

ABSTRACT

Title of Document: THE EVOLUTION OF SCIENCE
OWNERSHIP IN LEARNERS ENGAGED IN
DESIGN AND TECHNOLOGY USAGE

Jason C. Yip, Doctor of Philosophy, 2014

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Studies

In my dissertation, I set out to explore the following research question on bridging: *How does ownership evolve as learners engage in a guided inquiry-based science learning environment focused on design and technology usage?* My dissertation explores a case study of four learners involved in an afterschool program called Kitchen Chemistry (KC). KC is a nonformal learning environment in which learners engage in scientific practices within the context of cooking. Learners engage in inquiry practices through the development of their own scientific food investigations. In my study I examined how four focal learners come to develop a sense of ownership of science learning as they each develop their own personal food investigations. Using Wenger's (1998) framework of identity formation in communities of practice (imagination, engagement, and alignment), my study shows that a learner's identity and social dynamics from home, school, and informal learning shape and fashion what he or she chooses to own, how ownership is expressed, and how that ownership can both support and hinder a learner's science learning.

THE EVOLUTION OF SCIENCE OWNERSHIP IN LEARNERS ENGAGED IN
DESIGN AND TECHNOLOGY USAGE

By

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Dedication

To my loving wife, Sarah, without whose support, love, encouragement, and commitment this dissertation would not have been completed. She is my wife of noble character; the one I honor and praise.

This dissertation is dedicated to all the students, teachers, professors, and educators that have inspired me to live a life full of service to support life-long learning.

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Chapter 1: Introduction

It is a truth universally acknowledged, that a student in disfavor of science learning, must be in want of an escape. For many years, educational researchers have documented that youth find aspects of traditional school science as disengaging and irrelevant to learners' everyday lives (e.g., Atwater, 1996; Basu & Barton, 2007; Bouillion & Gomez, 2001; Lee & Fradd, 1998; Rahm, 2007). For instance, these three students offer their perspectives of science.

“We really do hate science! It's boring. All we do is read. Learn about plants and spaceships. It's boring and stupid.” – Maria (age 9) and Claudia (age 8) (Barton, 2001, p. 901)

“I don't want to be a scientist. I don't like all of science. It's about boring things.” – Anonymous student (Basu & Barton, 2007, p. 466)

“Scientists are just boring.” – Marvin, a fourteen year old male (Rahm, 2007, p. 525)

Often in school science, teaching science is the equivalent of transferring knowledge from some authority (e.g., teacher, curriculum, software) to the students. Even if materials are innovative, certain pedagogical methods and policy constraints may still push learners towards didactic views of learning (Cohen, 1990). Learners are often obligated to acquire knowledge from these credible and authoritative sources and later reproduce this abstract knowledge as correct answers (Fusco, 2001; Tsai, 2002). For example, teachers often present theoretical knowledge to prepare learners for standardized tests, often without addressing the practical applications of this knowledge for learners' everyday lives (Lee & Fradd, 1998).

Within these environments, students may often work individually to manipulate abstract knowledge only in the classroom setting, but rarely integrate

science knowledge into their everyday lives. Some science classrooms can help learners make personal connections. However, when pedagogical and curricular methods do not attempt to make connections to learners' lives, interests, and experiences, students may continue to have pervasive negative views of science (e.g., Basu & Barton, 2007). Policy makers and school districts also face a second issue: with the rapid growth of technology into society and science, educators need to determine the best ways of developing and integrating innovative tools into science curricula and classrooms. Researchers now face the immense challenge of trying to understand how to best implement technology into classrooms to increase science learning, while at the same time, addressing these issues of learners' disengagement in science.

These issues are not just a problem to produce future scientists. All citizens must be scientifically literate and be able to reason well about complex evidence to make educated decisions about important issues, such as health decisions and environmental policies (Chinn & Malhotra, 2002). Researchers argue that in order to challenge the dominant conception of science teaching, educators need to present science learning as relevant to learners and inclusive of students' diverse perspectives (e.g., Atwater, 1996; Lee & Fradd, 1998). Fusco (2001) argues that for science to be made relevant, learners might need to engage in a *practicing culture of science learning*. A practicing culture makes science relevant for three reasons. First, science learning is situated from learners' own concerns, needs, issues, and experiences both in and outside the classroom. Second, learners are engaged in a process of researching, investigating, developing and implementing their own scientific ideas.

Lastly, the culture of science is created within the context of the broader community of the learners (e.g., teachers, family, friends, neighbors).

1.1 The Need for Ownership of Science Learning

While many researchers advocate for developing learning environments that support learners' personal goals and interests in science, another aspect in understanding learners' motivation and engagement is examining the “noncognitive” factors in learning. For many years, education researchers have deeply examined the cognitive factors in learning (e.g., spatial reasoning and visualization, cognitive load, literacy, information processing). However, an important shift has been occurring in recent years to explore the potential of noncognitive factors (e.g., identity, attitudes, self-efficacy) to better support science learners, particular those that are disengaged and at-risk. For example, the United States Department of Education (Shechtman, DeBarger, Dornsife, Rosier, & Yarnall, 2013) has recently made it a priority to better understand and integrate the non-cognitive factors of grit, determination, and tenacity in learning and technology development and suggest that these factors are just as important to Science, Technology, Engineering, and Mathematics (STEM) learning as cognitive abilities:

These (non-cognitive) factors are essential to an individual's capacity to strive for and succeed at long-term and higher-order goals, and to persist in the face of the array of challenges and obstacles encountered throughout schooling and life. Importantly, we are deliberate not to treat these factors as residing only within the student—it is the responsibility of the educational community to design learning environments that promote these factors so that students are prepared to meet 21st-century challenges (Shechtman et al., 2013, p. v)

Although we know that learners that exhibit grit and tenacity show stronger learning gains (e.g., Duckworth, Kirby, Tsukayama, Berstein, & Ericsson, 2011;

Duckworth & Britain, 2009; Strayhorn, 2013), we do not yet know what role learning environments and noncognitive factors play into influencing long-term determination and engagement. One aspect to grit and motivation that needs further exploration is *ownership in learning*. Specifically, for this dissertation, I define *ownership of science learning* as aspects of control, possession, and investment into aspects of the practicing culture of science, such as idea elaboration, experimental design, hypothesis generation, and evidence-based reasoning. However, further into this dissertation, I explain how my definition of ownership of science learning does not match with how learners perceive this conception.

Ownership of science learning is both a noncognitive factor in learners and an aspect of social learning environments. As a noncognitive trait, ownership can be a powerful way to support students' engagement in science inquiry (O'Neill, 2010; T. O'Neill & Barton, 2005). Many science educators contend this construct is an important factor for initial motivation, engagement, and sustainment in science learning. For instance, ownership can be seen as the entry point for a learner to deeply engage in a science activity (Barton, Tan, & Rivet, 2008). To continue to function as critical agents and problem solvers, learners must have control of their ideas (Elmesky & Tobin, 2005) and develop agency for designing authentic tasks and solutions to solving relevant problems (e.g., Chin & Chia, 2004; Kolodner et al., 2008; Savery & Duffy, 1996). As learners begin to modify, design, and create models to solve problems, this process can further lead to a deeper sense of ownership of learning (Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004). The core assumptions of these studies are that if students were to be able to have ownership in

the learning process, this should lead to greater participation and motivation in the science learning process. As part of the environment, O'Neill and Barton (2005) contend that embedded within a practicing culture of science is the assumption that if learners were to have ownership of the science they were learning, they would be more motivated to learn science. To fully engage in a practicing culture of science, learners would develop control over their environment, create opportunities for more personalized learning, make investments into their learning, and express a sense of territoriality (i.e., this is mine, this is ours).

While there is consensus that learners' ownership can lead to higher engagement, researchers often examine ownership from different perspectives. First, studies on ownership can take an *individual outcome* perspective; ownership in learners is a set of feelings and emotions that evokes a sense of control and possession within individuals and groups (e.g., Pierce, Kostova, & Dirks, 2003). From an individual standpoint, learners' experience, beliefs, goals, and cultural influences shape how ownership manifests. In this view, ownership is something that is achieved, and once achieved in a learner, ownership can provide a means for motivation and engagement in learning. However, ownership can also be examined from a *social process* standpoint. In this perspective, ownership is a dynamic, and generative process that varies moment-to-moment for learners in various social contexts (e.g., Bandura, 2001). Ownership depends on the interacting relationships between learners, teachers, and the context. My study utilizes O'Neill and Barton's (2005) definition: "Ownership is a dynamic and generative process that exists in tension with ownership as an outcome" (p. 299). In this definition, there is the

acknowledgement that ownership is delicate and changing, but is still an innate part of people; thus, ownership exists as the dialectic between process and outcome and the dialectic between individual and social.

1.2 The Purpose and Motivation of the Study

Given O'Neill and Barton's (2005) definition and conception, there is a need to expand our understanding of ownership of science learning. While many researchers cite the importance of ownership for learners to engage in science learning, few studies have explored a deeper understanding of how student ownership evolves over time. For example, science inquiry frameworks such as Learning by Design (Kolodner et al., 2003), Problem-Based Learning (Savery & Duffy, 1996), and Design-Based Science (Fortus et al., 2004) only briefly discuss the need for ownership among learners, but do not go much further in documenting the evolution of ownership. Therefore, this study seeks to better understand how ownership evolves over time for learners. The following research question guides my study:

Research question: How does ownership evolve as learners engage in a guided inquiry-based science learning environment focused on design and what is the role of technology in supporting ownership of science learning?

The term *guided inquiry* in my research question should not be confused with “minimally guided instruction,” a category of instruction that Kirschner, Sweller, and Clark (2006) view as synonymous with constructivist learning, discovery-based learning, problem-based learning, experiential learning, and inquiry-based learning. In Kirschner et al.'s view, inquiry is conducted with little instructional guidance throughout the learning process. Instead, I approach guided inquiry with the same views as Hmelo-Silver, Duncan, and Chinn (2007). From Hmelo-Silver et al.'s view,

guided inquiry utilizes extensive scaffolding and guidance to engage in complex tasks, such as developing sense-making skills, constructing evidence-based explanations, and designing solutions surrounding a personally meaningful problem.

Better understanding of ownership in guided inquiry based science learning environments is a salient topic for study for many reasons. O'Neill and Barton (2005) point out that within the literature there is an overly positive assumption that that if science connected to learners' lives or encouraged active participation in a culture of science, this would help develop ownership of the knowledge and process of science. In turn, ownership would help motivate learners to engage in science learning. Despite these assumptions, researchers have only started to document the evolution of ownership in learners in science (e.g., O'Neill, 2010; O'Neill & Barton, 2005). Few studies have examined how social, personal, and cultural factors influence how a person interprets ownership and how an individual's own interpretation may change the dynamics of ownership in a context.

In particular, the community of researchers has been unable to consider how to integrate aspects of ownership into the design of science curricula and technology and how professional development can help science teachers facilitate students' ownership in the classroom. An implication from this study is a detailed examination of how learners develop ownership in a guided-inquiry science learning environment and what factors might cultivate ownership. This knowledge can help us to better conceptualize how to develop curriculum that facilitate and nurtures ownership to support learners taking on larger tasks of their choosing and give implications for facilitation in teacher education.

Specifically, if developers can understand how ownership evolves and how to cultivate ownership among learners, technological tools can be designed to take advantage of this knowledge. Technological tools are already attempting to make learning more personal for learners. For example, Scardamalia's (2002) work on computer supported collaborative learning advocates that technology can enable cognitive responsibility - the conditions needed so that the responsibility for the success of a classroom is distributed to all members, as oppose to just being concentrated in the leader (i.e., teachers) - to be distributed among students. This study seeks to find ways to derive implications on how designers can think about learners' ownership and responsibility into the inception of the technological design.

Lastly, this study will help to better understand the connection between ownership and science learning. Rivet and Krajcik (2008) argue that contextualizing science instruction, which involves utilizing students' prior knowledge and everyday experiences to help learn science, has a strong positive correlation to promote gains on standardized science exams. However, they were unable to explain the cognitive mechanisms as to why this occurs. I argue that developing a fuller picture of how ownership evolves in guided inquiry-based science learning can lead the community closer to understanding the connection between personal ownership and science learning. A development of a conceptual model of ownership in science learning may be the basis for understanding the connection between learning and ownership for a future study.

1.3 The Definitions and Assumptions of Ownership of Science Learning

The term ownership is often conceptualized as a noun, such as the state and

legal right of being an owner, the rights of possession and control of an object, and the feelings and affect for control by a person or group (see Chapter 2 for more detail). Ownership can also refer to the actions and behaviors of control, possession, and responsibility towards material or non-material objects that may link back to a central focus on a learner's self-identity. From this perspective, learners do not simply exhibit a single action at a specific time to own a single object that expresses a single identity. Instead, learners' actions may indicate an ownership of multiple objects that point to various identity constructs. For example, a learner might choose to spend an inordinate amount of time with a piece of technology in science learning. While ownership is expressed for the single piece of technology, other aspects might be in control for the learner, such as the role one plays with technology, the ideas generated from its usage, and the process of using the technology. A single action of control may be a manifestation of a learner's self-identity and the multiple views a person has of him or herself (e.g., learner as a scientist, designer, technology expert, investigator). While the focus of this study will examine specific aspects of ownership in science learning, such as ownership of knowledge, ideas, and learning processes, this study is not limited to other objects (e.g., artifacts, space, technology) that may provide an insight into a learner's self-identity in science.

1.4 Context of the Study

To examine the evolution of ownership, this study examines a *life-relevant learning* environment called *Kitchen Chemistry (KC)*. I define life-relevant learning (LRL) as a guided inquiry-based learning environment that engages learners in science through the pursuit of personally meaningful goals. LRL can be developed for

both formal school settings (e.g., Bouillion & Gomez, 2001) and informal learning activities (e.g., Fusco, 2001). KC is a LRL program that occurs after school and in summer camps. Our research group in the Human-Computer Interaction Lab has been developing KC as a way for learners to engage in authentic scientific practices (Chinn & Malhotra, 2002) through supporting learners' own design and implementation of investigations into everyday cooking science. Learners engage in cooking activities and discussions that strive to help explain causal mechanisms of observed phenomenon and the relevance of science knowledge in students' everyday lives. Specifically, participants use mobile technologies to help them in the design of their investigations. Here, learners bring their own interests, experience, and ideas to be direct producers of the activities in the program.

This study explores the evolution of ownership of four focal learners in KC as they design a series of personal food science investigations. Other researchers have attempted to increase participation and ownership in school science learning through guided inquiry-based learning environments that emphasize *design activities*. The research has shown that learning and engagement through designing artifacts, ideas, investigations, and other creations can promote ownership (e.g., Kafai, 1996; Paavola, Lipponen, & Hakkarainen, 2004; Papert, 1980; Shaw, 1996). My study builds on this research where learners had a chance to develop aspects of ownership for processes, ideas, and artifacts. The social settings, as well as the cultural materials, allow for social interactions and processes that help learners develop both individual and external constructs (Shaw, 1996). Each of these parts and components dynamically interact and influence each other; nothing remains static.

1.5 Overview of the Document

The following is the outline of my dissertation. First Part I outlines the setup of the study.

- Chapter 02: Related literature and theoretical framework - I review the literature on ownership and learning. Specifically, I claim that ownership is an internal trait of people that is affected and influenced by social factors and contexts. I also review the science education research literature on the use of the term “ownership” and present the patterns and gaps to our understanding. I also present the basis of my theoretical framework.
- Chapter 03: Methodology – I describe my research design and explain my use of case studies for the research question. I outline how I collected my data and how I analyzed the data. I briefly frame the organization of the case studies and the analysis.

Next, Part II goes into the details of the study.

- Chapter 04: Context of the study: I outline the background and context of the four case studies in Kitchen Chemistry.
- Chapter 05 – 08: Case studies on Arman, Ben, Freddie, and Donna – For each learner, I present three to four vignettes and my analysis. At the end of each chapter, I analyze the evolution of ownership through the use of Wenger’s (1998) imagination, engagement, and alignment.
- Chapter 09: Cross-case analysis – I analyze and discuss the four cases across three grounded categories: the characteristics of ownership, the cultivation of ownership, and the tensions and dilemmas presented.

