-like sounds, "bee-beep." Carlos, along with other participating children, were very excited about the mobility and sounds of BeeBots. These features seemed attractive to Carlos, drawing his attention and curiosity.

BeeBots' movements are controlled by commands given by a child, and this feature differentiates BeeBots from other movable toys, such as dolls and toy cars. The connection between programming (an abstract process) and the mobility of BeeBots (concrete physicality) was a key features of BeeBots.

Carlos understood the relationship between programming and the mobility of BeeBots. In our Summer Robotics Camp, he and his peers learned that the arrow buttons on BeeBots (again, see Figure 1 in Chapter 1) function as programming commands. Arrows are signifiers indicating directions and behaviors that BeeBots execute. The directional arrows presented in a simple, visual format seemed relatively easy for Carlos and his peers to understand. In the BeeBot class, the participating children were encouraged to use the names of arrows as commands (e.g., Forward, Backward, Right, Left, Go, Clear) for programming. By pushing the arrow buttons, the children made BeeBots move and turn. It was their programming. Teachers encouraged Carlos

and other children, who were 6 or 7 years old, to write their programming by recording the arrows in their engineer logs.

On the 8th day of the Summer Robotics Camp, Carlos and other children were enjoying free play time in the living room of the community center. Leading the BeeBot class, I – SE – recognized that some boys wanted to play with the BeeBots without any given tasks (e.g., programming BeeBots on the grid or creating BeeBot stories to program). For this reason, I provided the children with BeeBots for their free play time. Carlos found that Samuel, a 7 year-old Latino boy, who was Carlos's best friend, had three BeeBots and was playing with them. Carlos joined Samuel's BeeBot play.

Carlos and Samuel placed their BeeBots face to face with one another (see Figure 5). After randomly giving commands, they observed that the BeeBots bumped into one another. As described in Vignette 1, it was Carlos's first "BeeBot Battle," as he named it. The BeeBot Battle was characterized by several BeeBots bumping into each other. By bumping one another, the BeeBots were gradually pushed back.



Figure 5. Carlos (in the yellow and black striped shirt) places BeeBots on the floor with

Samuel (in the gray and black striped shirt).

In his BeeBot Battle, Carlos adopted the two key features (i.e., commands and mobility) of BeeBots and tweaked them for his purposes. To start the BeeBot Battle, first, Carlos mumbled the word, “Clear,” to himself and pushed the Clear button, which deletes previous commands. In doing so, he adopted the first programming step that I taught the participating children. Next, Carlos input many Forward commands at once (see Figure 6).



Figure 6. Carlos inputs Clear and Forward commands to his BeeBot.

The Clear command was the most difficult step and concept for many participating children to understand at the beginning of the BeeBot class. The Clear command deletes the previous programming and resets BeeBots to make them ready for new programming. If Carlos did not start with the Clear command, his BeeBot would execute actions according to a mixture of previous and current commands. His mumbling of the word “clear” to himself seemed to be his own reminder of the first step of programming. This showed that Carlos was aware of the first step of programming and applied it to his BeeBot Battle.

Carlos selectively adopted programming for his BeeBot Battle. For example, the Forward command is for making BeeBots move forward. BeeBots move forward according to the number

of given Forward commands. At first glance, Carlos did not appear to engage in programming because he randomly pushed lots of Forward commands. His programming (i.e., inputting only the Forward command multiple times) seemed too easy and simple for Carlos. Considering his level of programming ability, he should have been able to give more complicated commands and make the BeeBots move in more sophisticated ways.

Yet, Carlos used the concepts and skills of programming in different ways. The purpose of his programming during his free play was not to make his BeeBot accurately move along routes or grids. Instead, the purpose of his programming for the BeeBot Battle was to make his BeeBot push and bump into other BeeBots. Thus, Carlos's intention was to give his BeeBot power for pushing and bumping, and his programming became the source of that power. In this way, the nature of the commands was transformed from their original meaning (i.e., programming language for directional movements) into a new meaning (i.e., the source of power). The more Forward commands Carlos gave to the BeeBot, the more powerful his BeeBot became to forcefully hit other BeeBots. Although this way of using the BeeBots was different from the original purpose of our introduction of these programmable robots to the participating children, Carlos creatively and successfully adapted the command functions to his purpose.

Furthermore, Carlos changed the basic mobility feature of the BeeBots. Originally, BeeBots were designed to move in particular directions. However, Carlos's BeeBot Battle required different types of movements, including bumping and pushing. In this playful battle, the directional mobility of BeeBots was transformed into force. From Bakhtin's (1981) perspective, the original feature of the BeeBots (i.e., directional mobility) can be understood as the authoritative discourse. It was "*a priori* discourse" (Bakhtin, 1981, p. 341) decided by the BeeBot manufacturer and our research team and unilaterally given to Carlos.

However, Carlos engaged in “selectively assimilating the words of others” (p. 341) to transform the key features of BeeBots. In Bakhtin’s words, Carlos’s appropriation of the authoritative discourse was the

process of assimilation – more or less creative – of others’ words (and not the words of a language). Our speech, that is, all our utterances (including our creative works), is filled with others' words, varying degrees of otherness or varying degrees of "our-own-ness," varying degrees of awareness and detachment. These words of others carry with them their own expression, their own evaluative tone, which we assimilate, rework, and re-accentuate. (p. 89)

From Bakhtin’s (1981) perspective, Carlos’s BeeBot Battle still involved the original feature (i.e., directional mobility) of the BeeBots. However, the varying degrees of others’ intentions for the BeeBots (to program them with directional movements) mingled with the varying degrees of Carlos’s own intentions for the BeeBots (to push and bump one another). BeeBots as the others’ artifact became Carlos’s own through his appropriation of the key features of the manipulatives. In this way, Carlos reworked and re-accentuated the features of BeeBots.

Reshaping The Ways of Programming Practice

Programming is not merely a practice that requires the acquisition of programming languages and skills. From a sociocultural perspective, programming also requires the programmer’s participation in “[the software’s] own ways of talking, reasoning, and acting with its own norms, beliefs, and values” (Rosebery, Warren, & Conant, 1992, p. 3). In the BeeBot class, programming had distinct values.

According to the conventional definition, a program is a “sequence of orders ... [that]... a machine [a robot] performs automatically without intervention from the user” (Wilkes, 1956, p.

2). As the definition says, programming has the distinct norms that robots should be operated only by a sequence of commands (its distinct language) and that robots should act automatically according to those commands

In addition, the accuracy and certainty of commands are particularly valued in the practice of programming. Programming requires the programmers to identify the targeted actions of a robot first and then program the robot according to the identified actions. The programmer has to make sure the actual actions of the robots correspond with the given programming. This gives the programmer a chance to detect errors in the programming. For instance, during the Summer Robotics Camp, our research team suggested the following programming process: 1) identifying a route, 2) programming the BeeBot by inputting commands, 3) recording the programming, 4) testing the programming, and 5) correcting errors in the programming. As these steps show, the practice of programming required the participating children to engage in the reiterative process of identifying the goal, sequencing commands, testing the commands through observing the actions of the BeeBots, and revising the commands by identifying errors.

In this programming practice, accuracy and certainty were particularly valued. According to the programming process we suggested, Carlos was expected to accurately identify how far and in which directions his BeeBots would go. The more accurately Carlos could identify the targeted behaviors of BeeBots, the more predictable and certain his programming could be. Then, the more accurately Carlos could detect errors in the BeeBots' behaviors, the better he could revise his programming to ensure the BeeBots moved in the correct way. The success of the programming was determined and judged by its accuracy.

However, Carlos's BeeBot Battle transgressed against the norms of programming by adopting unauthorized and unofficial practices. For example, in his BeeBot Battle, Carlos used

his hands to adjust the direction of his BeeBot. In order to have a strength trial, two or three BeeBots had to look at and bump one another. For this reason, when his BeeBot moved away from the other BeeBots, Carlos quickly picked up his BeeBot and slightly changed its direction to face the others again (see Figure 7).



Figure 7. Carlos uses his hand to change the direction of his BeeBot.

Using hands was a necessary tactic to set up and continue the BeeBot Battle. However, from the authoritative view of programming practice, using hands to operate the BeeBots was against the norms of programming. According to the norms of the programming, Carlos should have used commands to reorient the direction of his BeeBot rather than using his hands. The BeeBots should have performed automatically without intervention from Carlos's hands. Using hands was not allowed and was thus a marginalized practice. It was not an official practice in programming. However, Carlos inserted this unofficial practice (i.e., using hands) in the middle of the official practice (i.e., using commands). The BeeBot Battle continued through the combination of Carlos's commands and bodily intervention.

Carlos's bodily intervention was an unauthorized way to operate the BeeBots. Nevertheless, this unauthorized practice allowed Carlos to further develop his understanding of

the BeeBots and programming by teaching him about the distinction between how the BeeBots turned based on his programming and how they were turned with his hands (like other non-robotic toys).

Also, Carlos's BeeBot Battle challenged the core values of programming, including accuracy and certainty. The BeeBot Battle was established by the bumping, pushing and shaking movements of BeeBots. In order to win the battle, Carlos did not need to accurately identify what kinds of commands and how many of them he needed to program his BeeBot. Instead, he just needed to input many or random numbers of Forward commands and watch how his BeeBot hit the other BeeBots. In the BeeBot Battle, irregularity and uncertainty led to his excitement and thus were more valued than accuracy and certainty. In this way, Carlos transgressed the values of programming.

In the BeeBot Battle, Carlos cited the irregularity and uncertainty he experienced in his boy peer culture. During the Summer Robotics Camp, Carlos and his male friends often brought toy cars or Pokémon toys from home and enjoyed playing with them. For example, Jaden brought his Pokémon toys on the 3rd day of the Summer Robotics Camp (see Figure 8). He demonstrated how to do a battle game with the toys.



Figure 8. Jaden (in the white shirt) and other boys have peer play with Pokémon toys.

(The image on the right is from <https://www.youtube.com/watch?v=fiF28xzVvMQ>)

In the boys' play, the irregular and uncertain movements of toys produced unexpected pleasures and performances. Before the toys bumped into one another, the boys did not know which toy would be the strongest. The irregular and uncertain movements caused unpredictable force in hitting and pushing others' toys. The irregularity and uncertainty seemed to enhance the fun elements while meeting the boys' desire for power. Carlos's BeeBot Battle cited these aspects. Although the objects used for the boys' play were different, Carlos's BeeBot Battle shared common interests with his play with other boys.

The two unauthorized ways (i.e., using his hands and incorporating peer play) that Carlos used BeeBots were not merely violating the norms and value of programming. Instead, these actions contributed to creating dialogic spaces where the official programming practice encouraged by our research team met with Carlos' ordinary practice experienced in his peer culture. The BeeBot Battle functioned as a heteroglossic space where the authoritative discourse of programming encountered Carlos's peer culture and his bodily practices. The two different worlds had heterogeneous norms for and points of view on using BeeBots. Bakhtin (1981) explained,

[The heteroglossic space] represents the co-existence of socio-ideological contradictions between the present and the past, between different epochs of the past, between different socio-ideological groups in the present, between tendencies, schools, circles, and so forth, all given a bodily form. These "languages" of heteroglossia intersect each other in a variety of ways, forming new socially typifying languages. (p. 291)

From a Bakhtinian perspective, Carlos's BeeBot Battle was a heteroglossic event. His

transgression against a norm (using commands) and core values (accuracy and certainty) of programming created an intersection where programming was a centralized practice and using bodies and incorporating peer play was a marginalized practice.

Bakhtin (1981) emphasized that dialogue always involves tension between centralizing forces and decentralizing forces. From the authoritative norms and values of programming, Carlos could be seen as not fully mastering the language and methods of programming. Yet, in his BeeBot Battle, Carlos appropriated the authoritative practice of programming, while positioning his peer play and his ordinary bodily practice as the central and official practice. Through this inversion, Carlos brought his informal, unofficial, and everyday interests and ways of being to the pedagogical space for programming robots in the Summer Camp.

Parodying the Programmable Robots to Engage with Perspectives on the Robots and Programming

As described earlier, Carlos's initial BeeBot Battle involved bumping. After Carlos found a paper clip by chance on the floor and realized that the BeeBots could be connected by the paper clip, the battle of bumping evolved into a tug-of-war (see Figure 9). While BeeBots pushed and hit one another in the bumping mode, they pulled one another in the tug-of-war mode. It was a different type of strength contest.



Figure 9. Carlos (on the right of the photo) and Mark (on the left of the photo) have a tug-of-war version of a BeeBot Battle.

In the Saturday A.L.T. program held in the fall semester after the Summer Robotics Camp, participating children were allowed to decide what activities they would do and when. In the 2nd week of the program, several boys entered the library room, which was set as a classroom for BeeBots. Carlos asked our research team to give him a paper clip and said to his boy peers, “Let’s do [a] BeeBot Battle!” (Video transcript: 09-06-2014). Carlos invited Mark, a 6-year-old Latino boy, to join the new version of the BeeBot Battle. Mark did not participate in the Summer Robotics Camp. It was his first day to experience BeeBots in the Saturday A.L.T. program. Carlos showed how to connect his BeeBot and Mark’s BeeBot with the paper clip. Then, he demonstrated how to give the same number of Forward commands to each BeeBot. Carlos pushed the Go buttons of the two BeeBots at the same time. The BeeBots began to move simultaneously in opposite directions. Because they were connected to each other, the BeeBots could not move further. Although their wheels spun around and around, the BeeBots remained in the same places.

At the second trial, Carlos gave more Forward commands to his BeeBot than to Mark’s. Carlo’s BeeBot, having more Forward commands, moved longer than Mark’s. Consequently, Carlos’s BeeBot pulled harder on Mark’s. Watching it, Mark suddenly and forcibly dragged his BeeBot with his hand in order to pull Carlos’s BeeBot to his side. The BeeBot made strange machine noises as if it was broken.

As a lead teacher, I needed to intervene to keep the children from damaging the manipulatives (see Figure 10). First, I tried to remind the boys of the authoritative definitions of

programming (i.e., robots should be operated only by a sequence of commands and the robots should act automatically with those commands).



Figure 10. Mark (in the blue shirt, not the blue stripes) forcefully pulls a BeeBot with his hand (the photo on the left), and I intervene (the photo on the right).

At the same time, I referred to the rules of the BeeBot class. In both the Summer Robotics Camp and the Saturday A.L.T. program, the children were given the following rules for using BeeBots:

- The Bee-Bot is very sensitive. Please use it only on the board or desk.
- Don't use your hand to change the direction of a Bee-Bot's movement.

By setting the BeeBot class rules, I and our research team determined in what ways the children used the programmable robots and learned how to program.

Rather than merely accepting the given perspectives on robots and programming and the determined ways of learning, Carlos navigated the meanings of robots and programming by parodying the BeeBots and programming with his toy car, as described in Vignette 2:

Vignette 2: Video transcript 09-06-2014

SE: It's allowed to explore these BeeBots as you want. But, these are machine... robots... so...

Carlos: (interrupting my speaking and making sounds) Woo~ Woo~ Woo, Woo, Woo, Wow~.

SE: So, you have to be careful to work with them! (stops talking to the boys and looks at Carlos)

Carlos: Wait! Wait! (taking a small toy car from his pocket and showing it to SE) My BeeBot! My BeeBot! (showing it to me once more). Hey! We can race! (taking a BeeBot from SE's hand, placing it on the floor again, and then looking at the toy car) BeeBot, you get to win!



Figure 11. Carlos (in the yellow and black striped shirt) shows his toy car and speaks to the toy car.

Carlos: (giving several Forward commands to the BeeBot placed on the floor)

Sam: (watching Carlos) Hey! (joining the race with his BeeBot)

Carlos: (rolling his toy car on the floor with his hand and following the toy car and BeeBots) My BeeBot is winning! My BeeBot is winning! (slightly touching the toy car with his hand to make it go faster and making car sounds with his lips) Vroom~ Vroom~ Vroom~ Vroom~.



Figure 12. Carlos (in the yellow and black striped shirt) rolls his toy car with his hand and has the toy car race against Sam's (in the blue and light blue striped shirt) BeeBot.

In Vignette 2, Carlos called his toy car a BeeBot. Although he knew that it was not a BeeBot, he used the word as a kind of parody. Instead of giving commands, he used his hands to operate the toy car to move forward for the race. Carlos imitated the mobility of BeeBots. When the imitated BeeBot (the toy car) ran, Carlos mimicked the machine sounds of BeeBots, “Vroom~ Vroom~ Vroom~” with his voice. He exaggerated the sounds and movements of BeeBots for dramatic effects.

After the race between the original BeeBot and the imitated BeeBot (the toy car), Carlos continued to use the toy car in a parody of the BeeBot. The other boys still enjoyed the BeeBot Race. However, as Vignette 3 shows, Carlos kept rolling the toy car with his hand in the corner of the room.

Vignette 3: Video transcript 09-06-2014

Carlos: (rolling his toy car on the floor with his hand and crawling to follow it) Run! Run! Run! I command you BeeBot to go straight! (slightly touching the toy car with his hand and following it) Straight! (slightly touching the toy car with his hand and following it again) Straight! (slightly touching the toy car with his hand and following it again)



Figure 13. Carlos follows his toy car (the photo on the left) and touches it with his hand to change its direction (the photo on the right).

Again, Carlos assigned the toy car to the position of the BeeBot. He gave verbal commands to the imitated BeeBot, saying “Straight! Straight! Straight!” Instead of giving commands, Carlos verbally commanded the imitated BeeBot (the toy car) to continue to race and borrowed the language of programming (“Straight”). During the Summer Robotics Camp, Carlos used to call the Forward command “Straight.” In this parody, Carlos again cited the programming language. In doing so, he still adopted the programming steps that he engaged in in the Summer Robotics Camp. First, he identified which direction the imitated BeeBot (the toy car) would go. Next, he gave verbal commands (“Straight”) to the BeeBot with his hand. Then, he checked how and where the imitated BeeBot actually went.

Carlos’ parody can be understood as his dialogic engagement with given authoritative discourses regarding robots, programming, and the robotics education programs. By designating his toy car as a programmable robot, Carlos questioned and grappled with others’ definitions of robots and programming. I interrupted the boys’ BeeBot Battle by reminding them of the definition of robots. When the children and I discussed what a robot is, I explained about robots and BeeBots as follows:

- “Robots can move automatically by following the commands” (Video transcript 6-2-14).
- “Robots are a kind of machine, but robots can move automatically. Robots can sense and think by themselves and then move and act” (Video transcript 6-2-14).
- “BeeBots can move by following our commands and our instructions. BeeBots have many command buttons. By having these commands, BeeBots can move by themselves” (Video transcript 6-3-14).

The research team and I tried to provide a simple and clear perspective on the robots and programming for the children; however, robots and programming cannot be simply defined and

discussed. From a servile executant to an autonomous agent, robots have been defined in many ways (Ackermann, 2013). For example, Ackermann (2013) explained that if a machine can modify and transform the given input (e.g., commands), the machine can be perceived as autonomous. A robot's degree of autonomy depends on the human's degree of control over the robot. Brandes (1992) explained that the factors that make something a machine include a source of power, a source of control, and a certain level of complexity of behaviors/functions. The meaning of "machine" can also differ. The relationship between the self-regulating ability of robots and human agency has been an important issue in professional fields such as technology, robotics, engineering, and education. (Krishnan, 2016; Kwak, Kim, Kim, Shin, & Cho, 2013; Okita & Schwartz, 2006; Takayama, 2009; Weng, et al., 2001).

The meanings of robots and programming involve existential and ontological issues. Nevertheless, simple and unified meanings of robots and programming were given to Carlos by our research team as an authoritative perspective. However, while comparing the toy car (using hands) to the BeeBots (using commands), Carlos engaged with others' artifacts (robots) and other's practice (programming). He attempted to make his own meanings of the robots and programming by exploring deep philosophical issues about robots and programming.

Both definitions of programming and robots given to Carlos can be somewhat ambiguous. In fact, as robots which have a self-regulated system, BeeBots are in between autonomous and dependent. In addition, as a type of machine, BeeBots are in between sensitive and strong. When Carlos moved the imitated BeeBot (the toy car) with his hand, the robot was treated as dependent upon and controlled by a human. As described in Vignette 3, the imitated BeeBot (the toy car) did not move straight as Carlos wanted. Thus, he had to follow it and slightly touch it to make it go straight. Although the BeeBots were portrayed as autonomous and

automatic in my discussion with the children, Carlos's parody treated the BeeBots as neither fully autonomous nor completely regulated. In this way, he explored the issue of locus of control over the robots by comparing programming with using his hands to operate the BeeBots and the toy car. Also, Carlos engaged with the imitated robots (the toy car) by exploring ontological and philosophical perspectives on the degree of humans' control over machines/robots and the agency of animated machines/objects.