Finally in Part III, I examine the significance and implications of this study.

- Chapter 10: Discussion and implications – I summarize my findings through my research questions and explain the significance.
- Chapter 11: I discuss my theoretical contributions for this dissertation. I made recommendations for education practitioners and learning environment and technology designers.

Chapter 2: Related Literature and Theoretical Framework

To begin to unpack how researchers have examined ownership, I considered how ownership was conceptualized both within and outside the field of education. First, I present two parts to ownership: the *dominant individual outcome* perspective and the *social influences on ownership* standpoint (2.1). I present what these two perspectives are and what limitations exist in both. Second, I review science education research literature that use of the term “ownership” (2.2). I consider the meaning of ownership in the education research literature. Third, I examine the patterns found in the educational research on the use of the term “ownership” in science learning (2.3). Fourth, I propose three gaps that exist in the knowledge of ownership of science learning (2.4). From these patterns and gaps in the literature, I justify my research question, “How does ownership evolve in learners in guided-inquiry based STEM learning environments focused on design?”

From this review, I present an argument for the theoretical framework I will be using in this dissertation to investigate my research question (2.5). Lastly, I summarize the current state of the literature with a review of my primary research question, “**How does ownership evolve as learners engage in a guided inquiry-based science learning environment focused on design and technology usage?**” (2.6)?

2.1 Two Perspectives of Ownership

In this section of the literature review, I examine studies from organizational theories from management and developmental psychology to better understand a

concept called “psychological ownership.” Studies on ownership are partitioned into silos; the ideas of ownership from management and psychology rarely intersect with STEM education literature. Therefore, I attempt to bridge these two research spaces through an examination of ownership from the individual outcome and the social process perspective.

2.1.1 Ownership as an Individual Outcome

Scholars from diverse fields have attempted to define ownership through psychological, organizational, sociological, and developmental theories. In their extensive review, Pierce, Kostova, and Dirks (2003) conceptually define *psychological ownership* as the “state where an individual feels as though the target of ownership or a piece of that target is theirs” (p. 5). The researchers conceptualize psychological ownership in four features:

1. Ownership manifests as feelings of possessions.
2. Ownership is an important and positive motivator for people in their behaviors.
3. Ownership can be detrimental to collaboration and stewardship.
4. Individuals and groups can exhibit ownership.

Ownership manifests as feelings of possessions. First, ownership is expressed in possessive emotions commonly associated with ‘my’, ‘mine’ and ‘our.’ Here, individuals might “feel” as though the target of ownership is theirs. Feelings of ownership are a complex state that represents a condition of thoughts, beliefs, attitudes, emotion, and affective sensation (Pierce, Kostova, & Dirks, 2001). Psychological ownership is different from other motivational bases - such as

commitment and satisfaction - because of the conceptual base of possessiveness. Van Dyne and Pierce (2004) contend that the explanatory power of psychological ownership is fundamentally different because ownership answers the question, "How much do I feel this object is mine?" However, commitment answers the question, "Should I maintain my status to this object?" while satisfaction asks, "What evaluative judgments do I make about this object?" Second, psychological ownership is reflected in a relationship between an individual and an object (either material or immaterial) in which the object has a close connection to the individual's self and becomes part of the extended self. Etzioni (1991) contends that this relationship is a "dual creation, part attitude, part object, part in the mind, part real" (p. 466). The object itself does not have to be a physical entity, but can be ideas, artistic creations, arguments, words, academic products (Pierce, Kostova, & Dirks, 2003), and information (Raban & Rafaeli, 2007). Psychological ownership is very complex and tied to the cognitive and affective core of an individual. In the cognitive state, there may be feelings of pleasure, self-efficacy and competence. In the affective component, feelings arise when others lay claim to the targeted objects of either personal or collective ownership. Other related concepts with psychological ownership in organizations are stewardship, risk for the organization, protection, caring, nurturing and developing the target of ownership (Pierce et al., 2001). Feelings of ownership can lead to the expectation of accountability of others and self. Pierce and scholars (2003) describe that individuals with strong feelings of ownership tend to hold others accountable for influences on the targeted object.

While ownership has been mainly examined in psychology and organizational

research, particularly within adult populations, there are lessons and theoretical concepts that are transferable to the field of education. Ownership is considered an inherent characteristic and trait of people that is independent of age, culture, and society (Furby, 1978). Scholars suggest that psychological ownership develops because of the basic human need for control and possession. Human development researchers contend that the nature to own is developed in early childhood (e.g., Furby, 1978, 1980; Lewis & Brooks-Gunn, 1972). For example, Furby (1991) suggests that young children develop a personal sense of competence and satisfaction as they increase in the ability to control objects.

Ownership is an important and positive motivator for people in their behaviors. Pierce et al. (2001) suggest that the roots of psychological ownership are found in three basic human motives: 1) efficacy and effectance, 2) self-identity, and 3) the need for belonging. For efficacy and effectance, ownership gives individuals ability to explore and change their environment for their own preferences. This control over action gives individuals a sense of efficacy and satisfaction. Avey, Avolio, Crossley, and Luthans (2009) aptly sum up the connection between ownership and self-efficacy, “I need to do this task, I can do it, and I therefore own the responsibility for achieving success” (p. 177). For self-identity, our possessions, whether they are material or immaterial, are symbolic expressions of ourselves (Dittmar, 1992; Porteous, 1976; Rousseau, 1998). What we possess often defines who we are and expresses this identity to others. For example, people may identify themselves as an artist, an athlete, or a scholar. The target of ownership, be it a painting, a winning goal, or a research paper, sets individuals apart and contributes to

their personal identity. In particular, when the individual's self-identity is closely linked to the target of ownership, researchers theorize that there will be a stronger initiative to protect, maintain, and develop responsibility for the object (Dipboye, 1977; Korman, 1970). From this increased responsibility and connection to self-identity, an individual may attempt to motivate others to share his or her vision or perspective on the object or develop an exclusive control. Lastly, people may also identify themselves through membership and feelings of ownership towards a specific organization, mission, or purpose (Rousseau, 1998). Albert, Ashforth, and Dutton (2000) suggest that this sense of belonging allows individuals to gain an organizational identity and engage in a process of identity change. The sense of belonging is also explained through the need for territory or space. For example, Porteous (1976) observes that personalization and control over space provides a sense of security and identity; this can be symbolically captured in what people call a "home." This home does not have to be a physical house or dwelling, but instead an individual needs to feel a sense of belonging. Here, individuals may feel ownership through the attachment of an organization or persons they perceive to connect with (Pierce et al., 2001).

Ownership can be detrimental to collaboration and stewardship. Overly possessive feelings and territorialism can be detrimental to collaboration. Brown, Lawrence, and Robinson (2005) suggest that ownership and self-identity are so correlated and tied to each other, that people mark and defend their territory as an extension of themselves. For example, when people hold to a set of arguments and beliefs, their defense of those ideals may be a protection of their own self-identities.

When individuals form strong feelings of ownership over physical spaces, ideas, roles, relationships, and other physical or non-physical objects, they may attempt to mark these possessions as exclusively their own. If the possibility of infringement or threat to take ownership away from those objects occurs, individuals may engage in protective territorial behaviors that attempt to maintain levels of ownership.

Brown and colleagues (2005) note that “the stronger an individual’s psychological ownership of an object, the greater the likelihood he or she will engage in territorial behaviors” (p. 580). Pierce and scholars (2003) call this threat, “the dark side of ownership” (p. 30). Here, individuals may feel so attached to the object, they feel a need to have exclusive control over it or engage in behaviors that might appear overly authoritative in groups. For example, a high achieving learner may be very possessive of the grades he or she earns. In this case, if the student collaborates in a group he or she thinks will not help him or her get the higher marks, the possessive student might engage in imposing and authoritative acts that may not support mixing ideas or benefit the well being of a group. The student may also choose not to help others in the class because this might put him or her in a vulnerable position of loss for the object. This psychological ownership for high grades may overwhelm the student with feelings of burden, which may also lead to stress and frustration.

Individuals and groups can exhibit ownership. Lastly, psychological ownership can occur not only within an individual, but groups and members of organizations can show a sense of ownership. Scholars contend that psychological ownership for groups can be defined as a possessive feeling that some object is ‘ours’ (e.g., Albert et al., 2000; Pierce et al., 2001, 2003; Van Dyne & Pierce, 2004). Pierce,

Rubinfeld, and Morgan (1991) suggest that ownership is a “bundle” of rights for individuals, that is, the right to voice an opinion, the right to make decisions that impact the object, and the right to have information on the target. When these rights are developed in organizations, groups of people can develop ownership for a specific target, such as a project or the organization itself. For instance, a strong culture of ownership in organization is developed when members have a right to make decisions and develop a sense of responsibility to invest time and energy for the advancement of the organization (Rodgers & Freundlich, 1998).

2.1.2 Ownership as an Individual Construct Influenced by Social Factors

Authors that take an individual outcome view of ownership often describe the construct as robust and as a product to be achieved. In this individualistic perspective, every person has feelings of ownership; therefore, the goal of innovations, curriculum, and teachers is to direct these innate feelings towards means that help learners engage more in the learning process. The individual only perspective focuses solely on self-identity as the core of a person with ownership as the expression of the inner-self. The perspective I take in this dissertation is that while ownership *is* an innate characteristic and property of people, ownership is also greatly dependent and *influenced by* interactions with social relationships and power structures within a person’s experience (Cornelius & Herrenkohl, 2004).

With the exception of O’Neill and Barton (2005) and O’Neill (2010), researchers are generally not examining ownership as a dynamic construct that changes and shifts based on the interdependent relationships between social and personal interactions. Examining social factors in ownership lead to important

questions such as what exactly gets owned for learners, when does something get owned, how do the factors in a social context cultivate learners' ownership, and how does ownership evolve in specific contexts. Culture and context from the individual perspective is seen as an influence on self-identity and ownership, but studies here tend to examine this impact from a macro-perspective (e.g., Pierce et al., 2003). Here, cultural values and beliefs are an overarching set of conditions that influence over a person's self-identity and expression of ownership. Therefore, self-identity and ownership is a product of a larger culture (e.g., laws, norms, customs, rules), as opposed to a dynamic process in which context, self-identity, and ownership dynamic impact each other. Without better understanding of ownership and its possible fluid nature, I argue new designs for curriculum, instruction, and technology might be missing essential features that help to foster ownership among learners.

2.1.3 Interactions with Social Factors and Ownership

As stated before, individual ownership can be greatly influenced by social factors, such as interactions with community members, curriculum, and technology usage. Sharples, Taylor, and Vavoula's (2010) research on mobile technology tools for learning raise an important point from the social process perspective: "Finally, the view of learning as the process of coming to know through continuous conversations across multiple contexts amongst people and interactive technologies, raises the issue of where the ownership of learning lies" (p. 22). Instead of assuming that ownership lies as an innate feeling in an individual, Sharples et al. argues that the entire learning system (e.g., teachers, students, curriculum, technology) and the interaction of its parts is responsible for ownership. The researchers contend, "The agency is not with a

single individual, nor with the technology; it lies in the democratic synergy between the different parts of the system with the aim to advance knowing” (p. 22). In this case, ownership for learners evolves as each part of the system supports or denies learners of opportunities for agency. As an individual’s ownership is impacted by social factors, the evolution of the individual’s ownership then changes the interactions in that social realm.

If the responsibility of ownership lies then within the entire system, keeping ownership at the forefront of student learning may be more difficult than scholars and educators first realized. For social factors, the tasks that are distributed to a group of learners can affect how ownership processes takes place. Eales, Hall, and Bannon's (2002) work on computer supported collaborative learning processes in the workplace found that although ownership of a problem can be a strong form of motivation for learning, workers might also quickly “surrender” their ownership of the problem “for a reduction in anxiety related to their own skill development” (p. 315). Eales et al. claims that learners’ experience in schooling teaches them to see learning as being measured (i.e., grades) and thus aspects of learning are solely motivated by extrinsic rewards. From a social process perspective, even if the problems or tasks are initially owned by a group, but the distributed tasks do not engage and support each member’s own personal knowledge, ownership may fail to take root. In this case, learners develop an inauthentic motivation towards their tasks and are more willing to give them up for some extrinsic benefit. The researchers conclude, “perhaps because it (ownership) is so compelling, so demanding, this type of motivation is also very fragile” (p. 314).

Although support of ownership needs to take place in the community, the lack of ownership can also be traced to power relations between students and teachers. The term power carries a lot of theoretical weight. I use Cornelius and Herrenkohl (2004) conception of power, whereby power is not an external force that an institution imposes or something a person or group possess. Instead, power is relational and manifests in interactions between agents. Cornelius and Herrenkohl identify ownership of ideas as a manifestation of power in student-teacher relationships. Ownership of ideas implies a relation in power between individuals and concepts. In the realm of education, “whomever students perceive as having ownership of an idea - either themselves, their teachers, their textbooks, or their peers - will influence the relation that the student has to the idea itself” (Corenelius & Herrenkohl, 2004, p. 470). Based on this definition, if a student perceives that a teacher owns an idea or knowledge, the teacher may be seen as more powerful than the student. Therefore, students’ expressions of ownership of knowledge are not standalone and separate from adults, but are tied up with the attitudes, participation and perspectives of adults.

Mannion (2007) points out that even adults are affected by their own experiences as students, their conceptions of childhood, and their current view of students. In this respect, without a full understanding between the relationships between adults and youth, adults can explicitly or tacitly act as gatekeepers to students’ perspectives on ownership and the quality that voices are expressed. The acquisition of knowledge is not value neutral. Instead, when an individual knows that some knowledge belongs to some people more than others (e.g., teachers), this can affect how a person engages in the learning process (Goodnow, 1990 as cited in

Cornelius & Herrenkohl, 2004). Teachers' own views about student-centered learning can dictate how learners develop ownership (Pedersen & Liu, 2003). Thus, autonomy and ownership for learners can be facilitated or denied through the actions of persons in power.

2.1.4 Needed Research in Ownership of Learning

Although the social process lens provides an in-depth examination of the evolution of ownership in learners, this set of literature has only started to take shape. The dominant literature on ownership tends to focus on the individual psychological aspects of learners. The social process perspective is still in development and more research needs to be conducted to better understand of how ownership evolves in different individuals and contexts. For instance, Cornelius and Herrenkohl's (2004) work on power relations, classroom participant structures, and ownership call for more studies that account for how different types of learners come to accept and develop ownership when affordances of power are made to them. Specifically, the research community does not yet understand how participation structures in classrooms allow learners to engage and develop ownership. We also do not fully understand how a transformation in power relationships that allows learners to take on more responsibility and agency for their learning affects their ownership. I contend that more work can be done utilizing this perspective and expand the ways of explaining how ownership evolves overtime for learners. While researchers have traditionally connected ownership to an individual's self-identity (e.g., Pierce et al., 2003), there has been a lack of examination how participation in a community of

practice changes ownership and how that change in ownership structures also influences the community and self-identity.

2.2 Ownership of Science Learning

In this section of the literature review, I examine the current literature on ownership of science learning. While I have covered both individual outcome and social processes of ownership, ownership of science learning has its own aspects to understand. I begin this section by first covering the current definitions and views of ownership of science learning. Next, I address the tensions and conflicts of ownership in science learning. Finally, I address the gaps that persist in this literature on ownership of science learning.