Carlos's parody did not suggest a final answer to the questions. Rather, the questioning in his parody questioned the given definitions of robots and programming and destabilized the monophonic perspectives on them. In regard to the role of parody, Momeni (2015) explained,

[The parodic voice] destabilizes the authority of the first domineering voice. In fact, the polyphonic nature of parody which actualizes itself in the clash of voices contributes to its carnivalesque feature with which parody undermines the hierarchy of voices and exposes the authorial or sacred voice to ridicule. (p. 52)

The parody was, in fact, Carlos's dialogical attempt to negotiate and engage with the external distance and unfamiliarity of others' perspectives on robots and programming. For Bakhtin (1981), parody is a way of acknowledging and appropriating dominant perspectives, not over-turning them in a manner that destroys them. Parody for Bakhtin is a pro-social engagement with the dominant views and norms. To parody the BeeBots, Carlos had to know about the authoritative view of robots and programming and the classroom rules. For Carlos, parodying the BeeBots was a kind of internalization of the concept of the robots that he then made his own by adding his own intentions and accent. Although Carlos's parody did not present a coherent view of robots, it contributed to generating new thoughts about and alternative realities of robots and

the programming of robots. Thus, Carlos's parody was not a mere mimic of the BeeBots, but an authentic engagement with them to construct his own understanding of robots and programming.

Discussion

Drawing on Bakhtin's (1981) dialogism, this chapter presented Carlos's dialogic appropriation of the programmable robots. The findings showed that Carlos engaged with the robots in a dialogic and parodic manner. In his dialogic appropriation of the BeeBots, Carlos fully and authentically engaged with them by transforming their features, challenging the rules of programming, and constructing his own perspective on the robots. Based on the findings of this chapter, I discuss several implications for early childhood education in general and early childhood robotics education in particular.

First, the findings of this chapter call upon us to recognize young children's agentive roles in engaging with the programmable robots. Defining the robots as a type of educational material or technology, existing studies have recognized young children as capable to operate the robots and to learn the programming concepts and skills (e.g., Bennie, Corbett, & Palo, 2015; Kazakoff & Bers, 2015; Sullivan & Bers, 2016; Sullivan, Bers & Mihm, 2017). These studies have tended to focus on the cognitive capabilities of young children by discussing what skills they are able to master. However, the studies have constructed an image of young children as either capable technology consumers or passive technology users.

However, Carlos's dialogic appropriation shows us how he was able to change the features of the programmable robots, determine how to use the programmable robots, and negotiate the given meanings he constructed. Pachler, Bachmair, and Cook (2010) argued that the notion of consumption of technology needs to be replaced with participation in and production of technology. Carlos's dialogic appropriations provide us with insights into how a

young child participates in, reproduces, transforms, and innovates the educational technology. In particular, Carlos's agentic authorship in engaging with the programmable robots challenges a pervasive concern about the power of technology over young children. In the field of early childhood education, there is a lingering fear that technology will make young children less creative, less active, and less interactive (Goldstein, 2013; NAEYC, 2012). However, building on Carlos's dialogic appropriation, I argue that young children can exercise and claim their own power in creating, modifying, remixing, and transforming technology, including programmable robots, in their own ways.

Second, the findings of this chapter suggest that we as educators need to embrace young children's emergent and ordinary practices when introducing programmable robots. In Carlos's dialogic appropriation, his personal and ordinary practices from his peer culture were brought to and incorporated into what he learned from the robotics curriculum. Using hands to touch the BeeBots and making them randomly move and bump into one another appeared to be boys' mischievous and off-task behaviors. Yet, these behaviors were unofficial and unauthorized ways to learn about the BeeBots and their key features. Lynch (2015) conceptualized young children's ordinary and emergent practices in the use of technology as marginalized practices. In school, where following adult directions and rules is emphasized, educational technology is often introduced in a predetermined manner for the mastery of particular concepts and skills (Lynch, 2015). In this context, children's bodily and ordinary practices are dismissed as trivial, irrelevant, and inappropriate.

Alimisis (2012) pointed out that simply adopting programmable robots in the classroom is not enough, and that pedagogical approaches should also be adapted to the programmable robots. Carlos's dialogic appropriation suggests that we need to appreciate young children's

ordinary and bodily practices and incorporate them into the robotics curriculum. Doing so will make the application of the programmable robots responsive to the children's needs, interests, and lives (Rusk, Resnick, Berg, & Pezalla-Granlaun, 2008).

Lastly, the findings of this chapter suggest that young children's engagement with the programmable robots has the potential to allow them go beyond learning about programming to explore complex issues around technology in general and robots in particular. Through his parody, Carlos questioned the definition of robots and reconstructed his perspective on them. Although he did not explicitly verbalize his thoughts, Carlos's parody showed the possibility of exploring the relationship between robots and humans, the differences and similarities between robots and other things (e.g., a toy car), and the degree to which humans can control robots.

Ackerman (2013) also noted that the interaction with programmable devices/artifacts can be a means for young children to engage in the questions of agency and control and to think about the ways in which they can communicate with and animate non-human things. The questions, such as "Do we direct and control robots or are we being directed and controlled by them?" are not just philosophical anymore but ontological and existential questions related to our lives (Rushkoff, 2010). Carlos's parody showed that young children are more open and flexible than adults are in their response to these complex issues related to humans and their relationships with robots and other technologies. Children are already ready to engage in these questions and issues. I suggest approaching young children's engagement with robots as a dialogic space where they can explore and think about the relationship between humans and technologies beyond the mastery of STEM concepts and skills, including programming.

CHAPTER 3

GIRLS' GENDERED ENGAGEMENT WITH ROBOTIC MANIPULATIVES

Introduction

Vignette 4: Video Transcript 10-04-2014

- The BeeBot Restaurant

Silvia, a 4-year old Latina, builds a road and town for BeeBots by using wooden blocks and recycled materials (e.g., boxes, rolls, and empty egg cartons) with two other girls in the BeeBot room. She programs three BeeBots to move forward on the road. When the BeeBots get to the final point, Silvia says to me, a teacher of the BeeBot class, “Look! He goes to the restaurant!” She points to a BeeBot at the end of the road (see Figure 14). I respond to her, asking “What are they doing?” Silvia answers, “Eating, because he can eat! Some restaurant food! He can eat! He can eat a lot!”



Figure 14. Silvia says, “Look! He goes to the restaurant,” pointing to a BeeBot.

Silvia puts a long wooden block in front of the restaurant, mumbling “He can eat and...lock! Lock... lock...because he can get out.” Silvia programs the BeeBot to move forward. The BeeBot goes straight and pushes the wooden block that Silvia had placed in its path. Watching the BeeBot and looking at me, she says, “Wow!” The BeeBot moves further and pushes the other wooden block. Silvia puts the block in front of the BeeBot again and holds the block so it can’t be pushed back. She mumbles to herself, “Lock! He is locked!” (see Figure 15).



Figure 15. Silvia puts wooden blocks in front of the BeeBot to interrupt its movement.

Vignette 5: Video Transcript 6-13-2014

- Building a robot

EJ – a teacher of the Cubelets class in the Summer Robotics Camp– helps Lucia, a 5-year old Latina, to attach four Drive Actors, an Distance Sensor, and a battery to the body of her robot. She had named her robot Juliana. Lucia says, “Oh! I like it!” She turns on the battery and places her robot at the corner of the table. As soon as Lucia puts her hand near the Distance Sensor, her robot begins moving forward.



Figure 16. Lucia designs and builds her own robot, named Juliana.

In Vignette 4 Silvia designated a BeeBot as male in her dramatic play. She accommodated the male BeeBot by building a road and a town for him. She seemed to be thinking about his needs. Simultaneously, she caused the male BeeBot to be in trouble by locking him in with wooden blocks. Meanwhile, in Vignette 5 Lucia built a robot with Cubelets and recycled materials. She

named her robot Juliana. Juliana had a girly appearance with big eyes, long hair, hair ribbons, and rosy cheeks and lips. Engaging in this robot design process, Lucia made a lot of effort to attach wheels (i.e., Drive Cubelets) on the bottom of Juliana. She emphasized several times that her robot could walk and carry something in the box-like body.

The two girls' femininity stood out in their robot building and programming activities. Robot building and programming can be considered an area of STEM. Given the masculine dominant images of STEM (Beede et al., 2011; Glass, Sassler, Levitte, & Michelmore, 2013), it was interesting to see how Silvia and Lucia expressed their femininity in programing and building their robots.

The persistent disparity between men and women has been an ongoing issue in STEM-related areas (Dasgupta & Stout, 2014). While national and educational attention to STEM professions has been increasing, women are still underrepresented in STEM jobs and among STEM degree holders (Beede et al., 2011). Researchers in the field of STEM education have been interested in what causes and drives this gender disparity and sought the pedagogical implications for engaging girls in STEM areas.

In connection to girls' gender identity, gender stereotypes are mentioned as an important possible factor driving girls' low participation in the field of STEM areas (Beede et al., 2011; Holmegaard, Madsen, & Ulriksen, 2014; Sulliva, 2016). The masculine-dominant image of STEM areas and the lack of female role models have been mentioned mentioned as obstacles girls' persistent engagement in the areas (Lumsden, 2010). For example, Holmegaard, Madsen, and Ulriksen (2014) identified that girls perceived STEM as less relevant to their heterogeneous feminine identities and thus as undesirable and unattractive.

Moreover, in terms of difficulties that girls experience, the gender stereotype threat has been suggested to explain girls' low interest and performance in STEM-related subjects (Cheryan, Master, & Meltzoff, 2015; Flore & Wicherts, 2015; Shapiro & Williams, 2012; Wang & Degol, 2013). The gender stereotype threat refers to the negative influence of gender stereotypes on someone's performance on a task (Steele, 1997; Spencer, Logel, & Davies, 2016). For example, girls experience explicit or implicit messages that associate their gender with their academic performance. The low expectations of or negative beliefs about girls' achievement in STEM-related subjects has become an obstacle to girls' interest, achievement, and persistence in those subjects (Brickhouse & Potter, 2001).

The literature on gender in STEM education has addressed the importance of examining the gender discourses Silvia and Lucia faced and how those discourses may have played a role in their engagement in robot building and programming (Tan, Calabrese Barton, Kang, & O'Neill, 2013). Also, the girls' participation in robot building and programming needs to be understood as a matter of the girls' perceptions of themselves. It is necessary to understand how the robotics classes, others (e.g., peers and teachers), and the forms/contents of activities influenced how the girls dealt with, negotiated, and constructed their feminine identity.

Therefore, in this chapter, I attempt to focus on what gender discourses the girls encountered and negotiated through their engagement with two robotic manipulatives, BeeBots and Cubelets, and in what ways they performed and constructed their femininity. I examined the following questions:

1. What gender discourses were involved in the young girls' engagement with robotic manipulatives?

2. In what ways did the girls perform and construct their femininity in relation to the robotic manipulatives?

Theoretical Framework

In this chapter, I used the same theoretical framework as in Chapter 2, Bakhtin's (1981) *dialogism*. Thus, I will not explain the concept of dialogism again in this section. However, I will explain how I applied his perspective to understand two girls' gendered engagement with the robotic manipulatives.

From a Bakhtinian perspective, young children construct the personal meanings of their gender through dialogue with others' voices in their lives. I apply Bakhtin's dialogism to see the girls' engagement with the robotic manipulatives as their dialogic attempts to negotiate with different beliefs, opinions, values, and norms related to gender.

Bakhtin (1981) explained, "Language is not a neutral medium that passes freely and easily into the private property of the speaker's intentions; it is populated – overpopulated with the intentions of others" (p. 294). Likewise, the girls' interactions with the robotic manipulatives were not a neutral way to exchange and develop objective knowledge. Rather, their dialogic engagement was ideological (Holquist, 2002; Tobin, 2000). According to Van Dijk (2006), meanings are not just referential ideas, but rather they always reflect certain points of views and thus are ideological. Being ideological in its nature, I think, the girls' engagement with the robotic manipulatives entailed particular positions on and value judgments of gender.

In order to understand how the girls dealt with others' views on and beliefs about gender, Bakhtin's (1981) notion of *appropriation* is helpful again for this chapter. According to this idea, the two girls not only engaged with others' views of gender but also appropriated them to construct their own perspectives. In addition, Bakhtin contrasted *authoritative discourse* with

internally persuasive discourse. According to him, the authoritative discourse, which can be “religious, political, moral; the word of a father, of adults and of teachers” (p. 342), is a type of perspective that does not allow dialogue. In this chapter, I consider the authoritative discourse to the static and rigid views of gender expressed in gender stereotypes.

The internally persuasive discourse, on the contrary, is intrinsically dialogic, as Bakhtin explained below:

Internally persuasive discourse – as opposed to one that is externally authoritative – is, as it is affirmed through assimilation, tightly interwoven with ‘one’s own word’. In the everyday rounds of our consciousness, the internally persuasive word is half-ours and half-someone else’s ... It enters into interanimating relationships with new contexts. More than that, it enters into an intense interaction, a struggle with other internally persuasive discourses. Our ideological [becoming] is just such an intense struggle within us for hegemony among various available verbal and ideological points of view, approaches, directions and values. The semantic structure of an internally persuasive discourse is not finite, it is open; in each of the new contexts that dialogize it, this discourse is able to reveal ever new ways to mean. (p. 346)

The internally persuasive discourse has a hybrid nature with heterogeneous perspectives. In this study, I consider the girls to be agentive agents who appropriated both external and given gender discourses and constructed their own meanings of gender. I believe the girls’ gendered engagement with the robotic manipulatives was not the passive “reciting” of authoritative words but “retelling in one’s own words” (p. 389).

In addition, from Bakhtin’s (1981) view, the robotic manipulatives can be seen as resources or texts that have discursive voices. The girls’ gender can be constructed and

performed through dialogue with these materials (Butler, 1997; Tobin, 2000). Thus, instead of assuming the robotic manipulatives as already gendered materials/things which send fixed messages or unilaterally teach the girls to become either masculine or feminine, I attempt to focus on what gender discourses the girls encountered and negotiated through their engagements with those materials and how the girls' femininity was performed in their interactions with the manipulatives.

Methods

Focal Children

In this chapter, I focused on two girls as focal children for this study: a 4-year-old Latina named Silvia and a 5-year-old Latina named Lucia. Both girls are bilingual children who usually spoke in English but occasionally spoke in Spanish as well. I selected these two girls as focal children out of five girls who participated in the Summer Robotics Camp. I considered Silvia's and Lucia's attendance of the Summer Robotics Camp. Because the robotics education program was provided in an informal community learning center, the children's attendance tended to be inconsistent. However, both Silvia and Lucia participated in all classes of the Summer Robotics Camp. Also, Silvia was the only girl who participated in both the Summer Robotics Camp and the Saturday A.L.T. Program. Thus, I think Silvia and Lucia can provide rich data for this chapter.

Data Collection and Analysis

The research project team collected a total of 37 hours and 20 minutes of video-recorded observation data from the Summer Robotics Camp and a total of 11 hours and 33 minutes of video-recorded observation data from the Saturday A.L.T. program. Multiple cameras were used to generate this data. The research project team generated artifacts by collecting engineer logs

and photos of Silvia's and Lucia's work and their participation as well as lesson plans of the Summer Robotics Camp and the Saturday A.L.T. Program. The documents were not produced by the children, yet they can provide further information explaining the contexts in which the girls were situated.

To conduct a micro-analysis of the video data (Graue & Walsh, 1998; Heath, Luff, & Svensson, 2007), I filtered a vast amount video data for analysis based on two criteria. First, I selected the video data that involved the two focal children's participation. Video data that did not show Silvia and Lucia was filtered out. Second, I considered the type of robotics activities. During the initial analysis, I reviewed all data relevant to Silvia and Lucia. However, I only chose to analyze the data showing the child-led robotics activities. The two girls participated in all classes of the Summer Robotics Camp; however, their distinctive interests about and verbal/nonverbal interactions with the robotics manipulatives, peers, teachers, and the classroom environments stood out during child-led activities. For this reason, I chose the video data showing child-initiated and project-based robotics activities.

To be specific, in the case of Silvia, I selected video data of Silvia's engagement with BeeBots during the Saturday A.L.T program. I found she was constantly active in the BeeBot class and developed dramatic play by integrating her distinct interests and themes with BeeBots. Considering her age, it seemed to be difficult for her to understand the systematic relationships (a sensor as input and an actor as output) and the vocabulary of the Cubelets. Thus, it was harder for her to operate Cubelets as she wanted. Since the BeeBots were easier for her to understand, Silvia's interest was continuously maintained and developed in the BeeBot class. Also, during the Saturday A. L. T. program, Silvia spent much more time constructing BeeBots' towns/roads/buildings, making stories about BeeBots, and having dramatic play with the

BeeBots than programming them to move on the given routes or grids. Thus, I considered Silvia's dramatic play with BeeBots as her robotics project and analyzed the video data of her play for this chapter.

In the case of Lucia, I chose the video data of her engagement with Cubelets only in the Summer Robotics Camp because she did not participate in the Saturday A.L.T program. During the Summer Robotics Camp, the last three out of ten days were for the robot project. Lucia voluntarily chose Cubelets for designing and making her own robot. Considering her voluntary participation in the Cubelets robot project and her particular interests in her boys' peer group, the data on her Cubelets robot project was appropriate for identifying her gendered engagements.

After filtering and selecting the data, I transcribed the filtered data (see Figure 3 in Chapter 1 again). In generating the transcription, I added artifacts into it in order to make a set of synthetic data. I used an inductive coding approach to review the transcriptions along with other data (Saldana, 2013). Similar to the thematic approach, inductive analysis can be a fundamental feature of qualitative inquiry (Vaismoradi, Turunen, & Bondas, 2013). The coding approach was helpful for me to identify emerging patterns in the data. This inductive coding approach helped me to effectively and systemically explore large amounts of different types of data and to determine themes.

To be specific, I had two coding cycles to analyze transcriptions. I conducted "process coding" (Saldana, 2013, p. 96) during the first coding cycle. Process coding can also be called action coding. Corbin and Strauss (2008) explained that this type of coding was appropriate for focusing on "ongoing action/interaction/emotion taken in response to situation, or problems, often with the purpose of reaching a goal or handling a problem" (p.96-7). Process coding can help researchers focus on participants' simple observable behaviors (e.g., watching, touching,

moving) and more conceptual actions (e.g., negotiating, adapting, struggling). For this chapter, process coding helped me identify what the girls actually did with the robotic manipulatives and to generate concrete codes about their actions as well as their interactions with and responses to the robotic manipulatives. Through process coding, I paid particular attention to the stories the two girls made in relation to their robots, the themes their stories addressed, how they behaved with their robots, and what they said about their robots.

For the second cycle, I utilized “external coding” (Graue & Walsh, 1998, p. 163), drawing on Bakhtin’s (1981) dialogism. Graue and Walsh (1998) explained that external coding involves generating codes based on theoretical and conceptual frameworks. I examined and categorized the key codes generated by the first coding cycle (process coding) in relation to my theoretical frameworks (Blair, 2015). Table 5 presents examples of codes generated through the two cycles of coding.

Table 5

Examples of Codes

The First Cycle: Process Coding	The Second Cycle: External Coding
• Operating the robot by giving commands • Operating the robot by using hands • Planning the design of the robot • Planning how the robot will function • Asking for help from a teacher • Helping peers • Showing the robot to others • Explaining about the robot to others • Decorating the appearance of the robot • Using Cubelets • Using recycled materials • Using other materials • Finding other types of Cubelets	• Citing authoritative discourse - Script of masculine aggression - Language of masculine codes - Language of feminine codes - Masculinized traits - Gender binary - Gender stereotypes • Appropriating authoritative discourse • Challenging/weakening the authoritative discourse • Performing scripts of caring • Performing scripts of accommodating

• Adding other types of Cubelets to the robot • Testing the movement of the Cubelets robot • Watching peers' robots • Naming the robot • Taking care of the robot • Engaging in pretend play with the robot • Designating roles to the robot • Talking with the robot • Hugging and stroking the robot • Following the robot • Crawling and walking with the robot • Blocking the robot with hands • Blocking the robot with blocks • Demonstrating the robot to others	• Performing feminine beauty • Performing scripts of battle/aggression • Positioning self as - an attractive peer - a competent robot builder/designer - a weaker counterpart - an accommodator - a powerful counterpart • Confronting the gender borderwork • Traversing the gender borderwork • Controlling masculine counterparts • Legitimizing her position • Enhancing her position • Maintaining her position
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Findings

In this section, I present Silvia's dramatic play with BeeBots and Lucia's robot designing and building in turn. In Silvia's case, I explain how the programmable robots (BeeBots) were constructed as masculine things. Juxtaposing the male BeeBots with female Silvia, I illustrate how Silvia performed her gender to position herself as an accommodating heroine. In the case of Lucia, I show how she performed her gender through designing and creating her robot which crossed the female and male binary. I describe how Lucia used gender tactics to legitimize her entry into the masculine peer group while affirming her femininity.