2.2.1 What is Ownership of Science Learning?

Only a few articles exist that directly examine ownership and science learning. The definition of ownership in science learning is not quite agreed upon, but a consensus exists that ownership in learners generally leads to greater motivation, active participation, and increased responsibility. One key aspect of ownership in learning is the ability to have choice into the problem and processes of learning. Under problem-based learning Savery and Duffy (1996) argue that learners need ownership over both the *problem* and *process* of solving that problem. Ownership over a problem means that learners buy into the relevance, goals, and value of a particular problem. However, teachers often give learners ownership of a particular problem, but learners do not have full control over the processes of solving the problem. Learners need the ability to choose their own strategies and make their own

decisions. In literacy education, learners need independence and choice of what to learn. Dudley-Marling and Searles (1995) contend that students need to choose what they want to read and write about. Enghag and Niedderer's (2008) study on physics small groups defined student ownership as the ability to have action of choice and control, both as a group and as an individual.

More recently, O'Neill and Barton (2005) defined ownership in science learning as a complex and multifaceted outcome and process that involves relationships between other students, teachers, and science learning. Ownership of science learning manifests as five themes (p. 296):

1. Positive and empowering perceptions of self in relation to science and school (self-identity)
2. Purposeful expenditure of human, social, and material capital (investment)
3. Expressions of pride in science, self, school, work, and neighborhood (pride)
4. Agency through personal and community changes (choice)
5. Positive and realistic personal and community changes (contributions)

O'Neill and Barton (2005) discuss that ownership in science learning is not just an individual or social process, but that both co-exist together. At the personal level, students own experiences, beliefs, and identities affect how they express ownership. From the social standpoint, learners outwardly express their ownership to others in the learning environment, such as pride and views of contributions. The context of the science learning environment is critical for supporting or denying ownership.

A second key aspect in ownership in science learning is the positive perception between ownership and motivation in science learning. A large portion of

the literature on science education and ownership emphasize the need for ownership of science learning to increase motivation and engagement. Prain and Hand (1999) suggest that control over learning was an important link in positive attitudes in writing tasks in elementary school science. The ability to develop their own thought and choice over writing tasks influenced how learners were motivated to write science tasks. Learners developed student responsibility and investment over the program, which was critical for deeper learning. Crawford, Krajcik, and Marx (1999) observed that in middle school science, as students became invested into their own learning, the group productivity increased. Learners became invested into their own learning through volunteering to stay during lunch and afterschool to take responsibility for projects. Evidence for productivity included generating new ideas, testing ideas, and developing group reports. As learners became experts in a particular responsibility, they took on new roles. Kentish (1995) observed that as ownership over the learning process increased, student motivation in an undergraduate physics program became more apparent. From elementary to undergraduate learners, ownership in science learning plays an important part in motivation, engagement, and investment.

A third aspect of ownership in science learning is that ownership needs cultivation and support. O'Neill (2010) work on ownership through an examination of how specific factors she implemented in her science classroom fostered ownership in her students. Certain factors included giving learners space in the classroom, providing them with her home phone number, and allowing them to take responsibility for managing a Class Zoo and Word Wall. She examined two vignettes

from her work in her classroom and found that fostering ownership is possible under traditional science classroom constraints.

The fourth aspect of ownership in science learning is that what students own in science learning is varied. Some of the STEM education research literature does acknowledge the complexity of targets. O'Neill (2010) determined that what learners own in science is multidimensional and complex and is relational and context dependent. Understanding these dimensions in context is key to examining ownership. Bloom (2001) identified multiple targets that learners owned, such as ideas, discourse, products, classroom community, dialogue, learning, knowledge, and content and process of argument. Fields' (2009) comparison of science summer camps acknowledge different targets such as research projects, creative and critical work, design and implementation of research projects, and mastery of a tool and piece of technology. Kamberelis and Wehunt's (2012) examination of hybrid discourse practices in science learning of fifth graders acknowledged that learners can own persuasive discourses, process and products of laboratory work, and new and unfamiliar sets of language practices. Berland and McNeill (2010) state that learners can own scientific practice, particularly aspects of argumentative discourse. Each of these authors breaks learning down into finer grained targets, which allows the reader to examine what exactly the learner might own and at what period of time.

2.2.2 Tensions and Conflicts in Ownership of Science Learning

Although an overwhelming consensus in the literature agrees that ownership in science learning is an important motivator for learners' engagement in science and learning, a few articles in the STEM education literature do discuss some of the

tensions that exist in ownership of science learning. From the literature in psychological ownership, a “dark side” of ownership exists that can derail collaborations and promote self-interests (e.g., Pierce et al., 2003). A detailed understanding of the problems and conflicts that exist on ownership is important for supporting and balancing learners in power dynamics.

First, ownership of science learning can produce tensions between students and teachers. In Bloom's (2001) study on students' argumentation about density found that arguments in science are a chaotic system. Conflict arises for teachers whether to control heated discussions and whether or not to place constraints on the argument or limit student behaviors. In this case, the teacher, acting in the role of power and control, “has the potential to limit or negate student ownership over the ideas generated” (p. 479). In this case, ownership of science learning in students can create necessary arguments, but can also quickly spiral out of control. Cornelius and Herrenkohl (2004) comment that ownership of ideas is a struggle between teacher-student power dynamics in the classroom. O'Neill (2010) recognizes that classroom culture and structures impact learners' ability to take on ownership. In schools, there are required demands and structures to adhere to. Teachers and facilitators need to give up control and this is often a formidable challenge. Sharing spaces and “letting go” is often difficult and not always possible due to the school structures, classroom structures, and trust and comfort at any given moment.

Second, ownership of science learning might conflict with authentic and legitimate science practices. Hay and Barab's (2001) study focused on two summer camps. Future Camp 97 (FC97) focused on constructionist learning experience;

children worked with advanced computer equipment to create virtual worlds. In this setting, learners could take complete control and ownership of their projects and personal goals. Scientists Apprentice Camp 97 (SAC97) emphasized legitimate peripheral participation; children could work together with a practicing scientist on an authentic research problem. In this case, children had less control over the project and the labs. Since this was a real research problem with far reaching implications and consequences, the practicing scientist directed almost every aspect of the research methodology. The scientists had ownership of the data and needed to make sure learners' mistakes would not set back the research. In Hay and Barab's work, ownership of science learning conflicted with the actual practice of science. Even though FC97 used actual equipment used in science labs, the students were not working with scientists and no scientists were invested in their work. They note that the ownership of FC97 was stronger, which is unsurprising given Papert's (1991) notions of constructionism as learners have the freedom to guide and control their own products. Learners in SAC97 could not take full control since the scientists had to follow the traditions and procedures of legitimate research science owned the projects.

Third, structure, guidance, and scaffolds can diminish ownership. Reiser (2004) notes that in project-based science, great care is taken to contextualize the problem in learners' lives to support ownership. Students may develop a sense of ownership over the problem as they explore solutions on their own. However, project-based STEM learning is not full open inquiry. Similar to the authenticity issue, providing scaffolds and guides to those problems can take control away from the

learners, thus weakening ownership. Kock, Taconis, Bolhuis, and Gravemeijer (2013) examined data collected from 12 grade-nine physics lessons on simple electric circuits. The researchers thought that by increasing student responsibility and investment, students would develop ownership over the investigations and increase motivation and engagement. What they observed, however, differed from their prediction. Kock and colleagues found that even though cooperative work on inquiry tasks combined with freedom to engage in these tasks were present, the motivation and engagement of the learners was low. While the learners appreciated the time in working in groups and building the electric circuits, the learners were mainly driven by the school motive to complete their tasks, which required only limited engagement. Open inquiry versus guidance and structure will continue to be an issue with ownership of science learning. Open inquiry allows for the personal exploration and development of ownership, but structure and guidance allows learners to focus in on the task at hand.

Fourth, ownership of learning can cause learners to be overprotective of arguments and ideas. Haglund and Jeppsson's (2012) study directly examines the concept of ownership as pre-service science teachers learn to develop analogies for thermodynamics. Learners developed a strong sense of ownership over the creative aspects of self-generated analogies. For example, using Enghag and Niedderer's (2008) framework for group and individual ownership, Haglund and Jeppsson observed that group ownership from Group B took over for a particular analogy called "the angry bees." Here, the angry bees were the particles, the impact of the collisions of the bees between other bees and the walls were the pressure, angeriness

represented temperature, and the degrees of freedom was the axes of rotation in flight. As the Group B engaged in exploratory talk the individuals made a contribution to the idea, thus building ownership of the analogy as a target. Here ownership acts as a positive motivator for the group. However, like many analogies for science concepts, the concept does not always work. Emergent phenomenon occurs as a result of random motion in particles. However, the bees were given feelings (e.g., angry) and a free will to act. Particular, given the sense of ownership over the analogy, Group B developed a “protective stance to their analogy” (p. 14). Haglung and Jeppsson recalled that the protective attitude may have hindered Group B from accepting and identifying points in which the analogy no longer worked to explain thermodynamics. In this case, strong ownership of the analogy can prevent acceptance of new ideas and perceptions.

2.2.3 “Ownership” in Science Education Research

The goal of this portion of the review is to briefly examine how the term “ownership” is used in science education research on learners. Currently, the research on ownership in science learning in learners is sparse, yet many researchers use the term ownership in discussions on science learning. I am conducting this snapshot review to see what patterns currently exists and if science education researchers are acknowledging the complexity of ownership, as seen in psychological ownership in organizational theories. By understanding how researchers are using the term ownership with students and science learning, I can better make interpretations of the state of the field.

For this portion of the literature review, I examined three top-tier journals on

science education from 2008 - 2013: *Science Education* (*h5-index* = 35), *International Journal of Science Education* (*h5-index* = 33), and *Journal of Research in Science Teaching* (*h5-index* = 42). I chose this time frame because these science education articles are recent, but show gaps in understanding ownership, I might be able to assume that other past studies have the same issues. I also chose these three journals since they represent the top *h5-index* rankings for science education research. I recognize a more substantial literature review will need to be delved later in the future to make stronger claims on how science education researchers use ownership in science learning. This is an exploratory and cursory look into the use of ownership in this line of research at the most recent journal articles' usage.

Using each journal's search engine (Wiley and Taylor & Francis), I searched for science education research literature on the use of ownership between the years 2008 - 2013. I examined how researchers used the term "ownership" in articles relating to student learning in science education. I excluded articles that dealt with teacher ownership, literature reviews, and terms of ownership that dealt only with property (e.g., home ownership) or with the data only (e.g., the teacher wanted the students to own science). I did include papers that dealt with teacher education and references on ownership of science learning in students. I only included empirical studies and theoretical papers dealing with science education learning with learners and students. Most of the literature I examined does not directly investigate learners' ownership. Instead, for this exploratory review, I examined how researchers use the term ownership when referring to learners and what interpretations researchers make about student ownership of science learning.

From my search, I reviewed $n = 35$ science education research articles with some usage of the term ownership or dealt with ownership of science learning directly.

- *International Journal of Science Education*: 22 articles
- *Journal of Research in Science Teaching*: 6 articles
- *Science Education*: 7 articles

I asked the following questions for this review:

1. Terminology: How is the term “ownership” and “science learning” being used in science education research?
2. Assumptions: What perceptions do science education researchers have on ownership in learning?
3. Indication of target of ownership: What targets do the authors refer to in the ownership in learners and science?
4. Claims: What claims can be made about how to sustain ownership in science learning?

Appendix A summarizes my results from my analysis. Using this analysis, I describe four persistent patterns I observed in the literature and two gaps in the analysis of ownership in science learning. I also provide a brief analysis of the patterns I found.

Pattern #1: The use of the term “ownership” in STEM education research is often not cited or the citations do not directly relate to research on ownership of science learning.

In my review, I found that out of 35 articles that used the term “ownership” as part of student learning, 19 articles did not make any citation or reference to ownership (Appendix A). Many times, the authors simply used ownership as descriptions of the learners in the data. For instance:

- The expectation motivating these gestures was that they would help students, while observing the phenomenon to internalise it, or achieve ‘ownership’ of it, through their body configurations. In the case of dynamic phenomena (relating to motions in the sky), learning of these body motions in turn would enable later

enactment in the absence of that phenomenon (Padalkar & Ramadas, 2011, p. 1721).

However, other articles used the term ownership, often without reference, to make claims about learners and outcomes in science learning.

- The recognition of interdependency of knowledge building and decision-making seemed to motivate them (students) to learn and share their knowledge with a level of accuracy. This developed a **sense of ownership** and responsibilities for their knowing and learning in group work (Kim & Tan, 2013, p. 372).
- The role of the teachers consists of guiding by prescribing student activities, or, less restrictive, guiding by modeling; that is, by showing students how to handle experiments, how to interpret data, and how to reach conclusions. In the autonomy setting, however, students **gain ownership** of their investigations, for instance, by framing research questions themselves and looking for appropriate methods to find answers on their own (van der Valk & de Jong, 2009, p. 832).
- This type of activity moves beyond simply telling students to evaluate one another's ideas. By asking the students to construct preliminary principles before joining the discussion we provide students with an opportunity to develop ownership over their ideas. This **ownership** provides students with intrinsic motivation to defend their principle. In addition, by asking students to agree upon a single answer they must engage with other students' ideas so that they can either weed out inaccurate ideas or combine ideas from their differing principles (Price & Lee, 2013, p. 307-308).

In these three cases, the authors make the assumption that the reader clearly knows what ownership is in student science learning. However, I have attempted to show in this literature review that ownership is a complex term that needs more elaboration.

Without references to a definition or conception of ownership, the term is too generalized to be understood.

Other studies that did make citations to ownership of science learning did not cite research directly on ownership of science learning or research on psychological ownership. Out of the $n = 35$ articles, only $n = 2$ articles directly made citations towards literature that focused on ownership in science learning. Haglund, Jeppsson,

and Andersson (2012) cite their own work on pre-service teachers' development of ownership over thermodynamic analogies (Haglund & Jeppsson, 2012). Rivera Maulucci (2013) references O'Neill and Barton's (2005) work on ownership. The other articles that did use references towards ownership (n = 14) often used references not directly on ownership of science learning.

When I traced back the citations, many of these references led to research in which ownership of science learning was ancillary. For example, below are two articles that invoke ownership of science learning in learners and make references to ownership.

Ha and Song (2009) – To support productive open-ended science inquiry, *Polman and Pea (2001)* suggested transformative communication, which helps to maintain the necessary balance between **student ownership** and teacher control since both parties make crucial contributions. They described the dialogue sequences of such communication and illustrated the utility of those in some episodes (p. 177).

Polman and Pea's (2001) work on transformative communication for inquiry does make a single observation on balancing student ownership and teacher control. However, the use of ownership is only a single quote that simply stated in the article as a secondary implication.

In fact, there is evidence of greater learning gains when students are given ownership of their learning process. In a comparison study ($n = 1,053$ students and 15 science teachers) between systems design-based approach to science instruction, where students take ownership in the design and development for their science learning, and scripted inquiry, where instruction is teacher-driven, *Mehalik, Doppelt, and Schuun (2008)* found that the systems design-based approach of instruction yielded greater science learning gains in achievement, engagement, and retention with the strongest impact for low-achieving African American students (Tran, 2011, pp. 1627 – 1628).

Similar to Ha and Song's (2009) use of Polman and Pea's (2001) quote on ownership, Tran's (2011) usage of Mehalik, Doppelt, and Schuun (2008) is dependent only on a

single instantiation of ownership of science learning. Mehalik and colleagues only mention students' ownership of science learning once in their article on the design-based learning comparison to scripted learning. While I acknowledge the focuses of all of these studies are not on learners' ownership of science learning, ownership as a term in science education research is not clear.

In other articles I reviewed that dealt specifically with issues of ownership in STEM learning (e.g., Bloom, 2001; Enghag & Niedderer, 2008; Haglund & Jeppsson, 2012; Hay & Barab, 2001; O'Neill, 2010; O'Neill & Barton, 2005), the term "psychological ownership" was also not used and no citations were made to this area of research. I argue that connections to organizational and psychological understanding of ownership can better help the community examine this complex part of human nature.

Analysis of Pattern #1. Although learners' ownership of science learning was not the goal in many of these studies I reviewed, the difficulty of using the term "student ownership" in the context of science learning without citation is a lack of shared understanding in the community of what ownership means for students. For instance, under organizational and psychological studies, ownership can be defined as strong / weak, positive / negative, and individual / group (e.g., Ceja & Tàpies, 2011; Pierce et al., 2003). Ownership is also complex and deals with both individual and social processes; ownership will also be expressed differently and manifest in many forms (e.g., Pierce et al., 2001).

Since ownership is not currently as defined well in the STEM education literature, I believe there is an assumption that the research community has a shared

understanding of ownership. However, like many complex terms in education (e.g., learning, identity, transfer), I do not believe that ownership is a simple term that is universally understood. Another possibility in not making citations to ownership or making references to literature in which student ownership of science is ancillary is the lack of prominent studies on ownership of science learning.

Pattern #2: An overly positive slant for learners' ownership exists in the STEM education literature.

In the $n = 35$ articles I reviewed, a large majority ($n = 32$) had a positive slant on learners' ownership in STEM learning. Often descriptions of learners' ownership were in the context of positive STEM learning. For example:

- Third, providing students a greater degree of **ownership** in investigating science issues in authentic science contexts may increase their understanding of the process (P. L. Hsu, van Eijck, & Roth, 2010, pp. 1263–1264).
- The table attempts to sketch out a comprehensive vision of the scope of the struggle for social justice teaching in science education. This vision builds on stances, such as opportunity-to-learn (Tate, 2001), the need to foster youth's ownership of and sustained interest in science (Basu & Barton, 2007; T. O'Neill & Barton, 2005), and ecojustice (Brandt, 2004) (Rivera Maulucci, 2013, p. 454).
- We focus on spontaneity here because it suggests that students have developed ownership over the scientific practice they are engaging in the argumentative discourse because it will help them solve the problem at hand (Berland & McNeill, 2010, p. 777).

None of the 35 articles I reviewed indicated that ownership of learning was a strong and negative detriment to learning. Instead, a number of articles indicated that learners did not have enough ownership over science learning (Evagorou & Osborne, 2013; D. B. Hay, Williams, Stahl, & Wingate, 2013).

Analysis of Pattern #2. While ownership of science learning may be a positive trait for STEM learning, when are the times ownership conflict with science learning?

Literature in psychological ownership indicates a “dark side of ownership” (e.g., Pierce et al., 2003) in which ownership prevents collaboration and tensions breed when multiple people or parties claim ownership over a specific target. Other science education researchers also acknowledge the tensions in ownership and student science learning (e.g., Bloom, 2001; Hay & Barab, 2001). Conflicts in ownership are often the cause of patent lawsuits, territorial disputes, and arguments over who has control of the television in the living room. An overly positive assumption of ownership of science learning masks the conflicts and tensions that occur in science learning. More studies need to be conducted on ownership of science learning, not just on what tensions exist, but why conflicts occur in science learning about learners’ ownership.

Pattern #3. The target of ownership is often unclear in both terminology and time frame

A third issue and pattern in the literature is the lack of clarity in what students own and when do they own the target of ownership. Psychological ownership discusses “target of ownership” as an important part of analysis in ownership. Targets in science learning that learners may own (but are not limited to):

- Inquiry and inquiry process (e.g., Anastopoulou et al., 2012; Cronje, Murray, Rohlinger, & Wellnitz, 2011; Ha & Song, 2009; Hsu & Roth, 2009)
- Gestures and modeling processes (e.g., Padalkar & Ramadas, 2011; Prins, Bulte, van Driel, & Pilot, 2008)
- Learning and learning process (e.g., Dianovsky & Wink, 2012; Dorion, 2009; Haglund & Jeppsson, 2012; Kim & Tan, 2013; Maskiewicz & Winters, 2012; Smith, Loughran, Berry, & Dimitrakopoulos, 2012; Tran, 2011)
- Science and scientific practice (e.g., Bang & Medin, 2010; Berland & McNeill, 2010; Hay, Williams, Stahl, & Wingate, 2013; Rivera Maulucci, 2013)

- Data and information (e.g., Hug & McNeill, 2008; Kind, Kind, Hofstein, & Wilson, 2011; Rule, Stefanich, Boody, & Peiffer, 2011)
- Projects (e.g., Fields, 2009; Price & Lee, 2013)
- Arguments and ideas (e.g., Clark & Sampson, 2008; Evagorou & Osborne, 2013; Lehesvuori, Viiri, Rasku-Puttonen, Moate, & Helaakoski, 2013)

Analysis of Pattern #3. In the literature, students can own a variety of material and non-material targets in science learning. However, I raise two issues. First, the targets that researchers claim that learners are often generalized. For instance targets such as “learning”, “science”, and “inquiry” are very complex terms. Specifically, what are the aspects that students own in learning, science, and inquiry? Second, STEM education literature has not yet examined when ownership occurs and if it changes over time. For instance, even if learners own science learning, do they own it for very long or a short time and when do they begin to own what it is they own? Currently, the language we are using is too broad and unspecific for such an important concept as ownership.

Pattern #4. Generalizations exist in the STEM education literature on how to sustain ownership.

In summary, I pointed out that 1) researchers may often not cite the use of the term ownership; 2) ownership has a heavily positive slant in the literature; and 3) the use of generalized targets can be ambiguous. All three of these points lead into my fourth observation: generalized implications and conclusions are often made about ownership in science education research. These generalizations are often in part due to the positive assumption ownership has on science learning. Researchers can make generalized claims about how to support ownership.

- In the case of modeling drinking-water treatment and human exposure assessment it is expected that students do experience ownership for the topic at hand due to clear motives and purposes for model construction from the student's perspective. The characteristic modeling procedures in both practices are expected to be in line with students' commonsense notions and pre-existing procedural modeling knowledge. The depicted modeling procedures are applicable to a choice of treatment steps and contaminants, or consumer products, chemical substances, and emission routes, thus facilitating implementation in classroom (Prins et al., 2008, p. 1886).
- Specifically, inquiry-based science teaching entails introducing students to authentic scientific discourse (e.g., tools, language, and practices including ways to critique and construct knowledge) by involving them in ways that meaningfully and appropriately challenge them to take ownership of and employ their own unique perspectives and creativity to ask and pursue answers to scientific questions (Luehmann, 2009, p. 1832)
- Price and Lee (2013) - Citizen science projects have a greater opportunity to build a social community (as evidenced in the forums) and to empower its participants more than individual or even classroom-based science projects. This agency stems both from a closer sense of ownership of the process and its products and, for collaborative and co-created projects, also in the influence the participant has over the project structure (Price & Lee, 2013, p. 795)

Analysis of Pattern #4. As I have pointed out, while ownership is positive for STEM learning, tensions exist in learners' ownership, which often complicates situations. While I do not disagree with the possibility that certain factors can promote ownership in the above studies, lack of acknowledgement of the difficulties of ownership dilute the complexity of this personal trait. Generalized implications may promote unintended consequences. Cultivation of student ownership is important for learners engaged in science (e.g., O'Neill, 2010). Each of the research above indicates that personal student experiences, meaningful involvement, engaged perspectives, social community, and agency can lead to ownership in learners. However, as researchers we must also better understand the limitations of ownership of learning and what potential roadblocks exist in science learning. How do factors

(e.g., agency, personal meaning) promote ownership and do these factors promote unintended consequences in science learning?

2.3 Gaps in the Literature on Ownership in Science Education Research

Based on my review of the science education literature in ownership of learning and the persistent patterns, I have determined that gaps do exist in our knowledge and understanding of student ownership. Here, I examine three gaps in the knowledge and what studies are needed for investigation.

1. Very few studies exist on how individual learners gain ownership and how that ownership evolves over time

In the studies I reviewed for this literature review, I found little to no studies that examined ownership from an individual learners' standpoint over a given period of time. O'Neill (2010) was the only study I could find that conducted a close analysis of learners' ownership of science learning for a period of a year or longer. The paper presents a finer-grained examination of two vignettes. First, O'Neill addresses the identity changes a child named Sneaker Boy's goes through as he develops ownership. His identity shifts from "bad kid" to "Zoo expert" as he gains ownership over time of the "Class Zoo". Second, O'Neill outlines how ownership structures in her class (e.g., giving out her personal phone number, Science Library, Student Center, Word Wall) allowed learners to take responsibility of the science classroom. Children over time became the "Teacher Assistants" and started to co-construct with O'Neill the ownership spaces in the classroom. In both vignettes, O'Neill conducts a close analysis of how these cultivation factors supported ownership in these learners and how the learners' identities changed over time.

O'Neill also shows the tensions that exist and the complex nature of ownership that comes into play under traditional science classrooms.

Other than O'Neill's (2010) close examination of specific learners and Cornelius and Herrenkohl's (2004) investigation on the role of teacher power in the classroom in ownership, I found very little in the STEM education literature that conducted a finer grained analysis on ownership in learners. Most of the literature on ownership of science learning situates itself on group dynamics (Enghag & Niedderer, 2008; Hay & Barab, 2001; O'Neill & Barton, 2005). Without a finer grained analysis on individual learners over the course of time, I believe that understanding the evolution of ownership in a given context is very difficult.

2. *Very few studies exist on how ownership may or may not transition between contexts and microsystems*

Similar to learning, psychological ownership is a trait that exists beyond the four walls of a classroom. In my review of the literature, most of the studies situate itself only in the classroom. The strongest example of literature on ownership I found that examines ownership between different learning contexts was Anastopoulou et al.'s (2012) work on engaging students through personal inquiry learning. In this study, learners carried out scientific investigations that were personally meaningful and relevant to their everyday lives. Researchers gave learners a digital camera and a netbook to take home to capture their food diaries and bring it to school for discussion. However, Anastopoulou and colleagues found that learners became guarded of the data, specifically their personal self-images of the photographs of the meals they ate. Some became reluctant to take or share these photographs because of concerns of self-image, such as showing to others they ate low-nutrition foods.

Learners wanted to control the flow and access of data, but this is not what scientists do. To be a scientist, learners needed to collect data in a meticulous manner and objectively scrutinize it. They needed to be detached from this data, instead of owning it. Although learners' developed their own personal inquiry and investigation on food, employing rigorous scientific processes was difficult for these personal reasons.

Anastopoulous and scholars give us a glimpse into how personal ownership and image issues from home affect learners' ownership of data and science practices. More research that examines ownership as a transition between microsystems is important in understanding how ownership affects science learning. Both Wenger (1998) and Bronfenbrenner (1977; 1994) acknowledge that learning does not just occur in schools, but exists in communities of practice and microsystems that cut across each other. However, most studies I found invoke and mention ownership of science learning only do so in the context of schools. Ownership is a human trait that is influenced by our social interactions and vice versa (e.g., Pierce et al., 2003). To this date, little to no studies have examined the evolution of ownership through an examination of learners' different communities of practice and microsystems.

3. Few studies examine why tensions exist in ownership of science learning

Education research studies currently explain what tensions exists for learners in science learning, but little to no studies exist on why these conflicts occur. Cornelius and Herrenkohl (2004) express that ownership of ideas is a struggle between students and teacher power dynamics. While we know that authority and limitations can diminish ownership, what we do not know is what role social and

individual processes between home, school, and everyday life contribute to these tensions. We also do not know how individual learners perceive these tensions in ownership and science learning. Education researchers have focused on issues of tension and conflict in ownership within group dynamics (e.g., Haglund & Jeppsson, 2012; Hay & Barab, 2001), but very little has been done to understand how specific the individuals react to such dilemmas.

2.4 Theoretical Framework for Studying Ownership and Science Learning

Based on these gaps and patterns, I believe there is a need to investigate the primary research question of my dissertation.

How does ownership evolve as learners engage in a guided inquiry-based science learning environment focused on design and technology usage?

In the section below, I outline the works I drew upon to frame my study on ownership.

- 1. Ownership is not a singular construct of control or possession, but is composed of themes based on the actions, behaviors, and perceptions of learners.*

One assumption I made about ownership is that there are traits and characteristics we can observe in learners that can indicate their ownership in science learning. This study relies on the idea that themes and patterns of ownership can be explored and used to explain how learners develop ownership in science learning.

To begin, I relied on O'Neill and Barton's (2005) work as a starting point to understand what ownership of science learning could be. I chose to begin with O'Neill and Barton because the researchers deconstructed the multifaceted and complex emotions of ownership into observable and evaluative aspects to study. Ownership is broken up into five themes (p. 296):

1. Positive and empowering perceptions of self in relation to science and school (self-identity)
2. Purposeful expenditure of human, social, and material capital (investment)
3. Expressions of pride in science, self, school, work, and neighborhood (pride)
4. Agency through personal and community changes (choice)
5. Positive and realistic personal and community changes (contributions)

Ownership is not just a single feeling or emotion, but a complex and multifaceted process that is interdependent on the individual and the relationships between the context and other learners. One of the strengths of this framework is the breaking up of ownership into specific and observable themes. For my work, I used O’Neill and Barton’s five themes as a way to understand how ownership could be tied to science learning. I wanted to examine these themes in learners within microlevel contextual interactions.

2. *Understanding ownership in science learning means examining what learners seek after – Targets of ownership*

Pierce and scholars (2003) argue that the “target of ownership” is an important aspect in how ownership is seen in action and self-identity is expressed. What we own, what objects people choose to gravitate to, and how people express their need for that object suggests that there is a close link between identity and objects (Dittmar, 1992). Ownership is an expression of our identity to others; possession tells people who we are, what we think, what we do, what we might become, and what we value. For these reasons, I have chosen to complement the O’Neill and Barton (2005) framework with an examination of what targets of

ownership learners have. These targets can be found through what choices and investments learners make towards a particular object (e.g., artifact, idea, process, material) and how they express their views of science and pride. Ultimately, a learner's targeted objects link back to the central focus of self-identity.

3. Examining ownership means understanding identity development in social settings.

For this study, I argue a sociocultural perspective of learning and identity can support the understanding of how ownership evolves in the specific contexts and social interactions. Research taking the sociocultural perspective contends that learning is linked to fundamental cultural practices and often examines cultural practices as the unit of analysis (e.g., Lave & Wenger, 1991). Therefore, better understanding of how goals, identity, and learning in communities can offer a better glimpse of how ownership evolves in learners and how cultural practices may influence and be influenced by this development.

Identity

I take a sociocultural perspective of identity that is heavily influenced by Nasir (2002) and Wenger (1998). In this dissertation, I use identity as a fluid construct that is being shaped in context and in turn, shapes the context (e.g., Nasir, 2002; Wenger, 1998). Identity is not just a purely individualistic or a purely social construct. Instead, Wenger argues that self-identity develops both through individual agency and social interactions. From Wenger's perspective, identity has a connection with practice in a community in six ways.

First, identity is formed through *our lived experiences*. It is not merely a personality trait, characteristic, or role. Instead, identity is part of our experience in participation and reification in the world.

Second, the formation of identity is part of a *negotiated experience* and engagement in the world. Wenger describes this as a “layering of events of participation and reification by which our experience and its social interpretation inform each other” (p. 151). As people experience the world and develop relations with others, layers of these experiences and relationships build to produce identity.

Third, identity is *social* and forms in communities of practice through mutual engagement, a joint enterprise, and a shared repertoire. Through mutual engagement, we become who we are through the relations of engagement that make up the community. As we invest into a joint enterprise, we develop a certain focus and perspective. While members of a community do not all share the same perspective, identity manifests as we make certain choices and value certain experiences through participation in the enterprise. The more we engage in a community of practice, we develop a history and shared repertoire. Our experience becomes a part of our history through memories, experiences, and references we can access and make interpretations.

Fourth, identity has a *trajectory* in communities of practice. Wenger (1998) states that trajectories are not a fixed course, but instead a continuous motion. Identity is fluid and ongoing and constructed in social contexts. It is constantly renegotiated during the course of our lives as we inhabit communities of practice. In this case identity is heavily influenced by learning and vice versa (Nasir, 2002; Wenger, 1998).

In this relationship, self-identity acts as a motivator in learning. Learners may choose to practice and develop new skills to their self-identities. Nasir points out that this development of learning and identity is not isolated just to the internal self, but is socially distributed among other learners. Ownership of learning may take place as a result of further development of a learner's identity. If learners find that learning certain knowledge or skill sets contributes to their identity, they may be more inclined to control and possess how learning occurs.