Robotic Manipulatives as Masculinize Things

BeeBots look like bees, with yellow and black stripes. Terrapin – the company that produced BeeBots – introduced BeeBots as child-friendly and easy-to-operate robots. Compared to more obviously gender-stereotyped toys (e.g., Disney princess dolls, Avengers toys), BeeBots seemed to be relatively gender-neutral materials for young children. Nevertheless, I observed

that Silvia designated the BeeBots as males in her storytelling. Vignette 4 presented at the opening of this chapter shows Silvia's dramatic play with and about BeeBots.

Interestingly, Silvia repeatedly referred to BeeBots as "he." Later, she assigned the other BeeBots to the roles of "son" and "papa" in her storytelling. Why did Silvia perceive BeeBots as males? She had not been taught that BeeBots were male in either the Summer Robotics Camp or the Saturday A. L. T. program. Nevertheless, Silvia maintained her perception of the BeeBots as males. Where did she gain this idea? Whose voices were presented here?

One possible factor might be Silvia's home language, which is Spanish. In Spanish every noun has a gender, and a robot is a masculine noun. When I first introduced BeeBots to the participating children in the Summer Robotics Camp, I taught them that the "BeeBot" was a compound word of "Bee" and "Bot." As a teacher of the robotics class, my intention was to emphasize that the BeeBot is a type of robot, not a bee-shaped doll. As a Spanish-English bilingual, Silvia might have been prone to assign genders to things around her and treat the bee-shaped programmable robots as males.

Another possible factor might be that Silvia cited the voice of the boys' group in the Summer Robotics Camp and the Saturday A. L. T. program. In Chapter 2, I presented that Carlos's BeeBot Battles were connected to boys' peer culture. As a participant in the two robotics education programs, Silvia watched how the boys played with the BeeBots. In addition, the boys frequently called their BeeBots "he" and never assigned a feminine noun to the BeeBots. In fact, many of these boys also were Spanish-English bilinguals. The masculine aspect of the boys' BeeBot Battles might have given Silvia the impression that BeeBots were masculine things.

However, I should note that both robotics programs were led by female teachers and researchers. Literally, there were no male adults. Even though the boys' group dominated the atmosphere of the BeeBot class with their masculine peer play, like the BeeBot Battles, the class and the two robotics programs were still under control by female adults. Thus, I think that the aforementioned two factors, albeit plausible, might not be the only aspects affecting Silvia's conceptualization of the BeeBots as males.

Drawing on Voloshinov's (1976) view on the doubling of meanings, Tobin (2000) suggested reading children's ambiguous and ambivalent utterances as the reflections of their social and cultural norms or beliefs rather than inconsistency and tension in their intrapsychic world. Similarly, I think Silvia's references to BeeBots as males could be read as the reflection of the norms and beliefs about gender in the larger society. Even though robots might not be ordinary materials in Silvia's everyday life, robots have been gaining popularity in society as an innovative technology for both industry and the domestic life (Rus, 2015). In particular, robots have been a popular and familiar theme in children's toys and media for a long time. Thus, I believe that Silvia not only appropriated her home language and male peers' perspectives on the BeeBots but also adopted the society's dominant perception and representation of robots as masculine things.

In contemporary media (e.g., films, TV, YouTube) and children's toys, robots have been depicted as embodying normative masculinity. When using the keyword "robots," I found the following images from the Google search:

They lacked facial expressions. They did not have breasts, long hair, or eyelashes. They did not wear clothes but had weapons, such as guns, a sword, a bomb, or a laser beam.

As programmable robots, BeeBots do not have cuddly bodies like Teddy bears (see Figure 19). The slightly shiny plastic body of the BeeBot feels firm and stiff. The texture and the body of BeeBots share some masculine traits with the images of robots in children's toys and contemporary media. Unlike the pastel colors used mostly for girls' toys (Kahlenberg & Hein, 2010), BeeBots wear bold colors (yellow, black, orange, blue, and green). These colors are a mixture of socially constructed boys' colors (blue, black) and girls' colors (yellow, orange) (Auster & Mansbach, 2012). Thus, the colors of BeeBots do not explicitly reveal masculinity. Rather, the gender of the BeeBots is more implicit. Nevertheless, Auster and Mansbach (2012) pointed out that supposedly gender-neutral colored toys are still perceived as masculine toys because they are "inoffensive to boys" (Schor, 2004, p. 210) and they do not demand boys to do gender crossing. Thus, a lack of explicitly feminine traits (e.g., a pink hair bow or sparkling jewelry) in the BeeBots could be read by Silvia (and the participating boys) as more masculine.



Figure 19. The appearance of BeeBots.

As seen in Figure 17 and Figure 18 above, most robot characters in children's films are characterized as heroic figures who could do a combat or a race with speedy and powerful actions, energetic vibes, and bravery (Boon, 2005). In Silvia's storytelling (see Vignette 4 again),

Silvia established a task for one BeeBot to push the long wooden block forward. She was convinced that the BeeBot could push it away, telling me that “he [the BeeBot] can get out” of the wood block obstructing its way. Silvia perceived the physical movement and speed of the BeeBot as force and appropriated those features as the main theme in her storytelling about the BeeBots.

Besides, the way the BeeBots were introduced and used in the two robotics education programs might have influenced Silvia’s perception of these programmable robots as male figures. BeeBots are not just robots but educational materials designed to help children engage in programming and learning about STEM concepts and practices. While participating in our robotics education programs, Silvia not only played with the BeeBots but also engaged with learning about command language and programming concepts and skills. Thus, these manipulatives delivered didactic messages to Silvia. Francis (2010) explained that children’s toys and resources holding didactic information, such as explicit educational concepts and skills relevant to science and technology, have been categorized as boys’ materials.

STEM in general and robotics in particular have been predominantly male fields (Beede et al., 2011; Glass et al., 2013). The images of robots are associated with the highly male-dominant professions. Mastering and controlling technology is regarded as a way of expressing masculinity (Van Oost, Oudshoorn, & Pinch, 2003). The taken-for-granted association of technological, logical, or intellectual competence with masculinity might echo in the process of engaging with BeeBots (Leathwood, 2013; Walkerdine, 1989).

In this section, I contextualized what was involved in Silvia’s designation of BeeBots as males. I suggested that her construction of BeeBots as masculine reflects the social and cultural contexts in which she was situated. Here, my intention is not to define the BeeBots as already

gendered materials. Even when external authoritative discourses influenced Silvia's perception of the BeeBots as males, there was still room left for her to negotiate the meanings of and relationships with these masculinized programmable robots. Drawing on Bakhtin's (1981) dialogism, I attempted to examine the ways in which Silvia's gender was performed and reconstructed in relation to the masculinized images of BeeBots. To this end, I analyzed Silvia's dramatic play in order to understand her gender performance (Butler, 1997) in relation to the BeeBots. In what follows, I present the finding of this analysis.

Silvia as an Accommodator

In Silvia's dramatic play with three BeeBots, her role as an accommodator for these programmable robots stood out as a main theme. According to Longman's dictionary, an *accommodator* refers to a person who (a) provides someone with a place to stay, live, or work, (b) accepts someone's opinions and tries to do what the person wants, and (c) gets used to a new situation. In the case of Silvia, she showed all these accommodating actions in her storytelling with the BeeBots. She built a road, a restaurant, and a store for the BeeBots by using recycled materials and different sizes and shapes of wooden blocks. She concentrated her efforts on creating a town-like environment for the BeeBots. When the BeeBots broke the entrance of a road, Silvia did not complain and rebuilt the road with different structures.

Accommodating actions have been discursively constructed as a stereotypical feminine trait, along with caring, mothering, and nurturing (Walkerdine, 2006). The accommodating actions as traditional female gender norms have been characterized as neglecting one's own concerns to satisfy others' concerns, seeking to harmonize with others, minimizing conflicts, or rejecting competition (Valentine, 2001). According to these traditional feminine roles and characteristics, women are often positioned as more passive, more subordinate, less confident,

and less competitive than males (Eckert & McConnell-Ginet, 2003; Roller, 2013). Jewkes and Morrell (2010) termed women's accommodating behavior as "acquiescent femininity" (p. 6). The caring and mothering ideologies were reflected in Silvia's stories. When I first observed her dramatic play with the BeeBots, her accommodating actions seemed to reflect her passive absorption of the authoritative gender norms. Following traditional gender roles, Silvia appeared to present herself as the normative feminine image in relation to the BeeBots.

However, reading Bakhtin (1981) led me to see Silvia's accommodating actions as something other than the passive mirroring of the authoritative gender discourse. According to Bakhtin:

An utterance is never just a reflection or an expression of something already existing and outside it that is given and final. It always creates something that never existed before, something absolutely new and unrepeatable, and, moreover, it always has some relation to value (the true, the good, the beautiful, and so forth). But something created is always created out of something given (language, an observed phenomenon of reality, an experienced feeling, the speaking subject himself, something finalized in his world view, and so forth). What is given is completely transformed in what is created. (p. 119-120)

From Bakhtin's point of view, Silvia's accommodating actions for the BeeBots could be read as her dialogic performance which allowed her to create and transform her gender position in her relationship with the masculinized robots. Tobin (2000) also suggested reading children's utterances (including verbal and non-verbal forms) about certain subjects "as not just an expression of their preexisting thoughts and feeling, but also positions that are being tried out and developed" (p. 19).

I noticed that Silvia's accommodating actions were based on the dynamic power relation between her and the BeeBots. In her storytelling about the BeeBot family going out to eat at a restaurant, Silvia designated a BeeBot in the role of a son: "This is the son!" (Video Transcript 10-04-2014). It was interesting here that Silvia positioned the BeeBot, first, as a boy. The son BeeBot was still a male but he was not too macho or strong for Silvia, a 4-year-old girl, to control. The son BeeBot still needed caring and help from the two parent BeeBots. The boy BeeBot was less of a threat to Silvia because of its small size and cute appearance. By designating the BeeBot as a boy, Silvia identified the BeeBot as a somewhat manageable and controllable counterpart. In the study of girls' video game play, Walkerdine (2006) noted that girls' selection of cute or cuddly male avatars repositioned the male avatars as less powerful than the girls. Silvia did not need to compete against the son BeeBot.

Yet, the dramatic moment occurred when the less powerful son BeeBot ruined and broke the road that Silvia had built for him. The following vignette shows how the son BeeBot challenged Silvia:

Vignette 6: Video Transcript 10-04-2014

- The Broken Road and a Rebuilt Trap.

Silvia gives several commands to the son BeeBot. The son BeeBot begins moving from the restaurant to the entrance of the road. At the entrance, the BeeBot suddenly changes its direction and hits a wooden block. The road is broken and the entrance falls down. I shout, "Uh-oh!" and say to Silvia, "You can build this road again."



Figure 20. The BeeBot (on the right side) breaks the road and the entrance made of wooden blocks.

Rather than rebuilding the road, Silvia gets the blocks used as the road and moves them near the restaurant. She says, “Let’s make it with more blocks. I can make... (inaudible) ... more ... I can make them ... (inaudible). Then, the BeeBot can pass ... because it is so harder!” While putting more blocks near the restaurant, she mumbles continuously, “I can make some more! The BeeBot can open it. I put ... [more blocks].” She finishes putting blocks together and mumbles, “This is a trap!”



Figure 21. Silvia moves blocks used as the road and puts them together to make a trap.

As shown in Vignette 6, at first, Silvia programmed the son BeeBot to move forward from the restaurant to the entrance of the road. However, the BeeBot moved out of Silvia’s control (programming). The son BeeBot deviated from the straight route and suddenly hit a wooden block. Although she gave a turning command (e.g., Right), Silvia did not pay attention to the turning movement of the BeeBot, which resulted in the broken road. The son BeeBot was

powerful enough to push the block and ruin the road (see Figure 20 again). With my encouragement, Silvia began to reconstruct the road but also change the road into a trap.

The trap that Silvia rebuilt was worth noticing. Initially, she had constructed the road for the BeeBot with several blocks by arranging the blocks in a thin line. After the road was broken by the son BeeBot, Silvia changed the road into a thick and heavy structure by putting the blocks together and layering them (see Figure 21 again). She built a stronger structure than the first road had been. Then, she named the structure a trap. Still, Silva was convinced that the BeeBot was able to pass the structure, mumbling, “He [the son BeeBot] can pass it” and “He [the son BeeBot] can open it.” Silvia seemed to accommodate the son BeeBot with a customized structure to suit the force of the BeeBot. Yet, the structure (the trap) had a challenging nature to control and limit the BeeBot.

In this scene, even though the son BeeBot demonstrated his power by destroying the road, Silvia maintained her control over the son BeeBot. While constructing a trap, Silvia used her scientific and mathematic competency as her power. She understood that the increasing numbers of blocks would increase the structure’s strength to endure the force of the son BeeBot. Applying this understanding, she built a structure that was stronger than the son BeeBot. She knew that she could control the son BeeBot by stopping him with heavier blocks. The thicker and heavier structure helped Silvia position herself as powerful.

At the end of her storytelling, Silvia created a stronger male character than the son BeeBot. At first, Silvia assigned two BeeBots placed out of the restaurant as parents, saying “They are going to be parents!” (Video Transcript 10-04-2014). When I ask her, “Then, who is a mother?” She answered, “This is the mother and this is the son,” pointing to one of the BeeBots. Yet, soon Silvia said, “I need more blocks. I need a lot of blocks! Papa can open this!” She chose

to assign a male adult (daddy) role to the other BeeBot, saying, “It’s papa!” (Video Transcript 10-04-2014). Her focus changed from the son BeeBot to the daddy BeeBot. Because the son BeeBot was constrained by the trap, she assigned a stronger male character to the other BeeBot. Compared to the boy, the daddy was, at least symbolically, a stronger and less constrained male. The daddy BeeBot as an adult male might represent as more of a risk to deal with for Silvia, a young girl.

However, Silvia confronted the daddy BeeBot by changing the trap into an expanded restaurant. She used available materials (e.g., blocks, tape, and a string) to build the extended restaurant and continued to position herself as a stronger counterpart of the daddy BeeBot (see Figure 22). She mumbled “I need a rope [string]! I need a tape!” (Video Transcript 10-04-2014) several times while building the restaurant. As much as the power of the BeeBot was increased, Silvia increased the number of the blocks. She added a string and pieces of tape to make the extended restaurant as sturdy and strong as she could. Once again, Silvia used her mathematical skills (e.g., counting, numbering) and scientific understanding of force in connection with the number of the blocks. By doing so, she materialized her strength through the extended restaurant.



Figure 22. Silvia builds an extended restaurant in front of two parent BeeBots.

Through her dramatic play, Silvia also had the opportunity to perform the role of a rescuer or a savior for the son BeeBot. Vignette 7 describes how Silvia helped the son BeeBot to move out of the trap.

Vignette 7: Video Transcript 10-04-2014

- The Rescue of the Son BeeBot

The son BeeBot is still inside the restaurant. Silvia still leaves the trap in front of the restaurant. Silvia gives several commands to the son BeeBot placed inside the restaurant. As the son BeeBot starts moving, she shouts out, “Play!” Yet, because of the layered blocks (the trap), the BeeBot cannot go forward. Silvia quickly removes some blocks with her hands. The BeeBot still cannot push the blocks. She takes away the remaining blocks in front of the son BeeBot, and the son BeeBot can get out of the restaurant.



Figure 23. Silvia helps the son BeeBot (the one in front of her) to move out.

Silvia pushes the Go command once more. The son BeeBot goes straight. With her hand, Silvia changes the direction of the son BeeBot. Then, the son BeeBot moves toward the other two BeeBots that Silvia designates as the parents. She follows the son BeeBot and supports the backside of it with her hand. Finally, the son BeeBot meets the parents.



Figure 24. Silvia takes the son BeeBot (in her hand) to the parent BeeBots (placed at the corner of the road).

In the above Vignette 7, Silvia demonstrated an ambivalent attitude toward the son BeeBot. In Vignette 6, she built the trap in front of the son BeeBot. Yet, in Vignette 7, she still helped and took care of the son BeeBot. Although she programmed the son BeeBot to move forward and push the blocks, she knew that the son BeeBot could neither push the trap nor get out of it. She had to help the son BeeBot move out of the heavy trap by taking away the remaining blocks in front of him with her hand (see Figure 23 again). She carefully looked after the son BeeBot by escorting him to make sure that the son BeeBot could meet the parent BeeBots. Rebuilding the trap, Silvia was able to challenge the force of the son BeeBot. At the same time, while saving the son BeeBot from the heavy trap, she performed again the role of an accommodator without losing her control over the son BeeBot.

In addition, Silvia tested and constructed her powerful position by controlling and constraining the male BeeBot. She used a thicker and heavier structure to trap the son BeeBot. Again, as presented in Vignette 4, Silvia repeated, “Lock... lock... because he can get out. . . . Lock! He is locked!” several times (see Figure 15 again). When the son BeeBot seemed to escape from the thicker and heavier structure, Silvia input more Forward commands to make the

BeeBot push the structures. However, when she determined that the son BeeBot could not leave the space that Silvia created with the blocks, she seemed to be satisfied with that fact.

Trapping the son BeeBot could be interpreted as Silvia's exercise of feminine power over males who tried to roam and get away. In his research, *Inner and Outer Space: Reflection on Womanhood*, Erik Erikson (1964) discussed how girls tended to build blocks for enclosures while boys built blocks for thrusting themselves forward. From this psychoanalytic perspective, Silvia seemed satisfied with keeping the male BeeBot inside and under her control as opposed to making it march on the road.

Silvia's performance as both an accommodator and a savior was her way to maintain her control over the son BeeBot and emasculate the male BeeBot. Both roles positioned her as a powerful heroine. In children's cartoons and films, such as the American science fiction action film, *The Transformers*, robots themselves are depicted as hero characters who preserve the peace in the world. In such films, oftentimes it is a boy or a male adult who invents hero robots and operates them from behind or inside of the robots. In children's popular culture, girls are rarely portrayed in the heroine position (Ryan, 2010). Instead, female characters usually play supporting and cooperating roles for the male heroes (Van Zoonen, 1994). However, through her role as an accommodator, Silvia inverted the status of male heroes (the BeeBots). In her interaction with the son BeeBot, Silvia became a heroine protagonist who helped and saved him.

Performing Gender through Designing and Building a Robot

Lucia was deeply engaged in designing and decorating her robot, which had some feminine traits of appearance. On the 9th day of the Summer Robotics Camp, she and Carlos (a 6-year-old boy) worked together to build their robots in the Cubelets class. While Carlos spent most of his time testing and rebuilding his robot by using only Cubelets, Lucia spent the entire

time designing and decorating her robot with girly features. In Lucia's original plan, she designed a butterfly robot. The butterfly robot had four rainbow wings. Lucia was interested more in the appearance of her robot than in its actions and role. When EJ, one of our research team members who led the Cubelets class, asked Lucia what her robot could do, she explained that the butterfly robot could fly, smell, and walk. However, when she found recycled boxes in the room by chance, she changed her plan. She got excited to be able to build her robot by using the recycled materials. She decided to use a small box as her robot's head and a big box as the robot's body. After connecting two boxes, she began to decorate her robot.

First, Lucia put two eyes on her robot's face. She wanted to make big eyes for her robot. She tried to draw circles on the paper, mumbling, "Oh, it (a circle she drew) looks something [like] a big eye." She continued to draw circles, saying, "bigger eye... bigger eye..." (Video Transcript 6-12-2014). In the end, she cut a kitchen towel tube and used two big circular pieces for the eyes. Then, she said to herself, "I need hairs. I need long hairs. I need to use this... this... this...(yarn balls). I need to use them." (Video Transcript 6-12-2014). She made a lot of effort to cut the yarn and choose the hair style of her robot. She tried to tie the robot's hair with bows. She was very skillful and careful to tie the bows (see Figure 25.1). When she found a basket filled with colorful pompoms, she picked up pink and purple pompoms. Then, she said delightedly, "I need to use these for his³ cheeks!" (see Figure 25.2).