Fifth, identity is formed through a *nexus of membership*. People do not reside in one community, but instead, we experience a multi-membership of communities and constantly reconcile our identities across borders. Identity is something that people do not switch on and off when we cross borders. Instead, we are constantly reconciling who we are through different forms of engagement, accountability, and experiences. Reconciliation does not just mean that people understand the rules of the different communities; it is a construction of an identity that understanding the different meanings of participation from place to place.

Finally, identity formation is the interplay between local and global. We have engagements in our local communities, but our engagements also fit into broader issues and relationships. Identity is the dynamic influence between what we do locally in our communities and the larger picture.

In this dissertation I assume that people's ownership is a reflection of their identity. If identity is dynamic and constantly renegotiated over time, context, and local-global interplay, I assume that ownership of learning will also show shifts and changes. Ownership in communities of practice will also have social component

based on mutual engagement, joint enterprise, and shared repertoire. Ownership will also change over different communities. What we own and what we are allowed to own in our home will be different than in our schools. Therefore, examining ownership across different settings and how those negotiations occur are important to study.

Goals

Sociocultural perspectives of learning also contend that personal goals for learners mediate between culture and learning (e.g., Saxe, 1999). Instead of goals being conceptualized as stable traits of individuals, goals are dynamic and emerging through both social interactions and an individual's prior goals and understanding. Based on this perspective, I argue if ownership is linked to self-identity, ownership will also take on these dynamic characteristics. Goals impact and are impacted by learner's identity development (Nasir, 2002). As identities evolve, learners develop newer, possibly more sophisticated goals they want to pursue. Learners also may develop new identities as they fulfill their goals. For example, participants that fulfill an independent science investigation on their own may see themselves as more of an expert in science learning and begin to develop ownership of the knowledge and skills they have attained. The attainment of the goal can shift learners' identities and support ownership of the goals, knowledge, and learning processes.

Learning

Nasir (2002) and Wenger (1998) assert that learning can be conceptualized in four ways. First, learning can involve what new content knowledge learners know

more of, but also the understanding of the concepts and relationships that tie knowledge and processes together. For instance, math learners may know how to apply a particular formula to solve a question, but they may not understand the mathematical relationships that underlie the procedures. Second, learning involves the development of new goals based on the learning of new knowledge. When learners begin to address new problems, they must reconceptualize older problems in a new perspective. As learners take on new tasks and develop skills, they develop new problem solving goals. Conversely, when learners have certain goals in mind, they may need to increase their knowledge base and skill sets to attain those goals. To fulfill the goals, learners may be required to learn new strategies, problem solving skills, and knowledge. As new goals are formed, learners may take on new identities, which may affect how ownership manifests in contexts. Third, learning involves coming to know and apply the established practices of a community and increase their participation into activities. Finally, learning involves coming to new ways of engaging in practices and reconceptualizing old problems in new perspectives. As learners develop new knowledge, they may setup new and different ways to solve problems.

4. *An analysis of ownership needs an examination of how learners perceive themselves in communities*

Learners' goals, self-identities, learning, and targets do not exist in a social vacuum. Therefore, ownership evolves within specific contexts and social interactions. Wenger's (1998) work on *communities of practice* may support further explanation of the evolution of ownership in learners. Communities of practice are everywhere; such examples include homes, work, school, and hobbies. In short, we

all belong to a community of practice. In a community of practice, learning is seen as an act of social participation. Participation does not just refer to the isolated and local events of specific activities and members of the community, but instead refers to the encompassing processes of being active participants in a social community. Wenger argues that classrooms and other learning environments can be viewed as communities of practice in which students' membership in these communities (or non-membership) affect their learning processes and identities (Lave & Wenger, 1991; Wenger, 1998). Within these communities of practice, learners' identities are dynamically constructed by social interactions and influence the context.

In this study, Kitchen Chemistry is a community that was still developing and not considered a deeply established community of practice. However, I argue that in designing a space that strives to promote science engagement, identity development, and ownership, we were attempting to build what Wenger (1998) calls shared histories of learning:

The negotiation of meaning is a fundamentally temporal process, and one must therefore understand practice in its temporal dimension. Some communities of practice exist over centuries – for example, communities of artisans who pass their craft from generation to generation. Some are shorter-lived but intense enough to give rise to an indigenous practice and to transform the identities of those involved. For instance, such communities may form as people come together to handle a disaster. The development of practice takes time, but what defines a community of practice in its *temporal dimension* (emphasis added) is not just a matter of a specific minimum amount of time. Rather, it is a matter of sustaining enough mutual engagement in pursuing an enterprise together to share some significant learning. From this perspective, communities of practice can be thought of as shared histories of learning. (p. 86)

In the case of Kitchen Chemistry, even though it was short lived (see Chapter 3 and 4), we have developed mutual engagement in pursuing of cooking and science together to share learning together.

5. *Understanding ownership means examining the internal perspectives of participation in learners.*

Wenger (1998) argues for three processes under *modes of belonging* that characterize identity development in communities of practices: engagement, imagination, and alignment. Wenger deems it necessary to consider modes of belonging in identity development and learning. Modes of belonging are the ways participants see themselves as members of a community based on their engagement in practice, alignment in coordinated activities, and imagination of their world. For this study, I used Wenger's conception of imagination, engagement, and alignment to examine the evolution of ownership in learners. Even though Wenger's framework of modes of engagement discusses trajectories of learning and macro-level changes over time (months and years), Wenger also describes identity formation as temporal and constantly being renegotiated over the course of people's lives. The learners themselves have also spent years conceptualizing what science learning means to them. The work of identity development is ongoing and constructed in social contexts. Even though participation in Kitchen Chemistry lasted for a short period, past interactions, perceptions, and experiences in science are interlocked within the learners. In this case, I made the presumption to use the modes of belonging (imagination, engagement, alignment) as a way to examine microlevel changes (time span of weeks) in the learners because they already had years of experience in science from home, school, and other informal interactions.

Engagement is process of how a member participates in the community.

Through engagement, people work together to build relationships and communities of practice. Engagement is very focused and limited due to space, time, and context. For instance, participants of a basketball team spend time playing and learning the game.

Alignment is the process in which members take actions to align themselves to the goals and purpose of the community. Alignment is indicated through commitment, allegiance, and investment of energy. Alignment bridges space and time; participants can coordinate their energies, actions, and practice across other communities.

Basketball players can align themselves to the community through what they wear, what they talk about, and what relationships they have outside the court. Finally

imagination is how members see themselves as connected (or not connected) to a broader community. Here, people imagine themselves as part of the community and gain a sense of connection with others. Imagination connects towards an extended identity and involves seeing ourselves within a larger purpose and community; imagination is very broad. Young basketball players can imagine themselves in bigger roles, such as going to play for a college team.

For this framework, I draw on Wenger's three processes of identity development in communities of practices as a way to examine how ownership evolves in these communities. For example, since learners' engagement in a community, perception of themselves in the community, and coordinate of themselves to community practices are based on dynamic interactions, ownership of learners may be influenced by learners' participation and actions with others in the community.

2.5 Summary and Conclusion

In summary, in my literature review, I showed the following:

1. Psychological ownership is often conceived as an individual outcome construct that is a core trait in people. I mainly examined literature from organization theory and psychology. However, the limitation of this perspective is that it does not take into account the dynamic changes between self-identity and how shifts in identity may change ownership.
2. Ownership can be influenced by social contexts, relationships, and power. However, researchers do not have a good understanding of how shifts in power and relationship support or deny ownership.
3. I showed that STEM literature that invokes or studies ownership have four persistent patterns: A) many researchers do not cite references when using ownership; B) an overly positive slant exists in the STEM education literature on the role of ownership in learning; C) targets of ownership are not well defined, especially the term “learning.”; and D) researchers may be making overly generalized claims about how to support ownership in science learning.
4. I found that three main gaps in the literature: A) Very few studies exist on how individual learners gain ownership and how that ownership evolves over time; B) very few studies exist on how ownership may or may not transition between contexts and microsystems; and C) few studies have been undertaken to understand how individual learners perceive tensions and conflicts in ownership of science learning.

My work focuses on the following features. First, the study had to be a close examination of individual learners as their ownership evolved over time. Second, the study needed to consider how border crossing and other communities of practice influence ownership. Third, the study needed to be detailed about what targets learners own and at what context and time they own them. Finally the study should continue to address the possible benefits and tension ownership have with science learning.

From the literature review, I developed the research question, “How does ownership evolve over time for learners engaged in a guided-inquiry STEM based learning environment focused on design.” To answer this question, I used four aspects from the literature to justify a theoretical framework that would support my investigation. My theoretical framework for this study focuses on 1) ownership as being composed of themes and patterns of behaviors and perception; 2) examining ownership through understanding targets of ownership; 3) understanding ownership through identity development in social settings; 4) an analysis of ownership through communities of practice; and 5) using modes of belonging (imagination, engagement, and alignment) as a way to explore ownership.

In Chapter 3, I outline the methods I used in this dissertation to begin to address my questions and the gaps in the literature. This chapter will provide the justification of the data collection, the methods I used to collect the data, and the analysis techniques I used to interpret the data.

Chapter 3: Proposed Methods

In this chapter, I describe the research methods of this study. I begin with my justification for case studies methods for this dissertation. Second, I explain my role as a participant observer in this study. Third, I address the overall research questions that guide this study. Fourth, I describe the case study design, which includes an explanation of Kitchen Chemistry (KC), the context of the study, the participants of the study, and the justification for the case selections. Fifth, I explain my case study protocol. I describe my selection criteria for the cases, the data sources, and data collection schedule. Sixth, I show how I analyzed the data through coding and direct interpretation.

3.1 Research Methods

For this dissertation, I chose to implement the standards and procedures of a case study. Case study methods have varying perspectives and different ways to implement the research design. For the purposes of this study, I aligned philosophically with Stake (1995), but used case study techniques from Yin (2003) to organize and plan the study. Yin's case study methods focus much on plausibility of explanations and determining construct validity, internal validity, external validity, and reliability, while Stake emphasizes research interpretation, reflexivity, and experiential understanding. Although epistemologically Stake and Yin can be construed as diametrically opposed, I chose to do this style of case studies for several reasons. Initially, I began with Yin's approach to case studies. Yin claimed that case studies are appropriate when, "a how or why question is being asked about a

contemporary set of events, over which the investigator has little or no control” (p. 9). In this study, I was interested in how and why ownership evolves in learners as they go through a design process. My questions are more explanatory; I was seeking to explore how ownership evolves in guided inquiry design learning activities in science and technology usage. The goals of Yin’s case studies are to collect, analyze, interpret, and present data to draw inferences about causal relationships pertaining to real-life phenomenon.

However, as I delved deeper into the data (see Data Analysis section), I found that explaining causal links in real-life interactions using categorical aggregation of coding patterns was too difficult. As I coded, the complexity of the data (e.g., social relationships, technology interactions, family life, school, and learning environment) became apparent and drawing a hypothetical story of why and how ownership was occurring was too overwhelming for a coding scheme. The coding scheme became incredibly vast and too complex to draw a single and valid interpretation of ownership. Making sense of individual codes, even through code collapsing, did not always provide me ways to understand the richness of the data.

I needed to understand and interpret the cases themselves before I could make hypothetical claims about ownership. I began to adhere to Stake’s (1995) perspective of case studies. From Stake’s perspective, case studies are developed within the context of the study and based on the interpretation of the researcher. As more information is discovered, the case study adapts to accept new information. Stake places focus on the importance of the researcher situating and experiencing the data and using this interpretation to guide the process. Yin (2003) emphasizes examining

the data through objective validity and through rigorous coding to find a single plausible hypothesis, whereas Stake's analysis of the cases is solely dependent on the integrity and bias of the researcher.

However, for this study, I found Stake's (1995) methods alone to be too convoluted to examine a complex phenomenon such as ownership. I did not understand exactly what Stake meant by making a "direct interpretation" of the data. At the same time, Yin's (2003) methods were too rigorous and potentially limiting in understanding the context and relationships of the cases. However, Yin does provide enough structure in the tools for analysis for a novice researcher to use. In this dissertation, I chose to find some middle ground in which I could use Yin's methods for data collection, organization, and initial analysis, while still adhering to the openness of interpretation from Stake. Therefore, the methods I describe for this study are situated in how Yin organizes and plans for the case study, but the interpretation and analysis is based on Stake's philosophy of case researcher interpretation.

3.2 Researcher Perspective and My Role

Since I am the primary instrument of data collection and analysis of this dissertation, it is important for me to reflect critically on my position, biases, assumptions, and experiences (Guba & Lincoln, 2005). Here, I am attempting to use reflexivity to make my position in this research clearer to my readers. Creswell (1998) defines reflexivity as an attitude of attending systematically to the context of knowledge construction and understanding how the effect of the researcher impacts the research process. Reflexivity allows researchers to become more aware of what

they are seeing (or not seeing). This allows for more careful consideration of how my own assumptions and behaviors can impact the study (Merriam, 2009).

For this study, I acted as a participant observer. I was both a facilitator of KC and a researcher of this implementation. Yin (2003) describes that participant observation is a special mode of observing in which, “you are not merely a passive observer” (p. 93). I adapted the design of KC as the program progressed. Throughout the study, I conducted analysis of KC, made improvements to the activities, facilitation and discussion in the science environment. Participant observation in case studies allows for specific advantages and disadvantages. As an advantage, the participant observer can gain access to many people and a wide range of information (Merriam, 2009). However, there are trade offs. First, I needed to be sensitive to the possible effects I would be having on the participants of KC. Second, because I was managing KC, I might not have had sufficient time to pay attention to all the details to take notes or raise questions about the events.

As a participant observer, I may also become more of an advocate for KC, as opposed to a documenter of the phenomenon. Since I both facilitated and documented KC, I wanted all of the participants to develop ownership of science learning and to have a meaningful experience in designing food investigations. Prior to my life as a researcher, I was a high school teacher that wanted to teach science to the best of my ability. As a teacher, I often wanted my students to learn specific knowledge about science. However, since this is an exploratory study situated in the real world, not everything we designed went according to plan. For example, this particular implementation of KC seemed to attract children with difficulties in attention and

social dynamics. Administrators and parents often told us that the small size of KC, the active hands-on activities, and the use of technologies appealed to children for which traditional public school settings did not work for them. Despite the setup of KC towards scaffolding science inquiry, not every participant fully engaged in science inquiry. Many of the children's own personal factors affected their own participation in KC. As well, my own views of science learning and teaching also affected how KC was implemented.

To see KC from multiple perspectives, I worked with a group of researchers together on the KC project. Working together with multiple investigators can foster dialogue, allow for divergent explanations to come forth, and reveal hidden beliefs, values, perspectives, and assumptions (Creswell, 1998). Two other researchers (Dr. Tamara Clegg and Elizabeth Bonsignore) worked with me to collect data and pay close attention to the environment. Two other volunteers (Charley Lewettis and Emily Rhodes) also helped me collect the data. The presence of multiple researchers can help to guard against threats to internal reliability (Goetz & LeCompte, 1984). Dr. Clegg, Elizabeth, and the other facilitators and I conducted weekly meetings with each other to discuss our field notes and observations to examine and share what possible biases we have. I also checked in periodically with the committee and other researchers to share my arguments and to see what other perspectives and rival explanations can be taken.

3.3 Research Questions

The purpose of this research is to explain how ownership evolves as learners participate in design activities in a guided inquiry science program. This study

addresses the following research question:

Research question: How does ownership evolve as learners engage in a guided inquiry-based science learning environment focused on design and technology usage?

The research question is broken up into four sub-questions. A summary of the research questions and its connections to the data can be found in Appendix B.

Sub-question 1 (SQ1): What aspects of the design activities (e.g., technology, products, ideas) do learners have ownership of when they are given the chance to design in a guided inquiry science environment?