³ Lucia uses male pronouns to refer to her female robot, Juliana, frequently referring to it with "he" or "his." Just as with Silvia, it can be understood that Lucia – as a Latina – might have been prone to assign her robot the male gender due to the influence of the Spanish language.



Figure 25.1. Lucia ties her robot's long hair with two bows.



Figure 25.2. Lucia selects pink and purple pompoms as cheeks for her robot.

In particular, Lucia wanted to make “a girl’s mouth” (Video Transcript 6-12-2014) for her robot. She attempted to make the mouth by drawing it on the paper and cutting the part. However, she had difficulty in making the shape of the mouth in the way she wanted it to be. Lucia asked help from EJ, saying, “I don’t know how to draw a mouth ... a girl’s mouth!” (Video Transcript 6-12-2014). EJ talked with Lucia to find out what a “girl’s mouth” meant for her. Lucia selected smiling lips from several shapes of mouths that EJ drew on the paper for her.

Through these processes, Lucia’s robot had big eyes, long hair with bows, rosy cheeks, and a smiling mouth. Thus, the robot had some traits associated with stereotypical feminine beauty. Also, Lucia gave the robot a feminine name, Juliana. Nevertheless, it is worth noticing that Lucia’s robot was not hyper-feminine. As shown in Figure 26, Lucia designed the face of her robot as feminine but not the body.

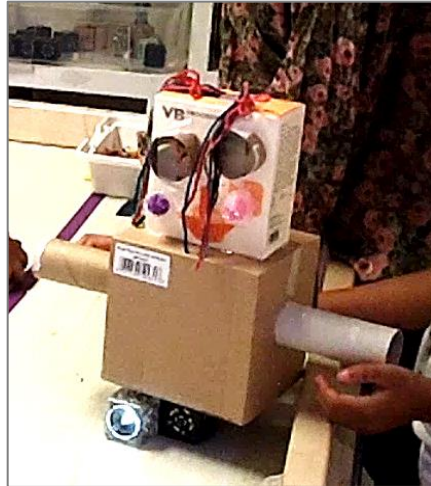


Figure 26. The face and body of Lucia's robot.

The body of Lucia's robot was made of a box and thus had a square shape. Lucia did not make any effort to add curvy elements or decorative clothes, which are traditionally associated with feminine bodies (Murnen, Greenfield, Younger, & Boyd, 2016). Thus, Lucia's robot had a somewhat ambiguous appearance: a feminine face and a less feminine body. The Juliana robot had a hybrid appearance. The cube box used for the robot's body part made the robot appear to be gender-neutral. In this way, Lucia designated her robot as neither female nor male. She kept her robot in between female and male identities.

However, Lucia faced a challenge of the status of her robot. Vignette 8 describes a situation that happened on the 8th day of the Summer Robotics Camp. On that day, the Cubelets class was divided into two small groups, and each group discussed what individual robot design project each child would be engaged in. Lucia and Carlos were assigned to the same group. EJ – the teacher of the Cubelets class – helped these children brainstorm and plan what kinds of robots they wanted to design and build with the Cubelets. After planning, Lucia and Carlos began to build their robots.

Vignette 8: Video Transcript 6-12-2014

- Baby Robot versus Moving Robot

Lucia pays attention to building her robot with a small box and a big box. With EJ's help, she tries to connect the small box with the big box. Sitting next to them, Carlos builds his robot only with Cubelets. Lucia decorates the face of her robot with art and craft materials (e.g., strings, pompoms, and colored papers). Then, she finds that one of her robot's eyes is slightly askew.

Lucia: (looking at the face of her robot) Uh? He is crying?

EJ: (laughing) Hahahaha

Lucia: (slightly changing her voice in a gentle tone) He is crying. Oh... he is crying.

EJ: (laughing) Hahahaha (giving her a piece of tape) No, you can do it this way (fixing the eye with the tape).

Lucia: (looking at her robot while hugging it) Were you crying, my little mini robot?

Carlos: Don't worry about your robot.

Lucia: (smiling and showing it to Carlos) This is my robot!

Carlos: (in a mocking tone) That's your baby robot?

Lucia: (not responding to Carlos, she stops smiling and then looks at EJ)

EJ: No, it's not a baby. This robot has a big body and [a] big head!

Lucia: He is going to move! We are going to put something here (pointing to the bottom of her robot). (Asking to EJ) Can we put some wheels [Drive Actor Cubelets] right here? Um... Four wheels! Where is my... (finding her engineer log and checking how she had planned her robot design). Oh, I needed two wheels. But, I need four wheels!



Figure 27. Carlos and Lucia talk about Lucia's robot.

As shown, while building her robot, Lucia had a short pretend play with her robot. She changed her voice to a soft and gentle tone. She also called her robot her "little mini robot"

during the play. As in a doll play situation, she pretended to worry about her crying little mini robot. In this play, she cited the embodied practice of caring for a baby and the script of motherhood by changing her tone and by giving her robot a hug (Blakemore & Centers, 2005). She showed a sympathetic and intimate attitude toward her robot. During her robot designing process, Lucia frequently showed emotional attitudes toward her robot by hugging and stroking it. When she broke some parts of the robot by mistake, she would say, “I am sorry. I am sorry, my robot” (Video Transcript 6-13-2014).

At first, Carlos seemed to sympathize with Lucia and join the dramatic play, saying, “Don’t worry about your robot.” However, through his mocking tone and calling Lucia’s robot a “baby robot,” he positioned Lucia’s robot as being passive, fragile, and weak and as needing protection. Although Lucia also called her robot her “little mini robot,” it was a way to express her personal affection for her robot (Madrid & Kantor, 2009) rather than ridiculing her creation. Playing the role of a caregiver, she also seemed to enjoy having control over her robot in a soft and gentle manner. Yet, Carlos undermined the script of caring in Lucia’s gendered pretend play by weakening the status of her robot. Moreover, Carlos’s designation of Lucia’s robot as a baby not only disrupted Lucia’s gendered pretend play but also imposed a masculine script on it. Later, when Carlos and Lucia tested their robots, Carlos said, “My robot is so strong. He can pick up something heavier than ... Look! Maybe he can pick up your robot!” (Video Transcript 6-13-2014). Citing the authoritative masculine discourse on strength and power, Carlos changed Lucia’s script of caring into his script of a competition and battle.

Thus, the authoritative discourses on normative femininity and masculinity challenged Lucia and her robot. Then, how did Lucia deal with these authoritative discourses through her

robot design? In the following section, I describe the gender tactics that Lucia used to maintain her and her robot's empowered position and to gain entry into the boys' peer group.

Lucia's Gender Tactics

As indicated at the end of Vignette 8, Lucia used Drive Actor Cubelets to affirm her robot as an empowered agent. Drive Actor Cubelets are a type of actor which contains a motor and roller wheels. If the Drive Actor Cubelet is connected to a Sensor Cubelet and a battery, this set of Cubelets can move in one direction. Since the first day of the Summer Robotics Camp, Lucia, like many participating children, had showed consistent interest in the Drive Actor Cubelets that she called "wheels."

In designing and building her robot, the "wheel" was a repeated and salient theme for Lucia. Whenever she talked with EJ and explained about her robot, she emphasized, "My robot can move to anywhere. The wheels help Juliana [the name of the robot] to continuously walk." (Video Transcript 6-13-2014). Lucia's drawing of a robot revealed her particular attention to the wheel. The research team asked the participating children to draw their images of robots on the last day of the Summer Robotics Camp. As Figure 28 shows, Lucia drew the same robot that she built and called it the same name, Juliana. Her Juliana robot in the drawing had many wheels on the chest and on the bottom of it. When Carlos and Lucia discussed what robots they wanted to build (Video Transcript 6-12-2014), Carlos shared his idea to make his robot go continuously even after the robot fell down. Lucia liked his idea and suggested that he and EJ put wheels on the back, front chest, legs, and arms of their robots. In her drawing, Lucia cited Carlos's ideas and referred to their conversation. Lucia explained that the wheels on the chest were to make her robot go continuously even after the robot fell down.



Figure 28. Lucia draws a robot with many wheels.

The fact that her robot could “move” and “walk” was an important feature for Lucia. In connection to transportation, wheels are a popular and attractive topic that young children tend to like in their play, songs, books, and media. According to Ruckenstein (2010), the mobility of wheels symbolizes a sense of physical autonomy and interaction with the wider world for young children. Wheels were not a mere mechanical part of a robot for Lucia. Instead, adding wheels (Drive Actor Cubelets) was a way to empower her robot through its mobility, a feature admired by many of the participating children in our robotics education programs.

Mobility is the ability to move and go. Explaining the gendered aspect of wheels and mobility, Morgan (2009) explained that the car was once a symbol of modern American masculinity which put females in the subordinate position. By gaining mobility, females have broadened the scope of their participation in daily activities and expanded their domestic space into the public space (Law, 1999). Therefore, historically, mobility has been a means of shifting the power relationship between males and females (Hanson, 2010).

Adding wheels (Drive Actor Cubelets) and mobility, Lucia expanded the capability of her robot. Again, as Vignette 8 described, Carlos denigrated her robot as a baby and Lucia as a

normative female caregiver. In doing so, he appropriated the authoritative discourse on the active masculine and passive feminine binary (Fine, 2012).

EJ, as an adult female teacher, tried to help Lucia by mentioning that Lucia's robot had a big face and body. EJ focused on the size, but Lucia emphasized mobility to defend her robot against Carlos's mocking. She tried to increase the number of Drive Actor Cubelets necessary for her robot. The increased number of wheels implied increased mobility. Lucia challenged Carlos by asserting that her robot had mobility, which symbolized autonomy, capability, and power. In this way, Lucia was able to shift her robot and herself from the position of subordinate little females (i.e., a girl and a baby) to that of empowered heroines (i.e., a robot with mobility and a robotics engineer).

Interestingly, Lucia appropriated masculine norms to legitimize her entry into the boys' peer group. Throughout the Summer Robotics Camp, Lucia attempted to join the boys' peer group. Carlos and Samuel were the key members of the boys' group and led their peer group play. The close relationship between Carlos and Samuel (a 7-year-old Latino) consolidated their leadership position among the boys. Lucia seemed to like playing with them and got along with them. For example, she used to sit near the two boys during snack time. She tried to have a talk with the two boys. Sometimes, Lucia mimicked Carlos's funny behavior (e.g., spinning the snack plate, making funny grimaces). By adopting masculine humor and behavior, she tried to join the boys' group (see Figure 29.1 and 29.2). On the other hand, Lucia did not seem to make much effort to join the girls' group.



Figure 29.1. Lucia tries to have a talk with Samuel (the first boy from the left)



Figure 29.2. Lucia mimics Carlos (the second boy from the left) by spinning the snack plate.

One possible reason for Lucia's preference for the boys' group might have to do with age. In the Summer Robotics Camp, a total of five girls including Lucia participated. Lucia and two other girls were 5 years old and Silvia and the other girl were 4 years old. The other 5-year-old girls actively participated in the classes. Yet, they tended to enjoy playing alone or playing with the 4-year-old girls. In her relationship with the other girls, Lucia tended to help the four-year-old girls during free-play time or during classes. Meanwhile, she seemed to consider 6-year-old Carlos and 7-year-old Samuel her play partners. In particular, Lucia, Carlos, and Samuel lived close to one another.

The other possible reason for her preference might be Carlos's and Samuel's performance in the robotics classes. Other girls tended to enjoy pretend play with BeeBots in much the same way as doll play. They also engaged in block play with Cubelets rather than completing the given tasks (e.g., doing experiments to learn about different types of Cubelets). On the contrary, Carlos and Samuel collaborated to program BeeBots and explore different types of Cubelets. Most of all, both boys were good at programming BeeBots to make them successfully go along difficult routes and grids. The boys were also creative in building Cubelets robots with different shapes and functions. Lucia enjoyed seeing the Cubelets robots the boys built. Adults'

compliments and positive responses to these boys' work might have made them stand out as well. Thus, Carlos and Samuel looked more attractive as playmates for Lucia than other girls.

However, gaining entry into the boys' group was not easy for Lucia. Carlos and Samuel tended to demarcate the gender boundary between them and Lucia. For example, Lucia frequently joined a Lego play corner which was usually occupied by boys (see Figure 30). Although there was a 5-year-old girl, Iliana, Lucia and Iliana did not interact at all. While boys discussed building cars with Lego wheels, Lucia did not directly speak to the boys. She silently watched what and how Carlos and Samuel built with Lego wheels and listened to what they said to each other. Like parallel play, she built her Lego car with the same wheels while staying close to the boys. It was a very tactful way for her to figure out what they liked.



Figure 30. Lucia (in the light blue sleeveless shirt) plays in the Lego play corner.

At times, Lucia attempted to directly engage in the boys' play, but this did not lead to her successful entry. For example, Carlos boasted that he found a bigger Lego wheel than others had. He showed it to Samuel, but not to Lucia, who was sitting close to them. Samuel also wanted to have the same size of wheel. Lucia did not seem to listen to their talk because she appeared to focus on building her own Lego car. However, Lucia rummaged through the block box and

found a Lego car with several wheels. The car had many wheels, but the wheels were smaller than Carlos's wheel. Lucia gave the car to Samuel. Samuel neither said anything to her nor received it from her. Lucia still stretched out her hand with the car to Samuel and waited for his response. Samuel rejected it by shaking his head and say, "No." The same pattern of interactions was observable in the Cubelets class. While Carlos built his Cubelets robot, Lucia tried to give him some suggestions to improve it. Yet, Carlos did not pay attention to what Lucia suggested. Although he rejected Lucia's ideas, Carlos showed his robot to Samuel and had active conversations with him about the parts of his robot.

The relationship between Lucia and the two boys was relevant to Thorne's (1993) notion of "borderwork" (p. 65). Thorne defined borderwork as moments and activities in which gender boundaries between boys and girls are activated and strengthened. Carlos and Samuel seemed to consider building with Cubelets and Lego blocks as boys' activities. Not allowing Lucia to join their group, the boys tried to consolidate the boundary between boys and girls and mark robot and Lego building as masculine practices. The external authoritative gender discourse (e.g., "robots/engineering/wheels are for boys") was echoed in the boys' borderwork.

Nevertheless, Lucia was able to eventually gain entry to the boys' peer engagement by appropriating the masculine modes of battle/combat/competition. Vignette 9 shows how Lucia appropriated a masculine practice to engage her robot with Carlos's robot. This tactic worked to make Carlos loosen the gender boundary.

Vignette 9: Video Transcript 6-13-2014

- Lucia's Robot Beats Carlos's Robot

Lucia and Carlos stand at a rectangular table placed in the Cubelets class. They assemble Cubelets to build their robots. They test their robots to make them move in the way they desire. Just then, Lucia's robot moves toward Carlos's robot and hits it by accident.

Lucia: (laughing and pointing to the robots) Hahahahah . . .

Carlos: Move your robot!

Lucia: (laughing) Hahahah. I broke yours! I broke yours!

Lucia gets her robot back and puts it on the table again. Then, she deliberately changes the direction of her robot to make it move toward Carlos's robot again. Lucia's robot goes toward Carlos's.

Lucia: I know I broke yours! I broke yours! Yeah, I know I broke yours!



Figure 31. Lucia's robot hits Carlos' robot.

Carlos holds his robot with his hands and makes it face Lucia's robot. The two robots face each other. Lucia does not put her hand above the Distance Sensor, which is placed on the bottom her robot. So, Lucia's robot stands still. As soon as Carlos puts his hand above the Distance Sensor, his robot begins moving toward Lucia's robot. Lucia and Carlos observe their robots. Carlos's robot tries to move but cannot move forward because Lucia's robot blocks it.



Figure 32. Carlos and Lucia watch their robots' battle.

Lucia: (laughing) Hahahahah. (pointing to the two robots) What the heck!

Carlos: (not smiling but taking his robot back) Do my robot again.

Carlos rebuilds his robot with Cubelets. Lucia repeats making her robot move forward on the table.

Carlos: (mumbling) I need to make my own... other robot that is hard to be destroyed by him [Lucia's robot].

Lucia: I destroy him [Carlos' robot]?

Carlos: (looking at and smiling at her) Yes! Yours destroyed him [my robot].

Lucia smiles at Carlos. She suddenly picks up her robot with her hands and puts it close to Carlo's robot.

Carlos: No!

Lucia: (holding her robot with her hands) Let's do it again!

Carlos: Noooh!

When Carlos and Samuel played together, they seemed to share implicit masculine rules and norms, such as playing together but competing and doing something that is enjoyable but challenging. Until she adopted these rules and norms, Lucia had difficulty in being accepted as a member of the boys' peer group. Lucia preferred to perform the script of caring with her robot. In her relationship with the boys, she also used the script of helping (e.g., finding the Lego car for Samuel, giving suggestions to improve Carlos's robot). Yet, these traditional feminine scripts did not help her gain entry into the boys' play.

However, in Vignette 9, Lucia appropriated the script of battle and the mode of aggression. Lucia's appropriation of the masculine script could be understood as her gendered tactic. She used the masculine script for her own purposes. Although the battle between her robot and Carlos's robot happened by chance, Lucia realized that attacking Carlos's robot with her robot could give her a chance to engage in play with Carlos. She used the language of aggression, "I broke yours," and adopted the mocking attitude. She succeeded in making Carlos respond to her robot and involve her in the robot battle, a masculine mode of engagement. After this moment, Carlos repeatedly asked Lucia to have rematches between their robots.

Lucia's tactic was successful and allowed her to engage with the other boy, Samuel, as well. Vignette 10 describes how Lucia appropriated the masculine practice and language of the battle in her attempt to interact with Samuel.

Vignette 10: Video Transcript 6-13-2014

- Samuel's robot

Samuel is in a BeeBot group for the robot project. Samuel finishes having his snack earlier than others in his group. The Cubelets class is still on going. Samuel visits the Cubelets class. He can have some free time to build his own Cubelets robot. Carlos shows the Cubelets robot he built to Samuel. Samuel wants to build his own Cubelets robot. He builds his Cubelets robot with a design similar to Carlos' robot (e.g., with Lego arms to sweep away stuff on the table). Carlos's and Samuel's robots do a battle. Carlos operates his Cubelets robot to push Samuel's. They observe the battle. Carlos's robot is bigger and stronger than Samuel's robot, and it can push Samuel's robot back.



Figure 33. Samuel (in the black shirt) and Carlos (in the yellow and white striped shirt) observe their Cubelets robots' battle.

Soon, Carlos goes to have a snack, and Samuel is left alone in the room. Although Lucia's robot stands near him, Samuel does not ask any questions about it. In fact, he does not pay attention to it. Instead, Samuel just builds and rebuilds his Cubelets robot. After finishing her snack, Lucia comes back to the Cubelets room. Picking up her robot, Lucia stands opposite Samuel. Samuel does not pay attention to her. Then, Lucia turns on the battery of her robot and places it on the table. Lucia's robot rushes toward Samuel's robot.

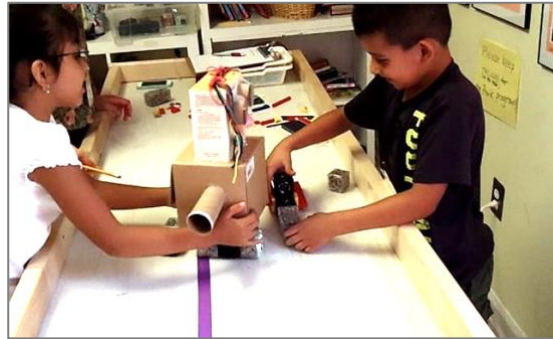


Figure 34. Lucia's robot rushes toward Samuel's robot and Lucia holds her robot with her hand.

Lucia: Hey! Hey! (holding her robot with her hands) Why does this robot [her robot] every time destroy the robots ... like Carlos's robot, right (looking at EJ and smiling)?

Samuel: (looking at Lucia) Did that robot (pointing to Lucia's robot) destroy Carlos's robot (pointing to it)?

Lucia: Yes! (still holding her robot with her hands)

Samuel: (looking at EJ)

EJ: (smiling and nodding her head)

Samuel: Then, did he (pointing to Ruben's robot) do the battle again?

Lucia: (smiling at him)

Soon, Samuel rebuilds his robot and fixes some parts of it. Then, he calls Lucia and shows his Cubelets robot to her. Lucia holds it with her hands and examines it. Lucia and Samuel fix the detached parts of his robot together.



Figure 35.1. Samuel shows his robot to Lucia.



Figure 35.2. Samuel and Lucia build some parts of Samuel's robot together.