Sub-question 2 (SQ2): At what points during the design activities do learners begin to take ownership of what they own?

Sub-question 3 (SQ3): What are the initial characteristics and outcomes from ownership and how do these characteristics change over time for learners as they participate in design activities in science learning?

Sub-question 4 (SQ4): How might the features (e.g., facilitation, technology) of KC, school, home life, and other contexts potentially impact and influence how ownership takes place in learners?

3.4 Case Study Design

3.4.1 What is Kitchen Chemistry?

Building a community of designers in science learning requires learners to socially construct knowledge within a *participatory culture*. Jenkins, Clinton, Purushotma, Robinson, and Weigel (2006) define a participatory culture as a culture “with relatively low barriers to artistic expression and civic engagement, strong support for creating and sharing one’s creations, and some type of informal mentorship whereby what is known by the most experienced is passed along to novices” (p. 3). Here, learners view that their contributions matter and they develop social connections between each other.

A team of three researchers (Dr. Tamara Clegg, Elizabeth Bonsignore, and myself) from the Human-Computer Interaction Lab (HCIL) developed KC. To support this participatory culture, we developed KC based on two frameworks: *Cooperative Inquiry* (e.g., Druin, 1999, 2002, 2005) and *Learning By Design* (Kolodner et al., 2003). In Cooperative Inquiry, children are *partners* with adults in the design process of technology and curriculum. From our previous work with Cooperative Inquiry, we established customs in KC that attempt to minimize existing power structures and help build good relations with children. The facilitators of KC insisted on basic practices, such as sitting together with children in discussion, calling each other by our first names, and allowing children to design investigations of their own interest. From Learning by Design, the facilitators of KC adhered to two principles. First, the facilitators maintained a culture of iteration; all participants in KC need to develop the responsibility for helping each other learn through critique of one another and iteration on their designs. Second, the facilitators supported scientific reasoning; members of the community must be able to utilize scientific principles and causality in explanations and refer to evidence to back up claims.

From these two frameworks, the HCIL developed KC as an afterschool or summer camp program where learners engage in scientific practices within the context of cooking. Holding the program outside of school enabled learners to choose the directions of their scientific inquiry without being bound to a particular curriculum. To provide an environment that learners can participate in scientific practices to design investigations that are personally meaningful to them, we developed two activity sequences. First, learners engage in *semi-structured activities*

that help familiarize them with cooking and science practices. In the cooking experiments, learners are given the tasks such as observing what eggs do in brownies and what leaveners (e.g., baking powder, baking soda) do in cookies. In these cooking experiments, learners vary the amounts of the ingredients in the recipe and examine the results. The semi-structured activities also include non-cooking experiments in which the ingredient variations in their cooking experiments are highlighted to help learners think about the underlying scientific phenomena. For example, learners can mix different amounts of eggs into fixed amounts of oil and water to observe how eggs act as emulsifiers in the mixture. Learners also compare the heights and amount of foam that are generated from shaking the egg, water and oil mixture.

Learners participate in these semi-structured activities to prepare them for flexible exploratory activities that we called *Choice Days*. Learners are given the opportunity to use what they have learned to prepare an investigation into a recipe of their choice. Here, learners make decisions about their investigations, such as what recipes to explore, what modifications to make to ingredient amounts, and what observations they will make. During this time, the facilitators will allow learners to design their own experiments and recipes based on their personal interests, to make new or different recipes, and to explore different ingredients. Using Chinn and Malhotra's (2002) framework, we attempted to work with learners to address four aspects of designing investigations: selecting variables, controlling variables, planning measures, and planning procedures. Whereas in simple experiments, where students usually have the variables pre-selected for them, participants in KC must select and determine their own variables of interest, decide as a group what

phenomenon they will investigate, plan out their goals, and implement their investigation.

Embedded in both the semi-structured activities and Choice Days are *whole group conversations* that learners further discuss and reason about their prior observations of the cooking experiments. Here, participants discuss what they observed before, what their thoughts are on the results, and what they think about the outcomes. We also discuss the authentic scientific practices (Chinn & Malhotra, 2002), such as making qualitative and quantitative observations, tying evidence to claims and reasoning, thinking about the underlying mechanism that causes the observed cooking phenomenon, and how independent variables may change multiple dependent variables. All participants work together to think about the underlying phenomenon and build on each other's arguments and check for biases. Because of our adherence to Learning by Design (Kolodner et al., 2003) all learners must back up claims with evidence, causal explanations, and scientific reasoning.

Learners also used *mobile technologies* on the iPad™ to conduct their investigations and reflect on their observations. In particular, learners used *StoryKit* (Bonsignore, Quinn, Druin, & Bederson, 2013), *Zydeco* (Cahill, Kuhn, Schmoll, Pompe, & Quintana, 2010), and *SINQ* (Science INquiry) (Ahn, Gubbels, Kim, & Wu, 2012) (Figure 1). StoryKit is an iPhone™ application for creating and sharing audio-visual stories through text, photos, drawings, and audio recordings. Zydeco is also an iPhone™ application that can be used to photograph, tag and annotate information within different contexts. Within classroom discussions and argument based activities, users can develop claims, evidence, and reasoning from the

collective data. SINQ is a social media tool used to help distribute and scaffold learners development of science questions, hypotheses, and investigation design. We used StoryKit, Zydeco, and SINQ together to support learners' scientific practice in the context of choice-based activities and to help them reflect during and after the investigations on the scientific aspects of the activities (Clegg, Gardner, & Kolodner, 2011).

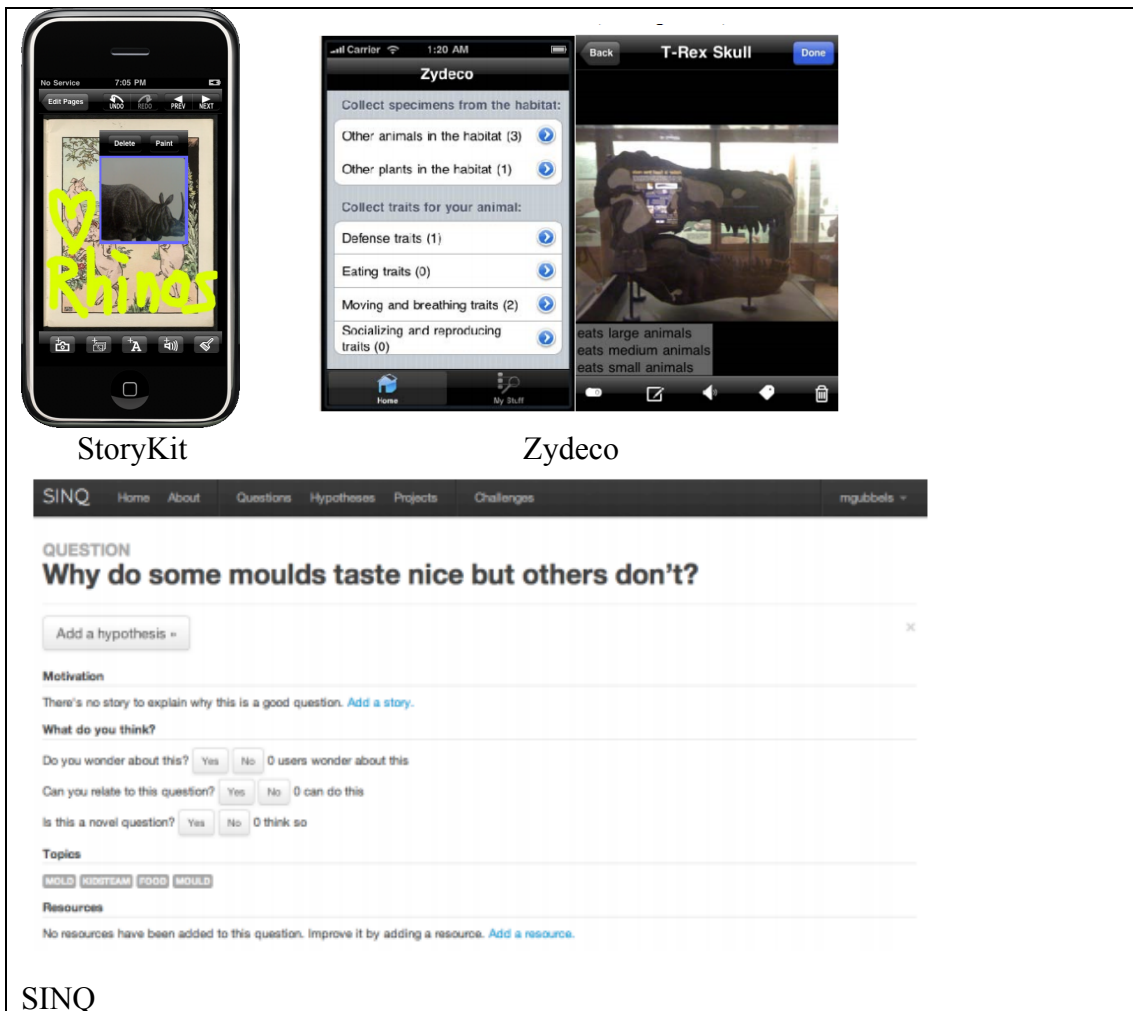


Figure 1: StoryKit, Zydeco, and SINQ are the three mobile applications we used in KC.

3.4.2 Context and Timeframe

For this study, this particular implementation of KC occurred between the months of February to May 2012 as an afterschool program at The Green School. Twelve sessions occurred (seven before spring break and five right after). We began the program at 3:45 pm each time and ended around 6:00 pm. We met in a classroom portable that was mainly not in use, but had amenities such as a stove and oven, sink, and closet (see Figure 2 for layout). I collected data during this five-month long study where the program is hosted at The Green School (see Chapter 4 for more details on the context). The participants consisted of six children (Anthony, Arman, Ben, Donna, Eric, Freddie - pseudonyms) between grades three to five. I chose these grade levels because the literature states that learners in the middle school age tend to lose interest in science (e.g., Archer et al., 2010). If upper elementary to middle school students are likely to lose interest in science, there is a chance that some of the participants of this program will vary in their level of participation.

3.4.3 Facilitators and Visitors

For this study, I had five main facilitators and three visitors. All of the facilitators and visitors had a research connection to the Human-Computer Interaction Lab. The main facilitators were Dr. Clegg, Elizabeth Bonsignore, Emily Rhodes, Charley Lewittes, and myself. At the time of this study, Dr. Clegg, was a postdoctoral fellow at the HCIL under Professor Allison Druin, also my advisor. Prior to Dr. Clegg's time at the University of Maryland she implemented a version of KC (called Kitchen Science Investigators) in her doctoral program. Dr. Clegg led the KC study. She and I were present for all of the 12-week implementation and held many

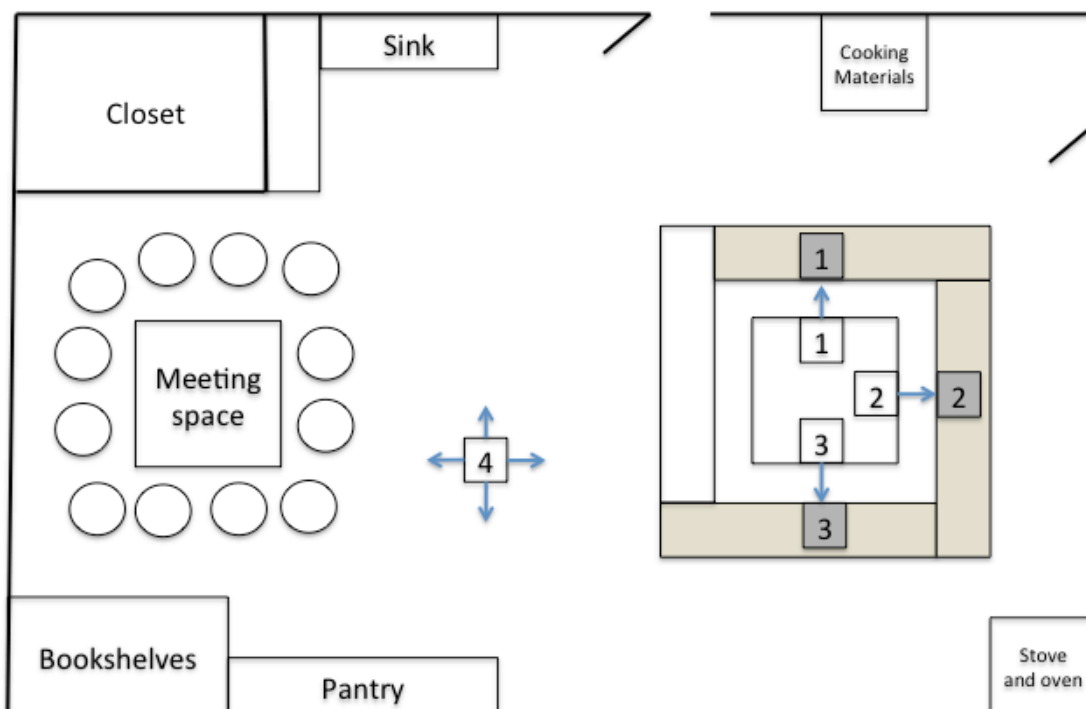


Figure 2: The layout of Kitchen Chemistry and the camera positions. Cameras 1, 2, and 3 are stationary and hooked up to table microphones 1, 2, and 3. Camera 4 is a movable camera on a tripod that can capture the dialogue in the meeting space and the larger view of the area. The shaded rectangles represent the working space and locations of the table microphones where the children tended to cook.

responsibilities, such as setting up the activities, recording the sessions, leading the discussions, facilitating the Choice Day investigations, observing the children, and participating in all activities. Elizabeth was a fourth doctoral student at the College of Information Studies and volunteered to support the KC activities. Her research is focused on how narratives can be generated through participatory cultures. Charley is the HCIL's lab manager and also volunteered to support KC. Prior to her time at the HCIL, she was a Montessori schoolteacher for young elementary school children between the ages of six to nine year old children (1st - 3rd grade). Charley was also Montessori certified by the American Montessori Society for ages six to twelve. Emily was an undergraduate intern at the HCIL. She volunteered to support the KC

research so that she could gain more Human-Computer Interaction (HCI) research experience. Elizabeth, Charley, and Emily attended most of the KC sessions.

During the time of this study, three visitors from the HCIL came to the 12-week KC to make visits and to test out new mobile apps with the learners. Dr. June Ahn, is an assistant professor at the College of Information Studies and College of Education. Together, with his graduate student, Michael Gubbels, they came on Week 05 to test out SINQ. Tobin Valenstein was an undergraduate senior working with Dr. Clegg on a prototype app called ScienceKit. Tobin came to visit on Weeks 02, 08, and 11 to act as both a participant observer and an app developer.

3.4.4 Reasons for Case Selection

Based on my review of the literature on ownership and design, I chose the implementation of KC as a case for several reasons. First, KC may represent an ideal case for investigating the evolution of ownership. Yin (2003) rationalizes the importance of the “unique case” as supporting theory building and exploration (p. 40 – 41). In this case, the implementation of KC portrays an ideal situation that I might be able to observe learners’ evolution of ownership. The school is a small Montessori independent institution that does not adhere to traditional constraints, such as high stakes standardized tests. Part of the science curriculum at this school highlights projects that are shared in a science exposition and development of an engineering project that builds boats for an annual race. The school also had the resources needed for this project: a kitchen space for cooking, a space for where the investigations can take place, wireless Internet, and LCD projector. For about a year, the school has partnered together with the HCIL to develop ideas for curriculum and technology

usage. The administration was supportive of this project and allowed us a venue to work there. Because of these supportive factors, I contend that learners may already be relatively autonomous and independent in their learning. Because I am looking for evidence of ownership in an environment where it might be more likely to appear than the traditional schools I reviewed in the literature, this situation was a good fit for this study.

As a possible ideal case, this environment may not have as many institutional barriers that prevent KC learners from developing ownership in their science learning. I am assuming that even if a researcher develops the most innovative curriculum that can promote ownership in design, if there already is not a community culture that supports ownership, I might not be able to examine the progression of ownership directly. I had reason to believe that specific aspects of KC, including the institutional supports, that may support ownership in science. This study may have potential lessons from this case that may be informative on how to develop ownership in design activities for schools. On the other end of the spectrum, if learners lack ownership of science in a more ideal situation, this also meant that ownership is very difficult to support. A difficult situation can also inform the theory of ownership and help better understand what might be important to focus on for future development of curriculum, technology, and professional development.

Lastly, KC integrates mobile technologies into the implementation of its design activities. As schooling progressively moves towards integrating technologies that support learning activities, curriculum designers and educators will need to acknowledge the presence of these tools. The usage of technology in KC and design

based activities allowed me to discuss what affordances and constraints these tools have on issues of ownership. For instance, StoryKit is a tool that supports creative writing. Prain and Hand's (1999) work with creative writing in science suggests the possibility that ownership can take place when learners can express themselves through innovative media. Therefore, an examination of KC and the usage of mobile technologies may help to better understand how ownership evolves when learners are able to document and create stories of their science investigations.

3.5 Protocol for Case Studies

3.5.1 Selection of Embedded Cases in KC – Criteria

From this implementation, I selected four focal learners (Tables # and #) for my embedded cases to examine how ownership develops and progresses through participation of design activities in science. The framework of this study examines how individuals develop ownership through social collaborative interactions and personal experience in design activities in science learning. In particular, I am interested in the different experiences and interpretations of ownership of different learners in the same implementation of KC.

I selected the focal learners based on three general criteria: personal views, participation style and social collaboration (Table 1 and 2). All of the focal learners went to same Montessori independent school that hosted KC. Chapter 4 will give a more detailed presentation of the school context. First, I added personal views because I am interested in what learners' experiences are and how they might shape and influence the progression of ownership. Learners have a range of prior experiences that contribute to what they find interesting, how they participate in the

activities, and how they see themselves and their contributions. Second, based on O’Neill and Barton’s (2005) themes of ownership and O’Neill’s (2010) examination of ownership in the classroom, participation style is an important criteria for selecting focal learners because how learners participate can indicate degrees of ownership, what is being owned, and what dynamic changes might take place. In these criteria, I am examining if learners participate in the design activities, I needed to examine if they see themselves as having ownership and what do they see themselves as owning. And vice versa, if learners do not appear to participate greatly in KC (e.g., quality of participation, frequency of participation), is there evidence to suggest if they have ownership or not. Lastly, because learners’ interactions with themselves and the context may provide understanding of how ownership evolves, I based my choice on focal learners’ interactions with each other and the adult facilitators.

Table 1

Selected focal learners and facilitators

Participants	Facilitators
<i>Focal learners (pseudonyms)</i>	<i>Main facilitators</i>
Arman (M – 5 th grade)	Dr. Tamara Clegg (Ph.D. postdoc)
Ben (M – 4 th grade)	Jason (me, doctoral student)
Freddie (M – 5 th grade)	
Donna (F – 5 th grade)	<i>Volunteers</i>
	Emily (undergraduate volunteer)
<i>Other KC learners (pseudonyms)</i>	Elizabeth (doctoral student)
Anthony (M – 5 th grade)	Charley (lab coordinator and volunteer)
Eric (M – 3 rd grade)	
	<i>Visitors</i>
	Dr. June Ahn (Ph.D. assistant professor)
	Mike (HCI masters student)
	Toby (undergraduate software programmer)

Table 2

Overview of the focal learners and relationships

	Parent	Teacher	Facilitator
Arman	Dad	Molly (5 th)	Charley (Week 06, 07 - Choice Day 01) Beth (Week 10 - Choice Day 02)
Ben	Dad	Terrie (4 th)	Charley (Week 06, 07 - Choice Day 01) Beth and Emily (Week 09 - Choice Day 02) Jason (Week 10 - Choice Day 02)
Freddie	Mom	Terrie (5 th)	Emily (Week 06 - Choice Day 01) Jason (Week 09 - Choice Day 02) Tammy and Emily (Week 10 - Choice Day 02)
Donna	Mom	Terrie (5 th)	Tammy (Week 06 – Choice Day 01) Jason (Week 07 – Choice Day 01) Beth and Emily (Week 09 – Choice Day 02) Tammy and Emily (Week 10 – Choice Day 02)

All names of children, parents, and teachers are pseudonyms

Table 3

Focal learner criteria

Personal views of the learners

- What are their views of science and their experience in science?
- What are their views of school?
- How do learners see themselves and their identity?
- What are their interests and goals?
- What are their reasons for participating in KC?

Participation style of the learners

- What decisions are learners making? How do learners make decision?
- Are learners quieter or more talkative during discussions?
- What investment of time and resources do learners make in KC and outside of KC?
- What contributions are learners making?
- What are learners using the mobile technologies for? (e.g., recording, games)

Social collaboration

-
- How do learners work together in groups (e.g., cooperative, territorial, quiet, active)?
 - How do learners work together in discussion time?
 - What interactions do learners have with adult facilitators?
 - What roles (e.g., leader, follower, active, passive, cook, documenter) do learners play in their groups?
-

From these criteria, I picked learners from a wide spectrum and diversity of perspectives. Having more than two focal learner cases makes for a stronger argument and more powerful analytic generalization about ownership and design activities in science learning (Yin, 2003). In this selection, I attempted to find contrasting focal learners (based on the characteristics in Table 3) for the embedded cases. Finding contrasting cases allowed me to make stronger claims about ownership because I could attend to how differing individual and social experiences influence ownership. Having contrasting cases allowed me to examine rival theories more deeply and examine how important or unimportant the actual context is to influencing the different interpretations of ownership.

3.5.2 Data Sources

I collected the following evidence from five data sources.

Participant observation and analytic memos: In KC, I was both a facilitator and an observer. As a facilitator, I ran and designed KC and as an observer, I took field notes, writing post reflections, and analytic memos. During my facilitation of KC, I took opportunities to write field notes quickly into my iPhone™. I also kept reflective journals after each weekly implementation. I wrote these reflections within 24 hours of implementation. In total, I wrote 12 analytic memos, one for each session. Tamara also took time and wrote 12 post observation reflections. After each session, our group met and discussed how each session went. I also took notes during this

time.

Software artifacts: Each semi-structured activity and Choice Day design investigation in KC was documented from the iPads™. Using StoryKit, the participants recorded audio, drew pictures, took photos, and wrote text. Using these features, learners could develop a narrative story of their experience in KC and their design. For the 12 sessions, I collected 32 stories from each of the learners. Using Zydeco (Weeks 01 and 03), participants could tag, take photos, record audio and video, and share their data. Finally, during Weeks 06 and 08, learners used SINQ to input questions, hypotheses, and investigation designs (<http://sinq-kc.appspot.com/>). All software artifacts were stored either on the flash drives of the iPads™ or uploaded to a secure server. StoryKit data is saved on a server in the Human-Computer Interaction Lab. Zydeco data is saved in a server at the University of Michigan. SINQ data is saved in appspot.com and can only be accessed through a specific login.

Video recordings of discussions and activities: All sessions in KC were video recorded. I recorded all the sessions using both stationary and moving cameras. Dr. Clegg, the facilitators and I took turns checking the cameras. Based on our prior implementation of KC, we found that there are key locations in the room that we can place a stationary camera. A stationary camera was placed in one of these key locations and records the whole group discussions and presentations. From our pilot data, we noted that capturing the dynamic interactions of the semi structured activities and the Choice Day design sessions proved to be too difficult using the stationary cameras. Therefore, I alleviated this problem by having one camera “float” around and capture the more dynamic and interactive activities. Static cameras were used to

capture the larger picture of the interaction in the cooking area of the room. Each stationary camera was fitted with a table microphone. In general, this captured much of the sound. I attempted to move the cameras into the right positions or move around with a camera to capture salient activities. However, I realize that video recordings can still provide a distorted picture of the nature and degree of the interactions. I recorded eight to nine hours of video per session, with a total estimate of 100 hours of video.

Semi structured interviews: I conducted a sequence of two in-depth interviews with my focal individuals for about 30 to 40-minutes each interview (Appendix C and D). The first interviews took place in the first six weeks (March) of the program to help me determine which participant is willing to be a possible focal learner. From the prior implementation, we learned that younger learners might not be willing to participate for a very long duration in interviews. This meant that I had to find the right time to interview the participants; I also had to interview them quickly. Based on field notes, video recording, analytic memos, software artifacts, and informal interviews, I selected the four focal learners that represented the spectrum of my three criteria: personal views, participation style and social collaboration. I conducted the second set of interviews in the last two weeks of the program (May). All of the focal learners interviews were done either at the participant's home, afterschool, or after KC was over. For two of the interviews (Arman and Freddie), a parent was always present sitting next to the child.

Triangulation of the interview data is an important way to check the reliability and validity of the informants (Stake, 1995; Yin, 2003). In order to triangulate data

from my observations and interviews with focal learners, I interviewed the facilitators of KC. I conducted a total of three in-depth interviews with our volunteer facilitators Elizabeth, Charley, and Emily (between March and June). Each of these interviews lasted for approximately one hour. I conducted the interviews with the facilitators at the beginning, middle, and end of the program because I wanted to make sure the facilitators and the learners supported each other's views.

To better understand how home and school life might be influencing ownership in KC, I also interviewed the parents and the teachers of the focal learners. I conducted two interviews (first six weeks and last two weeks of KC) with the parents for about 30 to 40-minutes each. For teachers, I conducted one interview for approximately one hour to better understand how science was taught in the school (Appendix C and D).

4a. Instrumentation for semi-structured interviews: I used a written interview guide for each of the participants (Appendix D). Although, I used a guide, I conducted a semi-structure interview that I explored and pursued my questions using a mixture of more and less structured interview questions. Either formal questions or main issues to explore mainly guide the interview, but there is no predetermined wording or order. I am choosing to use a semi-structure format because this format allows me to respond to the situation at hand. In particular, because ownership is a worldview based on the respondent that can be emerging, I need an interview format that is flexible and responsive. Some of the interviews went longer because I allowed for more open-ended, but systematized questions (Marshall & Rossman, 1998). This allowed interviewees to share more information and go deeper into certain topics.

My interview guides for learners, parents, teachers, and facilitators are adapted from Dr. Clegg's (2010) dissertation. Her study examined the emergence of learners' self-identity through participation in a program similar to KC. Dr. Clegg's investigation produced a rich case study that describes the changes in learners' identity through participation in the *Kitchen Science Investigators*. The dissertation study incorporated questions to elicit detailed descriptions about the learners' personal goals and interests, views of self, perceptions of schooling and science, and their motivations for participation. I took Dr. Clegg's guide for learners, parents, facilitators, and teachers and adapted it for this use of this study with the inclusion of themes of ownership (e.g., agency, decision making, investments, collaboration, targets of ownership).

4b. Recordings: I recorded all semi-structured interviews by video or audio (depending on the preference of the interviewee). I asked all participants for consent to record and assured that all data was rendered anonymous, confidential, and stored securely. All participants consented to either audio or video recordings. During the interview, I also took short notes on the interview guide and wrote down salient quotes when necessary. After the interview was complete, I immediately listened to the recording to check for completeness. I also quickly wrote a reflective journal entry of my experience for the case study database.

5. Classroom observations: To get a better understand of the influence of school for learners' ownership in KC, I conducted an observation of the classrooms at this Montessori school. Dr. Clegg and I acted as observers for the classes that the focal learners were attending. Instead of depending on video and audio recordings, I

took field notes on my experience in the class. Appendix E contains the field notes protocol I used to make my classroom observations. After taking the rough field notes, I wrote an analytic memo detailing and summarizing my experience.

3.5.3 Data Collection Schedule and Focus

These data are split up into two types – primary and secondary (Table 4). Primary refers to the focal learners and their direct experiences. Secondary sources are the facilitators that observe and interact with the learners in KC. Tertiary sources are the parents and teachers of the focal learners. Table 4 shows the focus of these data. Each data source has a purpose and focus for this study. The figure shows the number of times I will collect these data, who the informants are, and when these data will be collected.

Table 4

Primary and secondary sources

<i>Primary</i> – Learners (Interviews, video recording, field observations, and artifacts)
<i>Secondary</i> – Facilitators (Interviews, video recordings, field observations, analytic memos and artifacts)
<i>Tertiary</i> – Parents (interviews) and teachers (interviews, field observations)

Initially, I reviewed of my field notes and analytical memos. This allowed me to examine if my initial interview guide still needs reworking and retooling. Once I confirmed that my interview guide was ready, I conducted my first set of interviews with facilitators and learners. In this case study, interview data will provide the most exhaustive and elaborate information. Once the interviews were collected, I wrote post analytic memos about my initial feelings and perceptions of the experience. Next, I transcribed the interviews. To help in data reduction, I gleaned through the interviews and found sections that refer to specific times and context during KC the

interviewees thought were significant. From the interviews, analytic memos, and field observations, I selected specific video clips to transcribe and analyze. To efficiently examine the video data, I watched the clips and made analytical notes every minute that notes the themes and trends I observed. Based on these notes and the interview data, I selected salient vignettes to transcribe for further analysis.

Table 5

Summary of data collection

Data Source	Focus of Data	Number of times collected	Participants	When Data Collected
Video recordings of KC sessions	To record the actions and activity of the learners and facilitators during the implementation of the program	Each time KC is run	Primary Secondary	Each time KC is run 12 sessions from February to May
Analytic memos	To reflect on each of the sessions and interactions during KC	Each time KC is run Classroom observations	Primary Secondary	After each KC session 12 sessions from February to May
Semi-structured interviews	To gain insight into the views of the learners, facilitators, parents and teachers about KC	2 for primary (30 minutes) 3 for secondary (60 minutes) 2 for tertiary (parents) (30 minutes each) 1 for tertiary (teacher) sources (20 - 30 minutes per student)	All informants	Primary, secondary, and tertiary (parents) <ul style="list-style-type: none"> Beginning six sessions February to March Last six sessions March to May or early June Tertiary (teachers) <ul style="list-style-type: none"> April
Software artifacts	To record what stories and designs the learners develop as they progress through KC	Each time KC is run	Primary Secondary	Each time KC is run 12 sessions from February to May
Classroom observations	To observe what influence the school may have on learners in KC	Once during the implementation of KC	Tertiary (teachers)	April

3.6 Data Analysis

The analysis of these data was broken up into three parts: Phase 1 coding (*P1*), Phase 2 direct interpretation of the cases (*P2*), and Phase 3 cross-case analysis (*P3*).

3.6.1 Phase 1: Initial Development of Analytic Coding Scheme

The main goal in *P1* was to build an independent case study profile of each focal learner. I first began my analysis of this case study by using open, axial, and selective coding. Using methods outlined by Strauss and Corbin (2008), I started with open coded of trends in the newly collected data. Following open-coding analysis, I used axial coding to build connections between a category and its subcategories (Strauss & Corbin, 2008). I used selective coding to see if additional categories were needed or if certain categories are not needed due to infrequency. I contrasted, sorted, and compared until saturation, that is, no more changes could be made to the coding scheme. Finally, I conducted a code check through an external code audit.

Due to the amount and varying types of codes, I used *Transana v.2.5* (Woods & Fassnacht, 2012), a program designed to support the management of qualitative data. All interviews (audio and video), video clips, and analytical memos were coded using Transana. Using the research questions and guidelines I developed, the coding first began by working through the interviews, specific video clips, and the memos. While going though these data, I made interpretations of the emergent patterns and added them into Transana.

3.6.2 Phase 1: Initial Glean of Data and Open Coding

For a complete audit trail of the development of the codes, please see Appendices E - I. The audit trail shows the initial codes, how they were collapsed, and what the final coding scheme is. I first developed the codes based on the sub-questions of the dissertation. I initially split my coding phase into three phases in which I coded one-third of the data (Table 6).