In this vignette, Samuel again performed his borderwork, initially doing battle only with Carlos's robot. He did not show any interest in Lucia's robot, which looked like a girly robot. Yet, Lucia appropriated the masculine code of battle again to draw Samuel's attention. By using the aggressive masculine term "destroy," Lucia communicated that her robot was strong enough to beat Carlos's robot. Whose robot beat whose was important for Samuel. Designating her robot as a winner against Carlos's robot, Lucia positioned herself as a capable robot builder and a competitive battle player. Ultimately, her tactic worked in that it not only allowed Lucia to engage with Samuel but also encouraged Samuel to solicit and accept Lucia's help to fix his robot. By appropriating the masculine code of aggression, Lucia traversed the gender binary (Fine, 2012). Through this tactic, she was able to gain an advantage and achieve her goal of engaging with the boys in their robotics activities.

Yet, it should be noted that Lucia adopted the masculine discourse only at the surface level. Although she appropriated the authoritative gender discourse, which challenged her femininity, she did not blindly accept this discourse and limit her femininity within the masculine scripts. Drawing on de Certeau's (1984) notion of tactics, Oh (2013) explained that

one of the features of children's tactics is their creative and cunning ways of using the dominant rules and norms as resources for their own advantage. Lucia recognized the masculine norms of battle and aggression as resources which would help her gain entry into the boys' peer group and play. As described in Vignette 9, after her robot beat Carlos's, Lucia used the masculine code of aggression and pretended to attack Carlos's robot with her robot once again. Although she moved her robot close to Carlos's and suggested doing the battle again, she held her robot in her hands all the time in order to avoid hitting Carlos's robot. Similarly, in Vignette 10, she stopped her robot with her hands before it hit Samuel's robot. She then verbally presented how her robot "destroys" other robots, including Carlos's. Hearing this claim with EJ's agreement, which was expressed through her gesture, was enough for Samuel. In these scenes, Lucia took playful forms of threat and aggression as a means of positioning herself as a strong robot builder and as a competitive battle player while loosening the gender binary to engage with the boys' play.

Discussion

This study examined gender discourses involved in two bilingual (Spanish-English) girls' engagement with robotic manipulatives and how the girls negotiated those discourses while performing their gender. The case of a 5-year-old girl, Silvia, showed us how she perceived the programmable robots as masculine things. Through her pretend play and storytelling with BeeBots, we can see how Silvia negotiated the masculinized meanings of the robots and positioned herself as a heroine accommodator. Meanwhile, the case of a 6-year-old girl, Lucia, presented how her femininity was challenged by the authoritative gender binary and masculine discourses in the process of designing and building her robot. Lucia's case also showed us how she used gender tactics by appropriating masculine rules and language to legitimize her entry

into the boys' play and to affirm herself as a competent robot builder. Based on these findings, I discuss three implications for early childhood robotics education next.

First, the findings of this chapter depict a bigger picture of young children's engagement with robotic manipulatives. Our research team had intended to have the participating children experience robot design and learn about programming robots through our project. However, Silvia and Lucia explored broader topics than what our team had aimed at by bringing their own issues related to their gender, families, peers, media, toys, power, and identities into our robotics education programs. Engaging with the robotic manipulatives, the girls grappled with these topics and questions related to their lives in the world to which they belonged. This chapter shows that BeeBots and Cubelets lend themselves to these topics. However, this is an area that has not been well recognized in the discussion about the educational value of robotic manipulatives. Instead of limiting their usefulness only to STEM-related concepts and skills, a more holistic approach to these materials may well help create the pedagogical space in which young children can explore issues important to their lives inside and outside the classroom.

Second, this chapter suggests recognizing the ideologically complex process young girls have to go through as they enter robotics or other STEM-related fields. The findings of this chapter showed that Silvia and Lucia were capable of programming, designing, and building their robots. Nevertheless, the girls had to deal with the complicated and competing contexts where the authoritative and masculine-dominant norms and gender binary challenged their feminine positions. Empowering women through their increased participation in STEM-related disciplines and careers has been a persistent and important issue (Chesky & Goldstein, 2016; National Research Council, 2014; National Science Foundation, 2003). Robotics education has gained growing attention as a way to encourage an early exposure and an attractive entry to the

field of STEM, in particular for girls (Sullivan, 2016; MacDowell, 2015). However, Silvia's and Lucia's cases showed the need to understand the ideological and discursive challenges girls face in robotics and STEM-related fields as we try to broaden their participation (Grossman & Porche, 2014; Shapiro & William, 2011). Without careful attention to and support for the process of negotiating authoritative gender discourses and practices, I argue, early exposure to and ample experiences with robotics in themselves cannot sustain young girls' interest in STEM or ensure young girls' empowerment in STEM-related areas.

Finally, the findings of this study help us see how young children's engagement with robotic manipulatives can be a way for them to express their voices and identities. In her book *Coding as Playground*, Bers (2017) argued that the fundamental value of robot programming is in its expressive nature. Libman's (2011) study also demonstrated that Jewish children's engagement with robotics was a way for them to express their identity. In our robotics education programs, we provided the children with different types of activities (e.g., programming robots, designing and building robots, creating robot stories, drawing robots) that helped create a space for the two girls to express their femininity while negotiating with the authoritative gender discourses. Through a storytelling about the BeeBot family in her pretend play, Silvia expressed herself as a feminine figure with power and control over the BeeBots. In addition, by incorporating art and craft activities with Cubelets robot building, Lucia expressed her version of femininity and affirmed herself as a competent female robot builder. Rusk, Resnick, Berg, and Pezalla-Granlund (2007) recommended focusing on themes, combining arts, and encouraging storytelling rather than using challenges and competitions as pedagogical strategies for embracing a broad range of learners in robotics education. This chapter also shows that the robot projects allow girls to freely navigate and express different ranges of and forms of femininity. I

argue that we need to critically examine whether the existing approaches (e.g., challenge- and competition-based approaches) have privileged certain groups of children while marginalizing the interests, prior knowledge, and ordinary experiences of other children, including girls.

CHAPTER 4

A YOUNG CHILD'S HANDS-ON INQUIRY WITH/ABOUT ROBOTIC MANIPULATIVES

Introduction

Vignette 11: Video Transcript 9-20-2014

It is the 4th day of the Saturday A.L.T program. Keon entered the Cubelets class. Three girls have already begun freely exploring Cubelets on a big board. EJ – the main teacher of the Cubelets class – sits near the children and facilitates their activities. All children in the Saturday program can choose what they want to do with the Cubelets. When EJ sees Keon, she gives him a battery, an Distance Sensor, and a Light Actor. Keon connects them and put his hands above the Distance Sensor. The Light Actor shines its light.

Keon: (asking EJ) Hey, I need another car [a Drive Actor]! Another car (pointing to the box of Cubelets)!

EJ gives a Drive Actor to Keon. Keon assembles the Cubelets and puts them on the white board. When Keon puts his hand above the Distance Sensor, the Cubelets assembly begins turning around on the board, while emitting light.

Keon: (asking EJ again) Can I get another one [a Drive Actor], please? (showing the Drive Actor to EJ)

EJ: Doesn't it work?

Keon: No, it does. But, I need another one [a Drive Actor]. I need two [Drive Actors].

EJ gives one more Drive Actor to Keon. Keon puts all the Cubelets (a battery, an Distance Sensor, a Light Actor, and two Drive Actors) together. Keon puts his hands near the Distance Sensor again. Yet, the Cubelets do not emit light or move.

Keon: [My Cubelets are] not working!

EJ: Where is the sensor? The eyes... Do you have it? Did you turn on the switch of the battery? Check the green light of the battery.

Keon: Switch... (looking at the battery)

EJ: Check the green light [of the battery].

Keon: (turning the battery on) Oh, yes. Battery! (putting the Cubelets on the board and watching the Cubelets spinning around and around) Why is it going in a circle? (rebuilding the Cubelets in a row, putting them on the board again, and seeing that

the Cubelets are not moving straight) The sensor is not moving! My one is not working!
 EJ: Okay (taking the battery from his hand and looking at it)
 Keon: (pretending to play a monologue) So painful.... (making an exaggerated voice) Sensor is my hero!
 EJ: Why are you so painful? (replacing the battery with a new battery and connecting it to the other Cubelets) Look! (showing Keon that the Light Actor is shining)

Keon takes the Cubelets from EJ and connects all the Cubelets. Keon puts his hands above the Light Sensor. The Cubelets move and shine.

Keon: It works! (Cubelets are moving straight) My sweetie! My sensor! (shouting) My sensor is alive! It is alive!



Figure 36. The teacher and Keon have a conversation about the Cubelets.

The above vignette illustrates the initial moment of Keon's inquiry about Cubelets. While touching and assembling the Cubelets by himself and putting his hands above the Cubelets, Keon seemed to actively engaged in an open scientific/engineering inquiry. Keon's direct experience with and his manipulation of the Cubelets seemed to engage him in generating questions, doing investigations, making observations, and interpreting his observations.

Based on the tradition of constructivism (Piaget, 1973), hands-on activities are regarded as a fundamental teaching approach because young learners construct understanding and knowledge through directly interacting with things, rather than just passively hearing lectures (McComas, 2014). From the perspective of scientific inquiry, hands-on activities can be employed to support learners effectively in identifying problems, generating questions, designing

investigations, making and recording observations, interpreting data, creating explanations, and developing models and arguments (Crawford, 2016, 2014).

Many studies have argued that hands-on activities can effectively support young children's science learning (Antle, Droumeva, & Ha, 2009; Gerstner, & Bogner, 2011; Leung, 2008; Satterthwait, 2010). However, there is little research examining what specific aspects of hands-on experiences allow children to engage in scientific learning. Swarat, Ortony, and Revelle (2012) revealed that the form of the learning activity students engaged in made a difference in students' affective reactions toward science and willingness to engage in science learning. Their study stressed that students focused on the forms of activities rather than the topics or learning goals of the class. In particular, students preferred hands-on activities that involved using and directly manipulating physical objects. The researchers suggested paying more attention to the forms of activities and the roles of those activities in future studies of science teaching and learning.

In the area of robotics education, hands-on learning has been frequently mentioned as an advantage (Alimisis, 2013; Bers, 2007; Satterthwait, 2010; Yilmaz, Ren, Custer, & Coleman, 2010). With their tangible and interactive features, robotic manipulatives have gained particular attention as effective objects for hands-on learning. However, despite the great interest in robotic manipulatives, the existing literature examines the prescribed use of robotic manipulatives to achieve specific purposes or learning goals (e.g., computational thinking, programming, engineering design process). There is little attention paid to the open-ended nature of hands-on materials or to the bodily and physical engagement of hands-on experiences. Given that materials and physical interactions are the distinct features of hands-on experiences, it is necessary to

examine in what ways the key aspects of hands-on activities, including materials and physical interactions, engage young children in the process of inquiry.

In this context, drawing on new materialist perspectives (Barad, 2007; Bennett, 2010), I attempt to understand the roles of robotic manipulatives and the nature of autotelic and bodily engagement in Keon's hands-on inquiry. The following two questions guided this chapter.

- 1) In what ways did the Cubelets participate in and influence Keon's hands-on inquiry?
- 2) In what ways did Keon encounter, respond to, and get to know about the Cubelets?

Theoretical Framework

I draw on the new materialist notions of (1) vibrant matter (or actants) (Bennett, 2010) and (2) the intra-action of the assemblage (Barad, 2007; Bennett, 2010) to interpret the role of the Cubelets in Keon's inquiry and to understand his modes of hands-on inquiry about/with the Cubelets.

Robotic Manipulatives as Vibrant Matter

Bennett (2010) conceptualized materials as having a *vibrant capacity* to “make something new appear or occur” (p. 31). Recognizing non-human agency, Latour (2005) also saw non-human things as performative actants. In general, the term “actants” refers to people, creatures, or objects playing a set of active roles. By being treated as actors or actants, materials gain a position equal with humans. Bennet explained the “vitality” of non-human entities as “the capacity of things . . . not only to impede or block the will and designs of humans but also to act as quasi agents or forces with trajectories, propensities, or tendencies of their own” (p.viii).

From this view, inanimate materials like robotic manipulatives can change a course of human action. In addition, robotic manipulatives as actants are not subordinate to the intentions of humans (e.g., children, teachers) and of the curriculum. With their own capacity, the robotic

manipulatives can be the origin of changes and transformations in children's inquiry. This horizontal view on the capacity of things is different from the vertical/hierarchical view (Niccolini & Pindyck, 2015), which regards humans as "the sole or ultimate wellspring of agency" (Bennett, 2010, p. 30). New materialist perspectives question the idea of attributing agency solely to humans (Barad, 2007).

New materialism cuts across the boundary between the subject (e.g., young children, teachers) and the object (e.g., the robotic manipulatives). In this sense, new materialism does not posit humans as the "operators" (Bennett, 2010) who have agentic capacity to control given situations and determine their meanings. Applying new materialist perspectives, I assume that children can influence and determine their inquiry processes, while the robotic manipulatives can simultaneously affect and transform children's inquiry.

The notion of the vibrant capacity of materials guided me to pay attention to the roles of the robotic manipulatives. Drawing on this notion, in this chapter I focus on the moment when the robotic manipulatives actively triggered, changed, directed, constructed, and transformed the focal child's inquiry.

Intra-action of the Assemblage as the State of Inquiry

From a new materialist perspective, an assemblage is the ontological unit formed by humans and materials. Drawing on Deleuze and Guattari (1987), Bennett (2010) defined *assemblage* as "ad hoc groupings of diverse elements, of vibrant materials of all sorts" (p. 23). Similarly, Barad (2007) viewed the primary ontological unit not as an individual entity but as "dynamic topological reconfiguring/entanglements/relationalities/(re)articulations of the world" (p. 141). According to this view, humans and materials are not separate, but they are always interdependent and intertwined. Thus, the assemblage itself is "a co-dependency" (Taguchi,

2010, p. 47). Applying this idea, I see that the focal child, the robotic manipulatives, and other materials encountered each other and co-existed as an assemblage and as an entanglement.

The notion of *intra-action* (Barad, 2007) further explains how human and non-human elements affect one another. According to Barad (2007), intra-action is the constant transformation of an assemblage, which can also be described as “the ongoing ebb and flow of agency” (p. 140) and as “the ongoing reconfiguring of the world” (p. 141). The idea of intra-action refers to the ways in which humans and materials enact and change each other. Although new materialists acknowledge materials as actors/actants having agency, they emphasize humans and materials intra-actively co-constituting agency (Taguchi, 2010).

In terms of onto-epistemology, Barad (2007) claimed that the way of being cannot be separated from the way of knowing. She explained her perspective on knowing as follows:

We do not uncover preexisting facts about independently existing things as they exist frozen in time like little statues positioned in the world. Rather, we learn about phenomena - about specific material configurations of the world's becoming. The point is not simply to put the observer or knower back *in* the world (as if the world were a container and we needed merely to acknowledge our situatedness in it) but to understand and take account of the fact that we too are part of the world's differential becoming. And furthermore, the point is not merely that knowledge practices have material consequences but that practices of knowing are specific material engagements that participate in (re)configuring the world. (pp. 90-91, emphasis added)

Thus, according to Barad, the way of being and the act of knowing simultaneously take place through intra-actions. Likewise, the focal child's inquiry about the robotic manipulatives can be emergent in and contingent upon the intra-actions of the child and the materials. Thus, the

consequences of the child's inquiry can be seen as "intra-active co-constitutive accomplishments" (Taylor, 2013, p. 9). The process and even the consequences of the child's inquiry cannot be determined or anticipated solely by the child's will/ability, teachers' intention/curricula, or the robotic manipulatives themselves. Both the process and the consequence of inquiry emerge from the intra-actions of the child, the robotic manipulatives, and the material world that they share. Because the intra-action includes an affective energy flow through on-going mutual transformation (Thiel, 2015), the trajectory of the child's inquiry is obscure and unpredictable (Benett, 2011). Thus, the outcomes and the meanings of the child's inquiry cannot be made by linear causality.

Methods

The Focal Child

In this chapter, I selected a 6-year-old boy named Keon. Keon participated in the Saturday A.L.T. Program. As I explained in the introduction chapter, the Saturday A.L.T program had a more children-led and less-structured approach than the Summer Robotics Camp. By stressing hands-on and child-initiated aspects, our research team provided materials-rich classroom environments and allowed the participating children to choose what they would do with those materials, including the robotic manipulatives. I selected Keon as a focal child for this chapter for two reasons: First, unlike other children whose attendance fluctuated, Keon consistently participated in all of the Saturday A.L.T program sessions, except for one week. Thus, I think he can provide rich data for this chapter. Second, Keon voluntarily engaged in different hands-on inquiry activities with the Cubelets. During ten weeks of his attendance in the Saturday A.L.T. program, Keon actively participated in both BeeBot and Cubelets classes. However, he was especially drawn to the Cubelets and visited the Cubelets room each week,

spending a lot of time doing activities with them. In addition, I think that focusing on Keon allows me to examine how his different hands-on activities across the 10 weeks were connected to one another and how Keon and the Cubelets intra-acted in those activities.

Data Sources and Data Analysis

For this chapter, I used a total of 11 hours and 33 minutes of video-recorded observation data from the Saturday A.L.T program. After the initial review, I selected 5 hours and 6 minutes of video data taken only in the Cubelets classes to conduct a micro-analysis (Graue & Walsh, 1998; Heath, Luff, & Svensson, 2007). Because Keon participated in all Cubelets classes, I reviewed all video data of the Cubelets classes. In the Cubelets classes, Keon did not leave any artifacts, such as drawings and engineering logs. Instead, he attempted to build Cubelets robots by using a variety of materials. Thus, when I reviewed his video data, I captured the screenshots of different assemblies of Cubelets that Keon put together and used these still images as another data source. When I produced transcriptions of the video-recorded data on Keon (see Figure 3 again in Chapter 1), I combined the screenshots with the transcriptions to construct a set of synthetic data records.

I used an inductive coding approach to review the transcriptions (Saldana, 2013). The coding approach was helpful for me to identify emerging patterns and key themes in Keon's hands-on inquiry with the Cubelets. In particular, I conducted three cycles of coding (see Table 6 below).

First, I conducted process coding (Saldana, 2013, p. 96). While analyzing the transcriptions line by line, the process coding helped me identify what Keon focused and what he attempted to do and inquiry events emerged from Keon's engagement with Cubelets. The purpose of this initial coding was to trace and identify different hands-on inquiry events Keon

engaged in with the Cubelets. During the process coding, I paid attention not only to what Keon and a teacher, EJ, said but also to how Keon behaved toward, used, and treated the Cubelets and other materials (e.g., wooden blocks, Duplo blocks, and Lego blocks). Through this process coding, I reorganized the transcriptions according to the inquiry events I identified.

For the second cycle of coding, I used the reorganized transcriptions and conducted structural coding (Saldana, 2013, p. 84). Structural coding helped me analyze conceptual elements (e.g., the role of Cubelets, the inquiry question, the response of Keon, and the role of Koen) related to the research questions. This coding process was twofold. First, I focused on the material actants to analyze the inquiry events, identifying what material actants were involved in each inquiry event and in what ways the materials engaged in the inquiry events. Second, I focused on Keon, analyzing the modes in which he engaged with the Cubelets and other materials.

During the last coding cycle, I used external coding (Graue & Walsh, 1998). Again, using the reorganized transcriptions, I reanalyzed the inquiry events by drawing on the theoretical concepts discussed above. Table 6 presents examples of codes generated through the three cycles of coding.

Table 6

Coding Methods and Examples of Codes

The First Cycle: Process Coding	The Second Cycle: Structural coding	The Third Cycle: External coding
• Following the Cubelets • Putting hands above Cubelets • Checking the types of Cubelets • Finding other types of	• Cubelets: - Following Keon's hand - Moving along with Keon's block structures - Guiding Keon's location	• Intra-action • Assemblages • The state of knowing • The state of being • Ecological sensitivity • Openness

• Cubelets • Sorting and arranging Cubelets • Asking questions • Asking for help from peers • Asking for help from a teacher • Naming the Cubelets • Watching the movements of Cubelets • Touching Cubelets • Gazing at Cubelets • Singing songs and dancing with Cubelets • Putting fingers above the Cubelets • Randomly assembling Cubelets • Assembling all Cubelets • Expressing emotions • Comparing different Cubelets • Comparing speeds of Cubelets • Using other materials • Expending blocks • Using space off the board • Building a tunnel • Building a bridge • Building a road • Building a race track	- Guiding Keon to other materials - Refusing Keon's intention - Drawing Keon's attention with sound - Drawing Keon's attention with colors - Drawing Keon's attention with motions - Drawing Keon's attention with surfaces - Turning the teacher's attention - Collaborating with Keon • Inquiry: - Motion - Speed - Direction - Weight - Length - Force - Energy - Texture - Angle - Magnetism - Magnitude	• Response • Material actants • Human actors • The state of entanglement • Unexpected consequences • Discursive practice • Material practices • Bodily practices • Autotelic behavior • Dwelling • Physical features • Improvisational flow
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Findings

Cubelets the Co-Inquirer

Cubelets were one of the key instructional materials for the Saturday A.L.T. program. For this program, we structured each week's class to minimize adults' instruction and maximize the children's direct engagement with the robotic manipulatives. Instead of leading instruction about

the Cubelets, our research team made an effort to set up the room with Cubelets and other objects (e.g., wooden blocks, Legos, and a white board). We were curious to see to what extent the participating children's free engagement with the Cubelets would lead them to achieve the intended learning outcomes, such as understanding the function of each Cubelet sensor and actor. In doing so, we treated the Cubelets as a passive medium to fulfill our research team's intention.

However, the Cubelets did not exist as a passive medium nor did they perform in a predictable manner. The physical features of the Cubelets actively shaped Keon's inquiry topics, process, and methods. For example, Vignette 11 presented at the opening of this chapter shows what happened when Keon first encountered a problem with the Cubelets. Although he had correctly assembled all the Cubelets (a battery, an Distance Sensor, a Light Actor, and two Drive Actors), the Cubelets did not work. This problem presented Keon with a great opportunity to learn about the battery and the causal relationship between the input and the output.

In Vignette 11, EJ successfully caught the moment when the Cubelets did not work and used the situation to promote Keon's learning. It was a pedagogically appropriate time for her to engage Keon in applying and expanding his knowledge, vocabulary, and prior experience to the problem situation (see Figure 36). She intervened in Keon's inquiry by questioning, commenting, and explaining what Keon had missed and what he had to check. Keon also played an active role in his inquiry. He recognized that his Cubelets did not work and reported it to EJ for her help.

At the same time, it was the Cubelets that invited Keon and EJ to the problem solving situation. Like Montessori's didactic materials (Montessori, 1964), the Cubelets participated in Keon's inquiry by contributing to his learning. If Keon assembled the three basic Cubelets (an actuator or actor, a sensor, and a battery), the Cubelets were supposed to move in a straight line.

However, instead of responding in a predetermined manner, the Cubelets demonstrated an unexpected behavior. In doing so, these manipulatives led Keon and EJ to check the battery.

Through his participation in the previous sessions, Keon had already learned that he needed at least one battery to make the Cubelets move. Nevertheless, he normally paid more attention to the types of sensors and actors than to the battery because the sensors and actors made the Cubelets behave in a variety of ways. In the situation described in Vignette 11, the Cubelets actively engaged in Keon's inquiry by turning his attention to the battery. The manipulatives worked for a while after Keon turned on the switch of the battery. Then, he found the Cubelets repeatedly spinning in place. He reassembled the manipulatives to make them move straight, not spin. This was an important inquiry moment for Keon. Comparing the spinning movement to the movement of going-straight, he was presented with an opportunity to solve this mechanical problem. However, the Cubelets stopped working again. Keon checked the battery's green light. EJ also checked it with him. Nonetheless, the Cubelets stopped working. The Cubelets directed Keon and EJ's attention to the battery by demonstrating that they could not move, even though the battery was still turned on. The inoperative Cubelets led Keon and EJ to engage in learning about the degree of power held in the battery.

In addition, Vignette 11 shows how the Cubelets played a key role in stimulating not only Keon's intellectual curiosity but also his emotions, including frustration and joy. When the Cubelets did not submit to his will, Keon was frustrated. When the Cubelets resumed moving, he shouted with joy, "My sensor is alive!" In a sense, the Cubelets manipulated Keon's emotions through their responses. Thus, although Keon had the will and motivation for his inquiry, he did not have full control over his inquiry process as it was very much affected by the Cubelets.

In another situation, Keon collaborated with the Cubelets. As Figure 37 shows, Keon used two Drive Actors to build a set of Cubelets. The Drive Actors had two rolling wheels. When they were assembled with a sensor and a battery, the wheels could roll. Keon attempted to make the Cubelets stand and move vertically. However, the Cubelets could not stand by themselves. When Keon took his hands off, the Cubelets lost their balance. Keon tried to make them stand up again. Without Keon's hands, the Cubelets fell down. Then, instead of trying to fix and control the Cubelets by making them stand and move vertically, Keon led himself to be affected by the Cubelets and follow them.



Figure 37. The Cubelets fall down again and again.

Despite his repeated trials, Keon noticed that the Cubelets continuously lay down on the white board placed on the floor of the room for the Cubelets activities. This made Keon accept the Cubelets' response and let them lie down on the white board. With his understanding of the sensor, Keon put one of his hands above the Distance Sensor linked to the set of the Cubelets. The Distance Sensor detected Keon's hand as an input. Then, the Cubelets moved straight on the board. Putting his hand above the Cubelets and following the manipulatives, Keon said, "I am a train!" (see Figure 38.1).

Keon's hand and the Cubelets intra-acted to become something unexpected and new. Keon did not say, "It is my train!" Rather than representing and objectifying the Cubelets as a

train and separating them from himself, Keon announced, “I am a train!” Together, Keon and the Cubelets became a train. As a train, the Cubelets and Keon performed together. Keon influenced the Cubelets, putting his hand above the Distance Sensor and providing it with a source of input. Simultaneously, the Cubelets responded to and directed Keon’s bodily movements. Putting his hand above the Distance Sensor, Keon followed the Cubelets and moved along with them (see Figure 38.2).



Figure 38.1. Keon says, “I am a train!”



Figure 38.2. Keon tries to follow the moving Cubelets.

The Cubelets and Keon’s collaboration and their encounter with wooden blocks created another learning event. The intra-actively co-constituted Cubelets-Keon train encountered wooden blocks on the board. When facing the wooden blocks, the Cubelets demonstrated how they could push the blocks. Keon watched them. He held the Cubelets with his hand and placed them in front of the blocks. As Keon released his hand from the Cubelets and kept his hands above the sensor, the manipulatives showed once again that they were able to push the blocks. By repeating this performance together, the Cubelets and Keon engaged in a new inquiry question: Are the Cubelets able to see and push blocks? (see Figure 39.1)

Later, the Cubelets led Keon to other wooden blocks on the board. Keon responded to the Cubelets by following them and turning his gaze in the direction where the Cubelets were

heading. There he found other wooden blocks. Keon put one of the wooden blocks on the Cubelets. The Cubelets demonstrated that they were strong enough to carry the blocks (see Figure 39.2). This led the Cubelets and Keon to another inquiry event with expanded questions: Are the Cubelets able to carry the blocks? How many blocks are they able to carry?



Figure 39.1. The Cubelets-Keon train pushes a wooden block.



Figure 39.2. The train carries several wooden blocks.

Through these processes, the Cubelets performed and transformed with Keon to contribute to his inquiry. In this section, I presented how Cubelets as actants worked in unexpected ways, sometimes against Keon's will and intention, and changed and even directed Keon's inquiry topics and methods. In the next section, I turn to Keon's perspectives, while considering them within his entangled relationship with the Cubelets. I present the ways in which Keon encountered, responded to, and got to know about the Cubelets.

Autotelic Bodily Engagement

In the Saturday A.L.T. program, our research team intended to provide the participating children with opportunities for hands-on inquiry about Cubelets. We expected that such opportunities would help the children, including Keon, engage in posing scientific questions about Cubelets, formulating their explanations from their observations and exploration of the

manipulatives, and connecting their explanations to scientific knowledge (e.g., speed, motion, direction, energy, light, and vocabulary for the mechanical parts) (Crawford, 2016, 2014). We also hoped that tangible and sensory experiences would serve the children’s symbolic, intellectual, and discursive meaning construction of the Cubelets. In addition, considering that inquiry is “the act or process of asking questions in order to get information” (“Inquiry,” 2018), we expected the children’s inquiry to have a purposive direction.

In contrast to our expectations, Keon’s hands-on inquiry with the Cubelets appeared to be repetitive, bodily-sensorial, and purposeless. To understand his mode of engagement, I found Rautio’s (2013) conceptualization of “autotelic material practice” (p. 339) helpful. Rautio described children’s picking up and carrying stones as an example of autotelic material practice. According to her, autotelic material practices are children’s repetitive engagement with materials “for no external reward or motivation” (p. 399). Drawing on new materialism, she conceptualized young children’s autotelic materials practices as (a) emerging from their encounter with materials, (b) occurring as a response to materials with aesthetic-affective openness, and (c) joyful and sustainable for no particular reason. Applying this notion of autotelic material practice, I consider the patterns of Keon’s inquiry autotelic and bodily engagement. Vignette 12 presented below shows one such moment.

Vignette 12: Video Transcript 10-04-2014

Keon assembles a set of Cubelets. As he releases the Cubelets back to the board, the manipulatives spin around and around in one place. As the Cubelets spin, Keon spins his finger above the Cubelets.

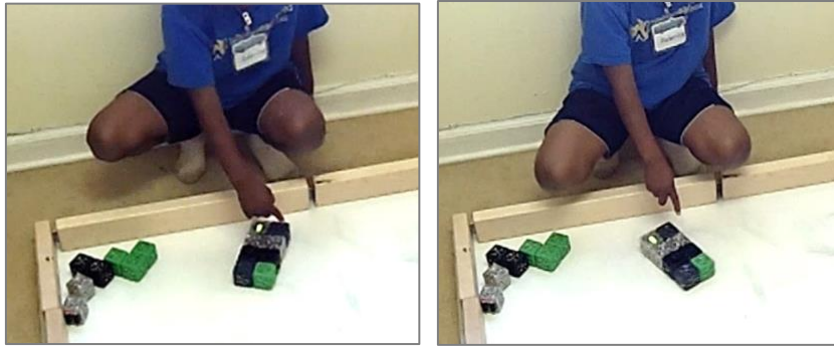


Figure 40. Cubelets spin around and Keon spins his finger above the Cubelets.

EJ – a teacher of the Cubelets class – suggests to Keon, “Keon, can you make your Cubelets go straight?” Keon looks at EJ, but he continues to watch the Cubelets spinning around by spinning his finger. Soon, Keon changes the structure of the Cubelets. As soon as the Cubelets are released from Keon’s hand, they spin again. EJ says, “It’s still turning around. Please check the directions of the wheels [of the Drive Actors].” Keon responds, “I checked the wheels.” He picks up the Cubelets and looks at the wheels of the Drive Actors. The wheels quickly go around and make rolling sounds. Keon puts his finger on the surface of the wheels. For a while, he listens to the sounds and watches the rolling wheels while touching the wheels. EJ gently reminds him, “Keon, do you know what I mean? You have to check the directions of wheels.” He answers, “Yes.” He looks calmly at the Cubelets and still puts his fingers on the wheels.



Figure 41. Keon puts his fingers on the surface of the rolling wheels.

As shown in the vignette, Keon enjoyed engaging in the Cubelets’ spinning movement. As if they became one body, Keon moved his finger along with the movement of the Cubelets. From the previous sessions, Keon had already experienced and learned how a set of the Cubelets (Distance Sensors-Drive Actors-batteries) he assembled would work. Thus, he did not need to test and check how the Cubelets worked. He just continued to enjoy the same motions of the

Cubelets. When he checked the wheels of the Drive Actors, his intentions and goals were not explicit. Nonetheless, he appeared to be attentive and look for something to do with the Cubelets. He carefully listened to the sounds of the rolling wheels and put his finger to feel the surface of the wheels. The wheels of the Drive Actors did not stop rolling but rather stroked Keon's finger.

From a teacher's perspective, Keon seemed to repeat seemingly off-task and purposeless behaviors in his engagement with the Cubelets. EJ tried to scaffold Keon's inquiry by suggesting a new task, making the Cubelets move straight. She also encouraged him to connect his observation of the spinning Cubelets to the relationship between the direction of the wheels and motion. Keon responded to EJ's suggestion and attempted to reassemble the Cubelets to make them go straight. However, when he encountered the sounds and speedy motions of rolling wheels, they invited him to the autotelic and bodily engagement with the wheels rather than changing their direction to make the manipulatives move straight.

Keon's autotelic and bodily engagement with the Cubelets was frequently observable. For example, as the Cubelets spun around in front of him, Keon sang a song and danced, shaking his body left and right (see Figure 42). Keon's singing voice and the sounds of the rolling wheels became mixed. Although the movements of Keon and the Cubelets were not synchronized, they looked as if they moved and danced together.



Figure 42. Keon sings a song and dances with Cubelets.

Keon continuously sang a song. He pulled out a Light Actor from the set of Cubelets. Still the Cubelets moved. Keon lowered his body and made eye contact with the Cubelets (see Figure 43). He gazed at the bottom of the Cubelets for a while, not touching them. He smiled at the Cubelets. He did not say anything or explain why he smiled.

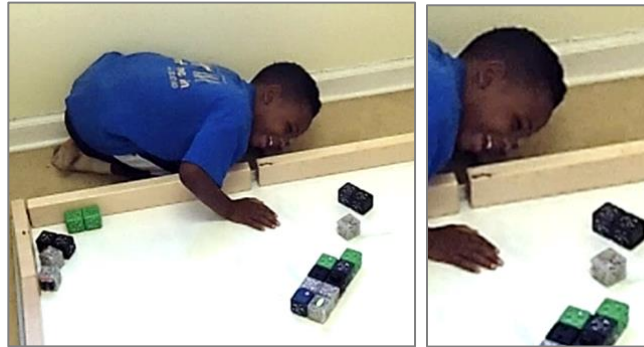


Figure 43. Keon makes eye contact with Cubelets and smiles.

It was interesting to see Keon's repetitiveness and attentiveness with no particular reason or goals. He did not verbally express what he came to know about the Cubelets. From a new materialist perspective, knowing and being cannot be separated (Rautio, 2013). Thus, Keon's autotelic and bodily engagements could be considered his way of knowing. The ontology of assemblage demands that we defamiliarize our view of Keon and the Cubelets as "individually determinate entities" (Barad, 2007, p. 128). To this end, in Figure 9 presented below, I edited the video-captured images to visualize them as the assemblage of Keon and the Cubelets. In doing so, I highlight the inseparability of Keon's state of being and knowing from the Cubelets in his inquiry.



Figure 44.1.

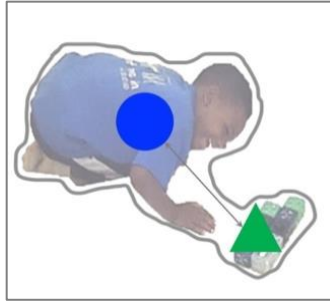


Figure 44.2.

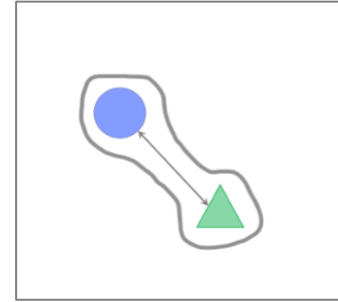


Figure 44.3.

Figure 44. Keon and the Cubelets mutually constitute the assemblage.

Figure 44.1 shows a familiar image of Keon and the Cubelets. Here, Keon and the Cubelets existed as individually determinate and separate entities. The Cubelets existed as predetermined objects, and Keon existed as an agentive subject. Keon's actions (e.g., manipulating the Cubelets and analyzing and interpreting different responses of the Cubelets) could constitute Keon's learning of the Cubelets. By carefully observing and handling the Cubelets, Keon could realize how the Cubelets operate. Keon could also use the Cubelets for his rational representation (Wohlwend, Peppler, Keune, & Thompson, 2017). For example, he could verbally explain his understanding of cause and effect by referring to the Cubelets.

By contrast, in Figure 44.2, Keon and the Cubelets can be seen as a connected and entangled configuration. As the gray contour surrounds and binds Keon and the Cubelets as a unit, the assemblage of Keon and the Cubelets emerges. As the arrow between Keon and the Cubelets shows, both the child and the manipulatives co-constituted the assemblage and were co-dependent on each other within the assemblage. When I blurred and removed the images of the human and the non-human actors in the assemblage and replaced them with geometric symbols (i.e., a circle and a triangle) in Figure 44.3, the horizontal and non-hierarchical relationship between Keon and the Cubelets stands out.

Within the assemblage of Keon and the Cubelets (see Figure 44.3 again), Keon's "aesthetic-affective openness" (Bennett, 2010) toward the Cubelets transcended the boundary between a subject and an object. Keon did not position himself as the observer and the analyst of the Cubelets. The relational practices between Keon and the Cubelets did not have clear or inherent boundaries. As Keon and the Cubelets repetitively encountered, touched, and gazed at each other, Keon became a part of the Cubelets and the Cubelets became a part of Keon.

This blurred boundary enabled Keon to feel, to sense, to reach, and to affect and be affected by the Cubelets. It was also a way for Keon to get to know the Cubelets. Although he was not a new materialist, I think, Polanyi's (1962) notion of "tacit knowing" helps us see Keon's inquiry as the assemblage of him and the Cubelets. Polanyi argued that scientific knowing has a tacit dimension, which is the essence of how an inquirer personally engages in scientific knowing. According to Polanyi, although Keon did not articulate what he was doing with the Cubelets or what he found, he was still in a state of knowing. Polanyi called this "ineffable" (p. 47) knowing, and this led him to make his famous argument: "we can know more than we can tell" (p. 95).

Similar to the notion of assemblage, Polanyi (1962) discussed the characteristics of tacit knowing by describing the close relationship between an inquirer and a tool in the inquiry process:

While we rely on a tool or a probe, these are not handled as external objects. . . . [They] remain necessarily on our side . . . forming part of ourselves, the operating persons. We pour ourselves out into them and assimilate them as parts of our own existence. We accept them existentially by dwelling in them. (p. 59)

I read what Polanyi said about “dwelling in [the tool]” as the intra-action of Keon and the Cubelets in the assemblage. Polanyi emphasized the inseparability of the body, mind, and tools in the inquiry process. By dwelling in the Cubelets, Keon poured his body, mind, emotions, and intuition into the inquiry process.

Keon repeated watching (as well as touching and dancing with) the already familiar and known movements of the Cubelets. At first glance, his repetitiveness did not seem to produce a new understanding of the Cubelets. However, every moment of intra-action with the Cubelets required Keon’s repetitive openness toward the Cubelets. And every moment was filled with differences in experiencing the Cubelets. Keon opened himself up to what was happening in each moment in his entangled relationship with the Cubelets. The unexpected changes in the Cubelets provided Keon with new understandings of the Cubelets. The moment when the assemblage of Keon and the Cubelets produced something new and different was a moment of new becomings and new discoveries for Keon and the Cubelets.

The Emergence of Both Inquiry Events and Meanings of Cubelets

I revisited the moment partially described in Vignette 11 to trace how the assemblage of Keon and the Cubelets had evolved, transformed, and produced inquiry events. Vignette 11 showed how the Cubelets drew Keon and EJ’s attention to the amount of power of the battery. Later, intra-actions of Keon, the Cubelets, and other materials (e.g., wooden blocks, Duplo blocks) presented different inquiry events while their assemblages continued to evolve. The initial inquiry about the battery was not a one-time event. Through the affective and improvisational energy flow (Rautio & Winston, 2015), the initial assemblage (Keon-Cubelets) became reconfigured into another assemblage (Keon-Cubelets-Wooden Blocks). Then, the

reconfigured assemblage evolved into a new assemblage (Keon-Cubelets-Wooden Blocks-Duplo Blocks).

I tried to visualize the ongoing assemblages of Keon, Cubelets, and other materials with a series of edited images. First, Figure 45 shows the encounters between Keon and various material actants (e.g., the Cubelets, wooden blocks, and Duplo blocks) and the different inquiry events that emerged from these encounters. However, this figure limits our view to the chronological sequences of the inquiry events. In Figure 45, the assemblages are “marked by an exterior parameter called time” (Barad, 2007, p. 234). In this view, the different assemblages of Keon, Cubelets, and other materials were fixed within the absolute and universally given time dimension. From the frame of chronological before and after, the former inquiry event seemed to cause the latter inquiry event. In addition, Figure 45 still presents Keon, the Cubelets, and other material actants as separate entities.

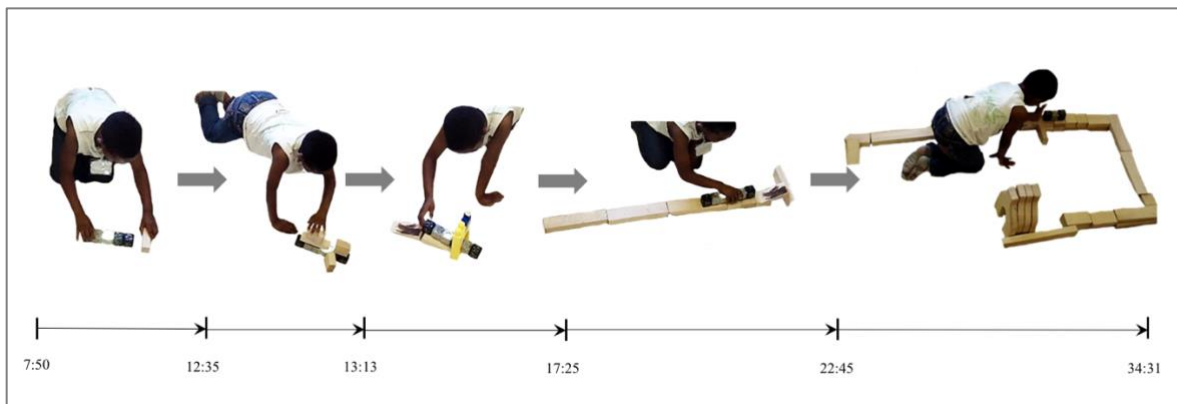


Figure 45. The ongoing inquiry events in chronological order.

Figure 46.1 is my attempt to present the ongoing inquiry events from the lens of assemblages and intra-active temporality. In this figure, I intentionally blurred the images of Keon, the Cubelets, and other materials in order to shift our human-centered and hierarchal view of the phenomena to a horizontal view. The two-way arrows among Keon, the Cubelets, and

other materials indicate how all actants within assemblages are mutually constituting the assemblage and inseparable from each other.

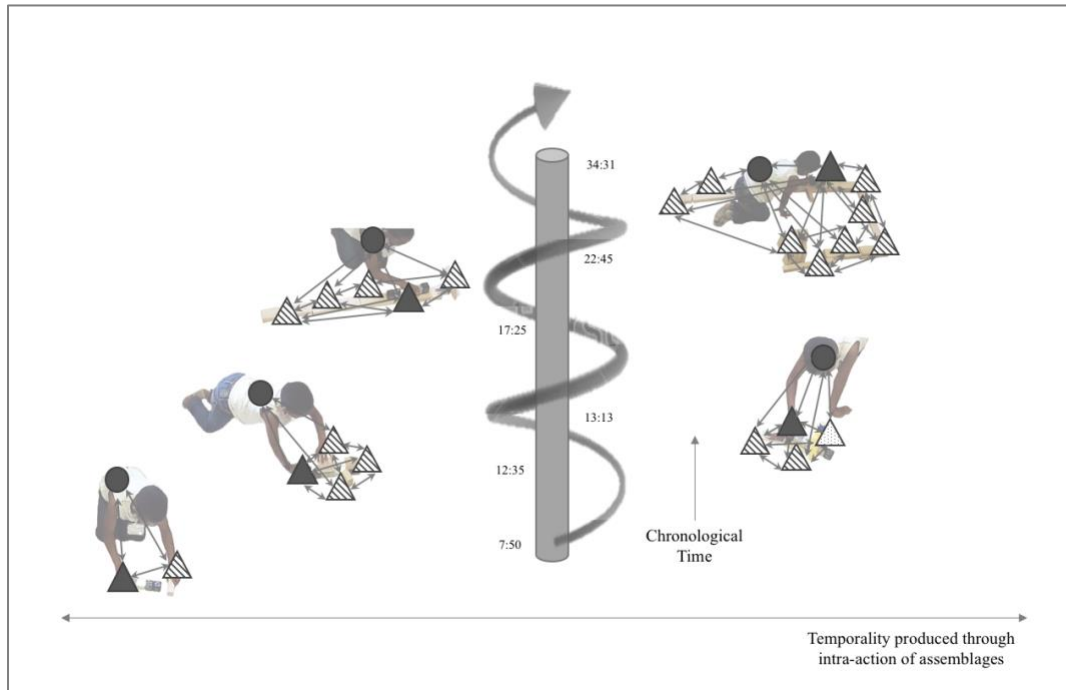


Figure 46.1. The ongoing assemblages

Finally, in Figure 46.2, I further abstracted the ongoing assemblages with shapes, lines, and patterns. I removed all images and replaced them with different shapes of equal sizes. The different shapes (e.g., triangles and circles) represent the heterogeneity among the actants of the assemblages. For example, circles represent Keon, and triangles indicate materials, such as Cubelets and blocks. Different colored patterns inside the shapes show how different types of materials were involved in intra-acting in the assemblages. Using equal sizes for different shapes emphasizes that Keon, the Cubelets, and other materials are equally positioned as actants. Through this abstraction, I noticed that the arrows in Figure 46.2 appear to be clearer than those in 46.1. These arrows connect the human and non-human actants and show intra-action among

them. Therefore, Figure 46.2 is the visualization of the assemblages of Keon, Cubelets, and other material actants entangled, reconstituted, transformed, and evolved.

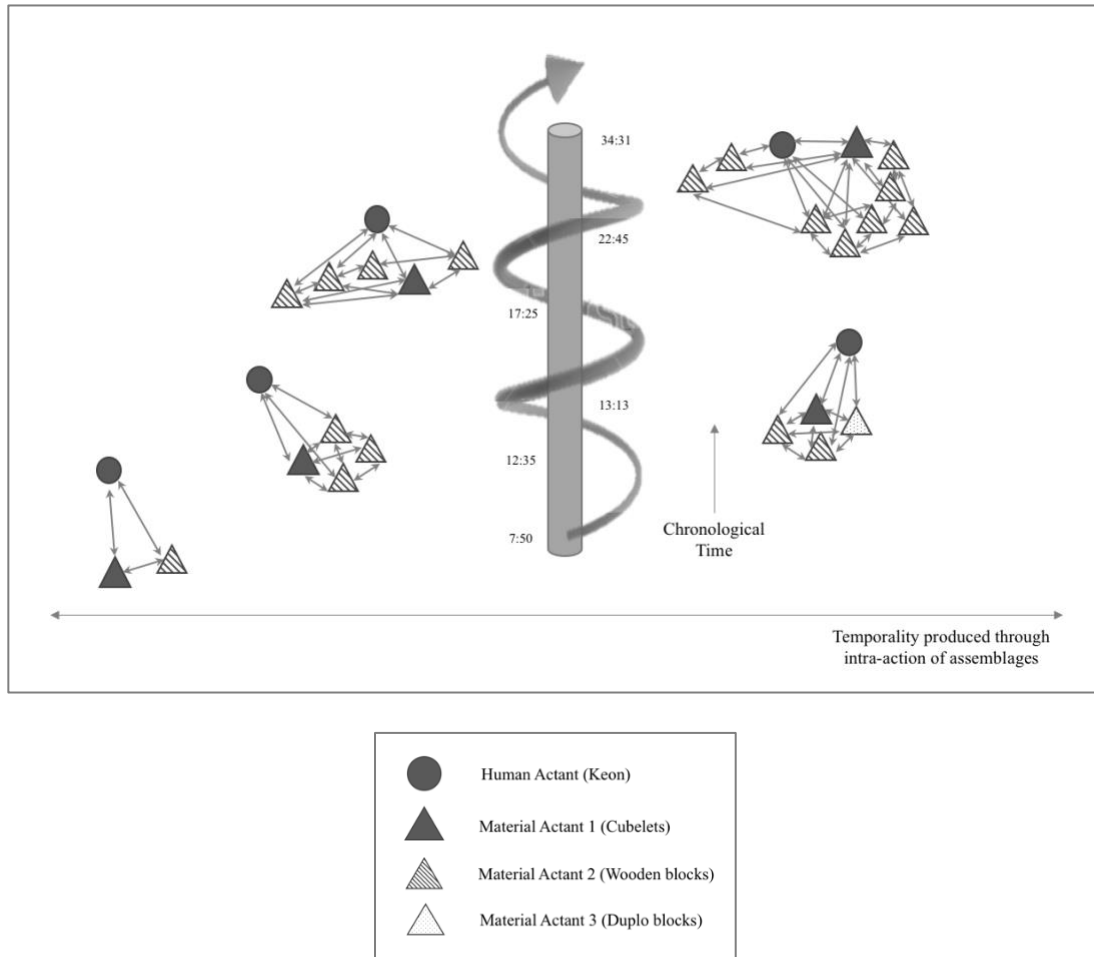


Figure 46.2. The ongoing assemblages.

Also, in Figure 46.2, the vertical cylinder shows that the different assemblages took place at different times. However, in this figure, I did not place the different assemblages on a chronological continuum. I added the horizontal line at the bottom of the figure in order to represent the distinct temporalities produced through the ongoing intra-actions of the assemblages. The horizontal line emphasizes that the past, the present, and the future of Keon-Cubelets-other material assemblages were “reworked” (Van der Tuin & Dolphijn, 2012) in the

ongoing intra-actions. By adding the temporal dimension to the figure, I attempted to stress that the changes in the assemblages were not “a continuous mutation” (Barad, 2007, p. 179) nor “a continuous process through or in time” (Barad, 2007, p. 182). In short, in Figure 46.2, the ongoing dynamics of the different assemblages did not have a determined past-present-future or cause-effect relation.

As shown in this series of figures, Keon’s inquiry events emerged from “the ongoing reconfiguration”(Barad, 2007, p.141) of assemblages and had their distinct temporality outside of chronological order. As “the ongoing reconfiguring of the world” (Barad, 2007, p. 141), the assemblages of Keon-Cubelets-other materials became the sources of the inquiry events. For example, the initial inquiry event in Vignette 11 had evolved and transformed into the following inquiry questions and events:

- Are my Cubelets able to see and push blocks?
- Are my Cubelets able to convey blocks?
- How can my Cubelets pass through obstacles (e.g., a tunnel or slope)?
- How fast are my Cubelets?
- To what extent does the Knob Sensor make Cubelets stronger and faster?
- When all the Cubelets are assembled together, do they still move or spin?

These inquiry questions and events were not produced through the linear causality of one event leading to another event. Instead, all these inquiry events resulted from momentary relationships among Keon, the Cubelets, and other materials. For example, Keon encountered wooden blocks and Duplo blocks with the Cubelets. The intra-actions of Keon, the Cubelets, the wooden blocks and the Duplo blocks generated intellectual engagement. As Figure 47 shows, Keon took

particular care to help the long Cubelets successfully pass through the Duplo tunnel, while using the wooden blocks as supports for the Cubelets.



Figure 47. An inquiry event produced by the assemblage of Keon-Cubelets-wooden blocks-Duplo blocks.

In this process, different properties of materials (e.g., the long Cubelets, the rolling wheels of Drive Actors, the slope of wooden blocks, and a Duplo block with a square-shaped hole) enabled Keon to engage in diverse aspects of the Cubelets and the materials, such as the angles and heights of the blocks, the lengths of the Cubelets, the strength of the movement of the Cubelets, the speed of the Cubelets, and the surface texture of wooden blocks. However, it was unpredictable how the same elements (i.e., Keon, the Cubelets, the wooden blocks, and the Duplo blocks) would intra-act and what inquiry events the intra-action would generate. The assemblage of the same elements would not ensure that the same inquiry events would occur. In this sense, the inquiry events that emerged from the ongoing transformations of assemblages were improvisational and arbitrary in their nature. In the improvisational flow of inquiry, the meanings of the Cubelets were not fixed, according to their designers' or the teachers' intentions. In their intra-actions with Keon and other materials, the meanings of Cubelets continuously changed and evolved.

Discussion

Drawing on new materialist notions of vibrant matter (Bennett, 2010) and the intra-action of the assemblage (Barad, 2007; Bennett, 2010), this chapter looked into a six-year-old boy, Keon's inquiry with and about Cubelets. The findings indicated that the Cubelets actively performed the role of a co-inquirer by both collaborating with and refusing to comply with Keon's intentions. In doing so, the Cubelets contributed to directing or changing the topics and the methods of his inquiry. The findings also showed that Keon engaged in his inquiry through autotelic and bodily modes, which involved purposeless, repetitive, tacit and spontaneous actions. The autotelic and bodily engagement was the state of being with and knowing the Cubelets for Keon as he intra-acted with the manipulatives and opened himself to encountering unexpected differences in the Cubelets. Lastly, the study revealed that different inquiry events emerged from the constant transformations of assemblages, not from the linear and causal relationships among Keon, the Cubelets, and other materials. The transformations of assemblages enabled Keon to engage with the evolving, rather than predetermined, meanings of the Cubelets. Based on these findings, I discuss the following implications:

First, this study highlights the importance of recognizing young children's interdependency with materials as a form of their capability. In this chapter, Keon showed how he was guided by, influenced by, and sometimes constrained by the Cubelets. At first glance, his dependence on the Cubelets appeared to position him as less autonomous, less persistent, and less capable of taking charge of his inquiry. However, Keon's dependency upon the Cubelets did not diminish or undermine his agency. In fact, Keon's responses to and reliance on the Cubelets positioned him as a capable and flexible inquirer. Lynch (2015) called this reliance on the materials/technology "the emancipatory possibilities" (p. 143) for both educational technology

and for young children. I suggest appreciating and valuing young children's distinct "ecological sensibility" (Bennett, 2010, p. xi), which is their ability to sense materials' vibrant capacity and to respond to it, as an important capability to be nurtured in their inquiry process.

Second, the findings of this chapter suggest affirming young children's tacit, bodily, and autotelic behaviors to engage with the robotic manipulatives as a mode of inquiry. According to the key definition of science inquiry (Crawford, 2014, 2016), I view science inquiry as engaging students in asking questions, designing and carrying out investigations, and interpreting data, creating arguments, building models, and communicating findings. From the view of this definition, Keon's engagement with Cubelets can be seen as an experiential and heuristic event rather than scientific inquiry. Because Keon frequently remained in autotelic and tacit modes to know about Cubelets, his engagement with Cubelets was not clearly articulated or formulated. Nevertheless, I emphasize here that Keon's tacit and bodily modes cannot be separated from his process of investigating Cubelets. Also, the tacit and bodily modes had the potential to engage him in scientific concepts such as motion, force, energy, matter, and weight in attentive, authentic, and voluntary manners. Based on the new materialist perspective (Barad, 2007; Bennett, 2010) and the findings of this chapter, I suggest that recognizing inquiry is not only a matter of words/articulation but also a matter of bodily engagement.

Third, the findings of this study suggest expanding our view and practice of "the pedagogy of listening" (Rinaldi, 2004, p. 2). As a philosophy of Reggio Emilia's approach, an internationally acclaimed early childhood education program in Italy, the pedagogy of listening emphasized that teaching should begin from carefully observing and understanding what children do, encounter, and experience and how they find their own meanings from their relationships with social and material environments (Rinaldi, 2004). This pedagogical stance can

also be applied to reading the intra-actions of the child and materials. The intra-actions between Keon and the Cubelets showed that the Cubelets, the intended structure of the class (e.g., guided instruction, free play), and the intentions of teachers and Keon cannot be solely responsible for or in control of the inquiry events. However, this does not imply a pessimistic view of the roles of teachers or of instructional planning. Introducing an intra-active pedagogy, Taguchi (2010) argued,

We need to plan very thoroughly and imagine possibilities of challenging intra-actions that *might* take place. We plan also in order to be able to *diverge* from our plan. We need to be on our toes ready to insert a previously unimaginable question or comment into what is going on, or suggest a new way of doing or thinking, or offer a new material that was not already planned for. (p. 61)

As Taguchi noted, the findings of this chapter urge us to pay particular attention to the invisible forces of non-human actants involved in teaching and learning, while awakening our collective and relational stance on setting instructional goals and planning activities (Rautio & Winston, 2015). We as educators may need to learn from young children to develop the ecological sensibility, which will help us encounter and embrace the unexpected emerging from the intra-actions of teachers, children, material environments, and other invisible and non-human actants.

Lastly, the findings of this chapter suggest expanding the narrow perspectives on children's hands-on experience by moving beyond the dominant logic of improvement of STEM learning and teaching (Bowers, 2016; Buxton, Harper, Payne, & Alleksaht-Snider, 2017). This logic assumes, for example, that if young children can physically and directly manipulate the tangible Cubelets, their STEM learning will follow. According to this logic, the value of an encounter between young children and educational materials/technology is primarily

instrumental (Trowler, 2012). In addition, according to this logic, educational materials/technology are considered only a means to ensure the intended and planned outcomes (Lynch, 2015,). However, the encounter between Keon and the Cubelets showed us that Keon's engagement with the manipulatives was not only his way of acquiring scientific knowledge and skills but also his way of being. Here, I do not intend to argue that the instrumental view of hands-on experiences has no value or is wrong. Instead, I want to point out that we as early childhood educators tend to limit young children's hands-on experiences to the frame of what they will be able to achieve in relation to planned instruction, rather than thinking about who children will be and become when they encounter human and nonhuman others. Unexpected inquiry events emerged from Keon's assemblage with Cubelets and other material actants. When we acknowledge children's hands-on experiences as their way of being and becoming, their engagement with materials may offer more possibilities, including, of course, expanding their intellectual capacity.

CHAPTER 5

CONCLUSIONS

In this dissertation study, I attempted to examine how young children, aged 4 to 6, engaged with robotic manipulatives (BeeBots and Cubelets) in two early childhood robotics education programs, which were offered in a community learning center. Drawing on Bakhtin's (1981) dialogism and on new materialist perspectives (Barad, 2007; Bennett, 2010), I considered the participating children's points of view, interests, and attempts at engaging with the robotic manipulatives in order to understand how they encountered, made sense of, and used these manipulatives.

In Chapter 1, I discussed the overall purpose and research questions of this dissertation study based on gaps that I identified in the existing research literature on young children's engagement with robotic manipulatives. I also explained the methodology used for this dissertation study. Chapter 2 examined 6-year-old Carlos's BeeBot battles to highlight his agentic role in appropriating both the features of programmable robots (BeeBots) and the ways of programming. I stressed Carlos's authorship in constructing his concept of and perspective on the robots by looking into his parody of the programmable robots. In Chapter 3, I showed how 4-year-old Silvia and 5-year-old Lucia had to negotiate with authoritative gender norms and discourses that challenged their femininity in programming robots and in building robots. I argued that these girls successfully positioned themselves as a powerful heroine through storytelling for pretend play with BeeBots or as a competent robot builder in designing and building Cubelets robots. Chapter 4 traced the emergent inquiry events of Keon's engagement

with Cubelets. I emphasized the role of a co-inquirer performed by the Cubelets, who contributed to shaping Keon's inquiry. I also shed light on the autotelic and bodily engagement as Keon's distinct modes of inquiry. I articulated how inquiry events and the meanings of the Cubelets emerged and evolved from the assemblages of Keon, the Cubelets, and other material actants.

At the end of each chapter, I discussed some implications of the case study presented in that chapter. In what follows, I briefly discuss the overall implications of this dissertation study for early childhood education practice and research in general and early childhood STEM education in particular.

Implications

For Early Childhood Education Practice

This dissertation study presents young children as actively adapting robotic manipulatives for their own purpose rather than as passively consuming or accepting them as intended by their manufacturers or by teachers. For example, in Chapter 2, Carlos, in his free play with BeeBots, changed the norms of programming and the key properties of the BeeBots by citing and incorporating the practice of both his peer play (e.g., a battle) and his ordinary life (e.g., using his hands to control toys). The study shows that young children are capable of using educational technologies in an innovative and unexpected manner (Lynch, 2015). This finding reminds us of young children's agency in their learning. Adair (2014) defined young children's agency as "the ability to influence what and how something is learned" (p. 217). To nurture their agency, I argue that children need to have ample opportunities to freely explore robotic manipulatives and other media beyond the context of teacher-led, structured instruction. Observing the ways in which children engage with materials will provide teachers with significant insights into how to

make their pedagogy dialogical (Bakhtin, 1981; Lee, 2017) and intra-active (Barad, 2007; Taguchi, 2010) while opening new possibilities for teaching and learning.

This dissertation study also highlights that engaging with robotic manipulatives is a way that children perform, construct, and express their gender identity. Carlos and his boy peers in Chapter 2 repeatedly performed their masculine practice and desire by programming the BeeBots to do battles. Meanwhile, in Chapter 3, Silvia, through her pretend play, positioned herself as an accommodating and yet powerful heroine over the masculinized BeeBots. In addition, adopting masculine codes, Lucia legitimized her entry into the boys' peer group and positioned herself as a competent robot builder. Therefore, from a Bakhtinian perspective, programming BeeBots and building Cubelets not only allow children to learn about STEM-related concepts and skills but also encourage children to negotiate and express the ideologies of their gender. For this reason, first, I suggest that early childhood educators critically examine the messages and values related to a child's identity they intentionally and unintentionally deliver through robotic manipulatives and other materials in their classrooms (Black, KorobKova, & Epler, 2013; Carter, 2007). Second, I propose using young children's engagement with materials, including robotics manipulatives, as a pedagogical strategy to allow them to navigate their identities and express who they are.

This dissertation study illustrates how the four focal children engaged with the robotic manipulatives through different types of practices. For example, in Chapter 2, Carlos enjoyed creative battle play with BeeBots. In Chapter 3, Silvia performed pretend play with BeeBots based on her spontaneous storytelling, while Lucia participated in a Cubelets robot building project by combining an arts-and-crafts activity. Keon, in Chapter 4, voluntarily engaged in emergent inquiry with and about Cubelets through hands-on experiences with different types of

blocks. I believe all these activities can be good examples for early childhood educators to see robotics education as a teaching approach which can be integrated into the existing curriculum rather than replacing it. As the aforementioned examples show, robotic manipulatives can be adopted by key teaching approaches to early childhood education, such as play-based teaching, a problem-solving approach, a project approach, a heuristic approach, an interdisciplinary approach, and a collaborative learning approach (Altin & Pedaste, 2013; Elkin, Sullivan, & Bers, 2014). To employ robotics education in an early childhood education classroom, I suggest that educators consider both how to adopt the robotic manipulatives and how to adapt the existing curriculum (Alimisis, 2012; Bers, Ponte, Juelich, Viera, & Schenker, 2002).

For Early Childhood Education Research

This dissertation study focused on understanding what young children attempted to do with the robotic manipulatives rather than how they improved academically with the use of these manipulatives. In doing so, I do not intend to neglect the importance of children's academic achievement in general and their STEM learning in particular. However, as discussed in Chapter 1, many studies on robotics education for young children have centered on examining the impact of such instruction on children's achievement of academic learning outcomes (Benitti, 2012; Lynch, 2015; Jung & Won, 2018). These studies tended to position young children as being in need of improvement and development (Bulfin, Johnson, & Bigum, 2015). In addition, in such studies robotic manipulatives were presented to children with predetermined meanings (e.g., tools for sequencing and programming). Illustrating four children's agentive engagement with robotic manipulatives, this dissertation study highlighted how young children are capable of shaping, altering, and adopting the given and unfamiliar robotic manipulatives for their own purposes and interests. I believe we need more studies which will help us understand young

children's voices on, interests in, and ways of engaging with robotic manipulatives and other new technologies.

Although this dissertation focused on young children's agency in appropriating robotic manipulatives and negotiating their meanings, it also emphasized the importance of recognizing the agency of the robotic manipulatives and other materials in children's inquiries. Drawing on a sociocultural perspective (e.g., Bakhtin, 1981), the robotic manipulatives are not considered neutral materials but perceived as artifacts reflecting values, norms, and beliefs in a given social and cultural context. Framed also by new materialist perspectives (e.g., Barad, 2007; Bennett, 2010), this study treats the robotic manipulatives as undetermined actants, which do not have predictable affordances. In the studies on early childhood robotics education, there has been a need for alternatives to the constructivist (Piaget, 1973; Vygotsky, 1978) and constructionist (Papert, 1993) frameworks dominant in the field in order to better understand the complicated and collective process involving young children and robotic manipulatives (Savard & Freiman, 2016, Strawhacker & Bers, 2015). Oliver (2011) also argued that research on educational technology needs a critical perspective to embrace both the undetermined features of educational technology and the learner's agency. This dissertation study is an attempt to close this gap in the existing research literature. Nevertheless, further research is needed to understand what happens when children and robotic manipulatives (or other materials in children's lives) encounter one another.

When studying young children's engagement with robotic manipulatives and their material environments, choosing effective and creative methods to listen not only to young children but also to materials is critical. For this dissertation study, I conducted a micro-analysis of the video data (Graue & Walsh, 1998; Heath, Luff, & Svensson, 2007). I found the video data

helpful to capture the material and bodily practices the children used to engage with robotic manipulatives and other materials. The video data catch series of children's motions along with subtle changes in their facial expressions, gazes, and gestures. In addition, video data have the potential to reveal unrecognized materials and help us trace how the materials transform in relation to other materials and children. To analyze children's and teachers' embodied practices, Hayashi and Tobin (2015) employed the technique of freezing a shot from video data, re-centering the shot, and zooming in. They found that this strategy was useful to analyze bodily techniques and details that they had neglected in their previous analysis. Similarly, for this dissertation study, I used micro-analysis of the video data to de-familiarize my understanding of how the focal children interacted with the robotic manipulatives and the material environments. For example, while muting the sound, I speeded up and slowed down the video. This technique challenged my anthropocentric views and allowed me to focus on the material aspects of the interaction. As a researcher studying young children by drawing on new materialism, I think we need more studies exploring creative methods beyond generating and analyzing data in verbal and written forms.

Finally, in relation to research methods, I also suggest creatively presenting and sharing research findings through visual images. In Chapter 4, I attempted to visualize the assemblages of Keon, Cubelets, and other materials with edited images. From a new materialist's perspective, I believe that the abstract and colored formats of images can perform as actants that engage readers not only with the images themselves but also with the theorized concepts they represent. Also, given that this dissertation study was interested in young children's engagement in material surroundings, as another de-familiarizing technique for readers, I believe that reformatting visual images can effectively present the idea of the horizontal relationships (Bennett, 2010) among the

materials and young children. I argue that researchers exploring young children's engagement with different kinds of materiality need to use creative strategies for presenting research findings.

For Early Childhood STEM

This dissertation study emphasizes that young children can engage in the ontological and philosophical issues of robots/machine and human's relationships with them through their engagement with robotic manipulatives. In Chapter 2, the focal child, Carlos, navigated the meanings of robots by comparing BeeBots with his toy car. Also, he explored the issue of locus of control over the robots by comparing programming with using his hands to operate the BeeBots. Beyond mastering programming concepts and skills, Carlos engaged with the programmable robots by exploring ontological and philosophical perspectives on the degree of humans' control over robots, the agency of animated machines, and the relationship between humans and robots. I believe this finding suggests that we rethink what young children can learn and experience through their engagement with robotic manipulatives. Ackerman (2013) argued that the value of learning programming for children was not learning how to give instructions to things but learning to distinguish between self-driven and other-induced courses of actions and between inner and outer locus of control. In Chapter 1, I pointed out that the majority of existing studies on robotics in early childhood education addressed the value of young children's experience of robotic manipulatives as a means of learning STEM-relating concepts, skills, and attitudes (see Table 1 again). In terms of the learning content and components of STEM education, I suggest adding ontological and philosophical perspectives on robots/machines and programming as a new and important component of STEM learning.

Also, this dissertation study reveals young children's particular interest in physics while engaging with the robotic manipulatives. In this dissertation study, the focal children commonly

attempted to explore core concepts of physics such as force, energy, motion, speed, weight, momentum, and vector by pushing, locking, and bumping BeeBots and building and following Cubelets. Manufacturers of the robotic manipulatives and teachers intended for children to use BeeBots for programming and Cubelets for learning about sensors and actors. However, even though the developmentally appropriate materials (e.g., BeeBots) were supposed to teach the focal children programming, the children used the programmable robots to engage in more basic scientific investigations about matter, force, motion, and interactions among objects. Also, the focal children explored robotics with a more sophisticated level of knowledge and skill than simply arranging the correct commands to perform specified actions. For example, when Carlos used his hands to operate BeeBots, he was engaging in the issue of what it means to act at a distance. This finding suggests broadening our limited and static view of young children's engagement with robotic manipulatives, that is, the view that robotic manipulatives are only for programming and building. I suggest that young children's engagement with robotic manipulatives can also provide them with opportunities for learning core components of physical sciences (e.g., force, motion, types of physical interactions, energy, and energy transfer) (Next Generation Science Standards, 2013) and applying them to tangible objects.

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APPENDIX A

EXAMPLES OF PRELIMINARY REVIEW ON VIDEO-RECORDED DATA

Summer Robotics Camp						
Date	Day	Video File	Focal Child	Robotic Manipulatives	The Goals of Daily Lessons	The Focal Child's Attempts/ Unexpected Events
6/11/14	D-8	BeeBot-Team 1.MP4	Lucia	BeeBots	Watching a video clip of different types of robots in real life	Saying anything Just watching Sitting between Samuel and Lisa
6/11/14	D-8	Free play 1.MP4	Carlos (with Samuel)	BeeBots	Creating a BeeBot story and planning a grid based on the story	BeeBot battle (pushing/bumping) Using clips to connect two BeeBots
6/11/14	D-8	Cubelets-Team 1.MP4	Carlos	Cubelets	Distance Sensor/ Drive Actor	Enjoying assembling and reassembling the structures of Cubelets
6/11/14	D-8	Cubelets-Team 2.MP4	Silvia	Cubelets	Distance Sensor/ Drive Actor	Following EJ's behaviors (putting hands above the Distance Sensor) Having block plays with Cubelets
6/12/14	D-9	BeeBot-Team 3.MP4	Silvia	BeeBots	Decorating grids based on team's BeeBot stories	Joining Lisa's team Enjoying decorating her team's grid Enjoying using recycle materials and tape
6/12/14	D-9	Cubelets-Team 1-	Silvia	Cubelets	Robot Building	Having less interest in building

		1.MP4			Project	robots Dr. Lee's one-on-one scaffolding Enjoying block play with Cubelets Focusing on the magnetics of the surfaces of Cubelets
6/12/14	D-9	Cubelets-Team 1-2.MP4	Silvia	Cubelets	Robot Building Project	Changing her interest from Cubelets to Lego blocks
6/12/14	D-9	Cubelets-Team 1-3.MP4	Silvia	Cubelets	Robot Building Project	Using playdough with Dr. Lee
6/12/14	D-9	Cubelets-Team 2-1.MP4	Lucia	Cubelets	Robot Building Project	Changing the targeted robots while planning and designing Deciding to make a girl robot (name: Juliana) Liking to use recycled materials Decorating her robots
6/12/14	D-9	Cubelets-Team 2-2.MP4	Lucia	Cubelets	Robot Building Project	Having difficulty in attaching arms to her robots Putting wheels (Drive Actors) and adding more Asking help from EJ
6/12/14	D-9	Cubelets-Team2-1.MP4	Carlos	Cubelets	Robot Building Project	Only using Cubelets Liking to building a standing and cleaning robot Having difficulty in fixing his robot stand Spending a lot of time to build, test and fix his robot

						Calling Silvia's robot a baby and weak
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Saturday A.L.T Program					
Date	Day	Video File	Focal Child	Robotic Manipulatives	The Focal Child's Attempts / Unexpected Events
10/4/14	D-3	BeeBot1.MP4	Silvia	BeeBots	Decorating long roads for BeeBots Building a town with girls Trying to program BeeBots by using commands (not using her hands) Dramatic play with BeeBots (Son BeeBots and parents, restaurants)
10/4/14	D-3	BeeBot2.MP4	Silvia	BeeBots	Making a trap Blocking and locking BeeBots Using wooden blocks to make a thicker structure
10/4/14	D-3	BeeBot3.MP4	Silvia	BeeBots	Adding strings, tape, a box to the thick blocks
10/4/14	D-3	Cubelet1.MP4	Keon	Cubelets	Sorting all types of Cubelets according to colors and types. Randomly assembling Cubelets Focusing on the Drive Actors Arranging Cubelets in a long row
10/4/14	D-3	Cubelet2.MP4	Keon	Cubelets	Sorting all types of Cubelets according to colors and types again. Assembling all Cubelets in a big square Watching the assembled Cubelets spinning together Focusing on the Drive Actor and the Bar-graph Actor together
10/4/14	D-3	Cubelet3.MP4	Silvia	Cubelets	Looking at the surfaces of Cubelets Randomly assembling

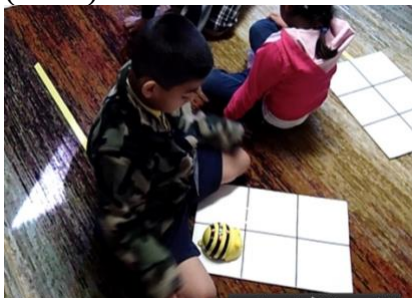
					Cubelets Asking for help from a teacher to make Cubelets move
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APPENDIX B

EXAMPLES OF WRITTEN AND VISUAL TRANSCRIPTIONS

Project	2014 Fall, ALT
Date	10-25-2014
Vide File	10-25-2014-BeeBot 2
Focal Children	Carlos
Place	Library Room
Context	Different sizes of grids are placed in the room. Children can use BeeBots on the floor and tables.

(00:34)



Jacob looks around the Bee-Bots class. The teacher gives a Bee-Bot to him. He goes near the grid boards and chooses a 2x3 grid board. He says “I need it!” He sits on the carpet. He decides where to make his Bee-Bot move on the grid board. He gives the sequences of commands by himself.



He attempts to give many commands at once to move his Bee-Bot repeatedly. However, when errors happen and his Bee-Bot goes out of the grid, he uses his hand to make his Bee-Bot go back on the grid board without stopping.

(04:34)



For a moment, he stops playing with the Bee-Bot and looks around. He puts his Bee-Bot on the line on the carpet. He measures how many steps the Bee-Bot needs to go along the length of the line. He gives the sequence of commands by himself.

(05:34)



He looks around again and picks up one more Bee-Bot. He brings two Bee-Bots to the table. He gives as many forward commands to both Bee-Bots as he can. He watches how two Bee-Bots bump each other. Whenever Bee-Bots miss each other, he uses his hand to make them stand facing each other again.



While looking at two moving Bee-Bots, he notices boxes near them. He puts the boxes in front of the Bee-Bots. He puts different objects (a tape and a tumbler) near them. He watches to see whether his Bee-Bot can move the objects.



He puts one Bee-Bot on the opposite side of the other Bee-Bot. Between them, there are two boxes. He randomly gives many commands and watches how they move together.



He drives two Bee-Bots to the wall and surrounds around them with different materials. He picks up blocks on the carpet and uses them, too. He says to people in the room, “Hey, let’s see how stronger our Bee-Bots!” When Bee-Bots move objects and move randomly, he mumbles “Oh, no! No!”

(10:34)



The teacher says, “Oh, Bee-Bots beat you?” He stops the Bee-Bots and says, “They are super strong.” The teacher agrees with him, “Yes, they are so strong enough to move many stuffs.” He sits on the table and looks at a pumpkin on the bookshelf. He says, “Let’s see they are super strong enough to move a pumpkin!” With the teacher’s help, he moves the pumpkin on the table.



Before moving the Bee-Bots, he goes to the block room and brings back two long blocks. He uses them to block the Bee-Bots from going in different directions. He just gives several forward commands to the Bee-Bots. The pumpkin shakes but does not move. He adds one more Bee-Bot and gives many forward commands to all three Bee-Bots. He says, “You will better work!”



The pumpkin is shaken by the Bee-Bots but still does not move. He tries to give more forward commands. When he moves the blocks aside, the Bee-Bots move around the pumpkin in a circle. He says, “These are very hard to work moving this pumpkin.”



He puts two more Bee-Bots on the table and keeps giving forward commands to all five Bee-Bots. He puts blocks around them to make the Bee-Bots stay in the space. However, the pumpkin does not move.



He changes the arrangement of the objects on the table. He attempts to block the five Bee-Bots so they can't escape. However, the Bee-Bots move randomly, and they get past the objects.



He brings several thick books from the bookshelf. He says, "More books. Heavy books!" He uses them to block the Bee-Bots. He says, "We have super heavy books." He watches to see whether the five Bee-Bots can push lots of objects around them and escape from them. For a moment, he takes out some books and watches again how the Bee-Bots work.

Project	2014 Summer, Robotics Camp
Date	6-11-2014
Vide File	6-11-2014-Cubelets 1
Focal Children	Lucia
Place	Library Room
Context	Lucia has an individual work time to design her Cubelets robots. EJ and Lucia talk about her robot.

(19:50)

Lucia starts drawing something.



(21:13)

Lucia shows her engineer log (her planning sheet for making a robot). She has drawn a butterfly-shaped robot as her initial plan for making her own robot.

EJ: Oh, do you want to make a butterfly robot?

L: (nodding her head)

EJ: Can your robot do something?

Lucia: He can fly...um...he can walk! When he falls down, he has wheels on here (pointing to her chest).

EJ: Do you think you can make this robot can fly with these Cubelets?

Lucia: Then...he can walk! He has the wheels here (pointing to her chest again). Then, he can have [wheels on] his arms like this (pointing to her arms) and he can put wheels on the back (pointing to her back) and here (pointing to her feet). Then, he can do everything!



L: (coloring her drawing of the butterfly robot)



(24:07)

EJ: What your robot can do?

L: (doesn't answer)

EJ: You can make ... um... there are many other robots. You can make a cleaning... and... and....

L: Oh! I want to make a cleaning butterfly robot!

EJ: Cleaning butterfly? Or, cooking butterfly?

L: No, cooking is boring!

Carlos: (while building his robot with Cubelets, he overhears) Cooking is fun!

EJ: Or... your robot can draw something with this pen. Or...

L: It's a cleaning butterfly! (She keeps focusing on coloring the butterfly robot).

EJ: Do you think your robot really can fly?

L: Yes.

EJ: Are you sure you can make your robot fly with Cubelets?

Lucia: (smiling at EJ and shaking her head)

(32:18)

L shows the drawing to Cho but she is busy talking with Carlos.

L comes to her space and continues to draw and color.

L: My robot can fly! Ms. Teacher! Ms. Teacher (showing the drawing)

EJ: Wow! It's very cute butterfly! The robot has the butterfly shape. How will you make this with Cubelets? Tell me what is this. What kinds of Cubelets will you use?

L: Square.

EJ shows Lucia a chart presenting different kinds of Cubelets.

L: Umm. That one (pointing to the recycled materials)

EJ: Oh... recycle materials?



L: I am going to use this (a small box). I gonna open it and cut it. And then make it squares and pull them as wings.

EJ: Wing?

L: Yes.

EJ: Alright.



L: Here here... here... here ...here... My robot has wheels on all of his body. Wheels, everywhere! My robot has wheels everywhere on the body.

EJ: (smiles) Lucia, do you think you can do that?

L: Yes.

EJ: Okay. That's all? Or is there other thing something special? Another one?

L: And my butterfly can pick it up.

EJ: Pick it up what?

L: (sigh) Clean up my room?

EJ: How will you put the Power?

L: In the back. I don't care. My robot will be ... ugly. (cleaning up the pencil basket)

EJ: What kinds of sensor will you use?

L: This one. (light sensor)

EJ: Light?

L: In the light, he can turn on my leg.

EJ: The light sensor cannot turn.

L: I can tell... he (pointing to the light sensor).... He can turn.

EJ: No, the flash light can turn on the light. One has light... he can make my light. Is that flashlight you need?

L: What flashlight you mean? Sorry?

EJ: It makes light. Do you remember?

L: Yes.

EJ: So you want to make your robot makes light during the night or in the dark. It means you need to put the flash light (pointing to the chart) to your robot. Where do you want to put the flash light?

L: (pointing to the top) This is eyes. When it is night, he can turn on his eyes and see... and I can see him!



EJ: So, you means it sees...mean you need Distance Sensors. Do you need Distance Sensors too?

L: Yes.

EJ: How many?

L: Four to five? That's my plan. My butterfly is going to be giant like that! (pointing to the statue in the corner of the room)

EJ: How many flash lights do you want to put here too in front of the robot? So, the flashlight.. one or two? You can choose.

D: Three?

EJ: How about sensor? You need also sensors.

(43:24)

L: I need wheels, too! Wheels come to here and here.



EJ: Wheels.. here... two or four?

L: Two wheels.... Two drive. ... (seeing the chart) Do we need this? (the green one).

EJ: What do you think?

L: It (the robot) can fall.

EJ: Aha... do you think you need the Passive Cubelets? How many do you need?

L: My robot is Juliana!

Lucia's Engineer Log

My robot's name is Juliana

1. My robot looks like below.

2. My robot can do ...

Smell, walk,
fall down all body has wheels for moving
pick something up
clean up my room

3. What kinds of cubelets I used...

	Power	Light Sensor	Object Sensor	Flashlight	Passive	Drive
4						
3						✓
2						✓
1	✓		✓			✓
Total	✓		✓			3