Table 6

Matrix of analysis

Type of data	Set 1	Set 2	Set 3
Interviews	Arman (all)	Ben (2 nd half)	Donna (all)
Video recordings	Ben (1 st half)	Freddie (all)	
Participant observations (memos)			
Software artifacts			

I began to collect data from February to June of 2012; at this time I systematically reviewed and organized the data and information (Creswell, 1998). During the transcription of the interviews and video clips from July to October 2012, I wrote memos and notes down and started categorizing the data into themes. From October 2012 to January 2013 after the data collection, I conducted open coding analysis (Maxwell, 2005), that is, while I had themes and patterns to examine in relation to children's development of ownership of science learning, I did not use any pre-set codes before the data was collected. Although I did not use specific a priori codes, I used the research questions and the prior literature to guide my development. In the first pass of the data, I used *SQ1*, *SQ2*, *SQ3*, and *SQ4* as my guidelines (please see Appendix F for details). I mainly allowed myself to look for emergent patterns from which I could develop new categories (Marshall & Rossman, 1999). Data from

all sources – participant observation, artifact analysis, video recordings, interviews, and classroom observation – were consistently triangulated to examine if the different data could support each other. As well, during the process of open coding, I realized that in order to better understand the focal learner cases I had to account for the learners’ personalities, characteristics, and preferences. An emergent set of themes I focused on in this process was “talents” and “difficulties” children had, “affect” (see Appendix F for more information on affect) and what emotions the children displayed, and the “likes” and “dislikes” children had.

3.6.3 Phase 1: Audit Trail and Code Collapsing

After these data were first coded (Table 3 – 6, Set 1), I met with two researchers to validate and collapse the codes. One researcher is an assistant professor in STEM education that had intimate knowledge of the project (Dr. Clegg). In contrast, the second researcher is a research scientist that was not directly involved with KC (Dr. Mona Leigh Guha). Having one researcher who knew the project well and another researcher who did not know the project allowed me to compare and contrast the codes and determine which were important for the study. I presented the initial set of codes to them in two separate meetings. Each researcher worked with me independently to collapse the codes together. From my meetings with these two researchers, I reorganized the codes (Appendix F and G).

Over time in the first review of the data, the coding scheme became quite large and extensive. Certain codes became redundant and others needed to be deleted. Other codes needed to be combined together and be subsumed within broader themes. In the first meeting with Dr. Clegg, we went through a majority of the codes. We

determined that certain groupings needed to change and that codes need to be collapsed together (see Appendix F for more details). In multiple meetings with Dr. Guha and Professor Druin, we began to reorganize the codes for further collapsing (please see Appendix G for full details). In a final meeting with Dr. Clegg, I presented to her a second preliminary version of my framework with the codes (Appendix H). We began the selective coding and started to change and eliminate codes. From this meeting, we agreed on the categorization of the codes.

3.6.4 Phase 1: Validation of Coding Scheme

Once the codes were finalizing, I worked with a third researcher, Elizabeth Foss on the validation of the final codes. We chose to perform an external audit (Creswell, 1998; Merriam, 2009) for verification. As we began to validate the codes, we found that the large number of codes was too granular and large for validation. The external audit allows an external consultant to examine both the process and the product of the coding account. The auditor should have no connection to the study. In this case, Elizabeth Foss is a graduate student researcher that had little knowledge of the project and the coding scheme. In assessing the codes, she determined whether or not the codes and interpretations were supported by the data. This procedure provided a sense of interrater reliability to the study (Lincoln & Guba, 1985).

For my external audit, I gave Elizabeth F. approximately 10% of my codes and a detailed codebook (Appendix I). Based on the finalized coding, I had 26 major coding categories. We numbered each code from 1 – 26 and used a random number generator to pick three of these categories. Elizabeth F. received the code categories: engagement and alignment: affect, engagement and alignment: attention, and target of

ownership: tangible. Next, for the audit, I gave 291 codes for verification. Out of the 291 codes, we only had disagreement on 24 of them (92% agreement). Based on her comments, I reworked the definitions of the codes to make sure the codes fit or I recoded them. Since I had 92% agreement, I finished coding Set 3 and reexamined Sets 1 and 2 (Table 6) and finalized the codes. Appendix J is the final codebook I developed.

3.6.5 Phase 1: Visual Representation of the Cases with Codes

After the final development of the coding scheme, I developed each of the individual focal learner cases to answer the sub-research questions. For this cross case analysis, I employed Miles and Huberman's (1994) monster-dog data displays. The monster-dog table displays data from the individual cases study according to a particular framework (Table 7). I created monster-dog data displays for each learner based on the six main coding categories (Profiles, Engagement and Alignment, Imagination, Learning, Target of Ownership, and Communities). Each monster-dog table is split up based on the codes and the communities of home, school, and KC. Table 7 shows the code for “relationship to science” and how it splits across the communities of home, school, and KC. If a parent discussed about the focal learner’s experience in science at home, the corresponding code for “relationship to science” would be placed into the “home” category. Similarly, if a focal learner talked about their relationship to science experience in the classroom, the corresponding code would be placed in the classroom. Not every matrix is filled out in the monster-dog data display. These complementary word tables allowed me to analyze the similarities and differences through interpretation.

Table 7

Sample monster-dog data displays (Miles & Hubermann, 1994)

Imagination

	Home	School	KC
Arman	Relationship to science Arman Interview	Relationship to science Arman Interview	Relationship to science Arman interview
	1.01 - Authority - Math; Einstein-like	1.01 - Authority - Math; Einstein-like	1.30 - Epistemology - Everyday knowledge
Ben	Ben interview	Ben Interview	Ben interview
	1.14 - Science: Long wait; Science - Outcome importance	1.02 - Long wait	1.26 - Hands on - Experiments; Science - Einstein-like
Freddie		Freddie interview	
		1.01 - Science - Einstein-like	
Donna	Mom interview	Donna interview	Donna interview
	2.04 - Hands on - Science by doing	1.02 - Authority - Degree; Authority - Math; Hands on - Experiments; Science - Beneficial for Cures and disease	1.19 - Hands on - Explosions;

3.6.6 Phase 2: Direct Interpretation of the Data

Throughout the larger coding process, I noticed that interactions in ownership with the learners were too complex to be analyzed through coding. Even with collapsing, the amount of codes was incredibly large and difficult to parse down. Inter-rater reliability would have been impossible given the large amount of codes and the largeness of the data. At this point, with so many elaborate codes (see Appendix F – J) I needed another way to analyze the data without just looking at the pattern of the codes alone. Stake (1995) notes that coding systems can become so elaborate, with too many equivalent terms, that even highly trained researchers can find limits to its usage. Even though I attempted to reduce the number of codes and

collapse them further into more general categories, it was difficult to ignore the complexity and sheer amount of the data. Once I developed the monster-dog data displays, it was still unclear to me what these codes meant and how to use them to conduct a cross-case analysis. Examining the larger patterns in the data was too difficult and did not explain the motives, social relationships, and engagements of these learners.

Instead of searching for patterns in the large codes, I began to “winnow” down the data analysis by focusing directly on the most important pieces of data. Both Stake (1995) and Yin (2003) agree that highlighting the most important and critical pieces of evidence is more important than examining everything. However, Yin recommends looking for extensive aggregation patterns in the data, whereas Stake emphasizes examining a specific portion of the observations of the data. The quantitative research side of me wanted to look for emergence of meaning through repetition in the phenomenon. Too much time focused on the codes distracted me from looking at the interactions and contexts of these learners. Instead of staying on the course with the analysis of the codes, I opted to complete the analysis of the data by selecting the most outstanding vignettes that demonstrated instances of ownership in science learning. This is not to say that the coding was not helpful. The extensive amount of coding exposed me to the data by helping me to look very carefully at specific clips and transcripts. Spending time on coding allowed me to know the data intimately. The codes themselves now acted more as quick summaries and bookmarks when I needed to search for specific important instances.

Therefore, in *P2* instead of looking for numerical patterns or broader themes in the codes, I decided to conduct a direct interpretation of the data (Stake, 1995). A direct interpretation of the data finds specific portions of the data that are meaningful to the researcher to present and interpret. Using the codes as organizational tools, I went back into the data looking for how the learners interacted socially, what affect I observed, and what I thought were interesting vignettes to explore. Using Transana (Woods & Fassnacht, 2012) I wrote analytic memos in the transcripts, field notes, and software artifacts to determine if the vignettes had significance to ownership of science learning. For the two to three vignettes I selected, I did a close direct interpretation analysis (Stake, 1995). In the next section, I explain how I organized the cases for direct interpretation, how I selected the vignettes for analysis, and how I analyzed the vignettes for the cases.

3.6.7 Phase 2: The Organization of the Cases

Using the direct interpretation method from Stake (1995), I organized the case studies of the focal learners (Arman, Ben, Freddie, and Donna) into the following three sections:

- Section A: Brief profile of the focal learners
- Section B: Vignettes from Choice Day and analysis of the vignettes
- Section C: Overall discussion of the case study

Section A

Each case study begins with a brief paragraph on the profile of the focal learners. The profile contains each child's age, grade, gender, ethnicity, general likes and dislikes, and family background.

Section B

Reasons for examining Choice Day closely for the focal learner case study

For each case study on the focal learners, I selected two to three vignettes from Choice Day in KC between Weeks 05 - 10. KC was broken up into 12 weeks. Weeks 01 – 05 composed of semi-structured activities to prepare learners for Choice Day. Choice Day 1 occurred on Weeks 05 – 07 and Choice Day 2 occurred from Weeks 08 – 10 (see Chapter 4 for more details on KC implementation). I chose to analyze Choice Day interactions as the boundaries of this study for several reasons. First, since this dissertation is about ownership of science learning, I wanted to analyze interactions based on O’Neill and Barton’s (2005) framework on ownership. I needed to examine conditions in which learners could exhibit the following themes:

- 1) how learners made independent choices and decisions;
- 2) how learners put investment and responsibility into their decisions and learning;
- 3) how learners expressed pride about their work;
- 4) how learners envisioned their self-identity in relation to science; and
- 5) how learners saw science as contributing to their goals.

Second, Cornelius and Herrenkohl’s (2006) study on power in the classroom suggests that further studies must account for the affordances of power that is made available to learners by the environment. These scholars also suggest that understanding the forms of collaboration that are present in these kinds of learning environments, particularly participation without direct supervision from a teacher.

Based on O’Neill and Barton’s (2005) framework and the implications of Cornelius and Herrenkohl’s (2006) study on power dynamics in the classroom, I chose to base the case studies on a deeper examination of Choice Day. Choice Day was a time in which learners independently developed their own food investigations

and took time to invest into the implementation of their own ideas. During Choice Day, we as adults give up some power and authority and allow learners to have more autonomy to select personal projects they wanted to explore. Learners also had to collaborate together and work with facilitators in ways that might allow a look at the benefits and tensions of ownership in science learning. The interactions in Choice Day also allowed me to examine how each of these five themes of ownership in science learning manifested when learners were given the opportunity to exert their own choices and decisions. Through my analysis of Choice Day interactions, I was able to provide a more rich depiction of how ownership of science learning evolved over time and how opportunities for autonomy, personal choice, and collaboration supported or hindered ownership.

Selection criteria for Choice Day vignettes

Each vignette for the focal learner is a detailed depiction of the interaction of the focal learners in KC for a particular week. I selected these vignettes based on the following criteria from O'Neill and Barton (2005):

1. Choices and decisions: Did learners make independent choices and decisions during Choice Day?
2. Investments: Did learners make investments into their personal projects?
3. Collaboration: Did learners collaborate with other learners and facilitators?
4. Pride: Did learners express pride over their Choice Day investigations?
5. Affect: What kinds of expressions did the focal learners show?

I chose to examine three to four vignettes per case study to compare and contrast multiple interactions to see whether ownership of science learning was stable or shifting across different times. Two to three vignettes are often typical for these types of analyses (Creswell, 1998). At least one vignette shows the focal learner taking a

lead role in the investigation and the other vignette shows the learner in a follower role. The vignettes contain information from multiple data sources, such as video recordings, adult interviews (teachers, parents, and facilitators), focal learner interviews, StoryKit and SING posts, and two sets of field notes from myself and Dr. Clegg.

3.6.8 Phase 2: The Analysis of the Vignettes

For the two to three vignettes per focal learner I selected, I did a close direct interpretation analysis (Stake, 1995). Using the coding scheme as an organizational search tool, I analyzed the vignettes based on the sub-questions for this dissertation:

Sub-question 1 (SQ1 - targets): What aspects of the design activities (e.g., technology, products, ideas) do learners have ownership of when they are given the chance to design in a guided inquiry science environment?

Sub-question 2 (SQ2 - points): At what points during the design activities do learners begin to take ownership of what they own?

Sub-question 3 (SQ3 - characteristics): What are the initial characteristics and outcomes from ownership and how do these characteristics change over time for learners as they participate in design activities in science learning?

Sub-question 4 (SQ4 - factors): How might the features (e.g., facilitation, technology) of KC, school, home life, and other contexts potentially impact and influence how ownership takes place in learners?

Each analysis is broken up into two to three main themes of the vignette. Within the analysis of the vignettes, I demarcated codes for ownership based on the sub-questions. *SQ1 - targets* indicates the specific target of ownership. *SQ2 – points* are turning points in which learners either take on ownership or change their position. *SQ3 – characteristics* show the particular attribute of ownership I am highlighting. *SQ4 – factors* are the features of the KC context and outside life of the learner that

was impacting the learner's ownership. For each vignette, I also provide multiple interpretations of the cases so that the reader can examine for his or herself the strength of the case.

3.6.9 Phase 2: How Each Overall Discussion Section Was Developed

Once each vignette was analyzed, I developed an overall discussion on the ownership of science learning for the focal learners. Each discussion is a time-series analysis based on chronology (Yin, 2003). Using data gathered from the interviews, videos of other KC events, and field notes, I developed a holistic analysis of each focal learner's ownership of science learning. For each focal learner, I started out with a summary of the targets of ownership I observed in the vignettes. Next, I analyzed the vignettes as a whole using Wenger's (1998) framework on communities of practice: imagination, engagement, and alignment. Each section of this discussion is broken up into (not in this particular order):

- Imagination and Ownership
- Engagement and Ownership
- Alignment and Ownership

Imagination is the way learners create images of the world and how they seem themselves being connected to a broader community. Engagement is how learners participate in a community of practice. Alignment is how participants coordinate their energies, actions, and practices to become a part of something that is larger and broader. Using this framework, I tie together the vignettes to answer my research question, how does ownership of science learning evolve over time in this context.

3.6.10 Phase 3: Cross-case Analysis

During the development of each individual focal learner case, I began to conduct a cross-case analysis. For each focal learner case, I started categorizing the vignettes on ownership into broader themes that I could see more visibly than by the narrow coding. I started placing these vignettes into themes of ownership and went back and forth through multiple rounds of analysis to refine these categories. After the first round of putting the vignettes into themes, I showed these ownership themes to Professor Druin and Dr. Clegg for external verification. From these meetings, we reorganized the themes into broader categories of characteristics of ownership, cultivation of ownership, and tensions in ownership (Chapter 9).

3.7 Summary and Conclusion

Summary. Chapter 3 outlined how the research took place, the justification for the methods used, and how I conducted the analysis. I described my research design, the rationale for use of a case study design, my biases and roles in this study, my research questions, my study design and protocol, the methods used to collect my data, and how I analyzed my data through open, axial, and selective coding.

In Chapter 4, I provide a description of the context of the study, including the profile of the school and teachers, an overview of the facilitators and visitors, and a summary of the 12-weeks of Kitchen Chemistry.

Chapter 4: Profiles of the Case Studies

In this chapter, I outline the background and context of the case study of Kitchen Chemistry. To protect the privacy of the participants, all names of children, parents, and teachers are pseudonyms. I begin with description of the The Green School (pseudonym) and the science program (4.1). I also describe the teachers that work with the focal learners of this study. Next, I outline the details of this specific implementation of the Kitchen Chemistry (KC) program (4.2). I include the facilitators of KC and the 12-week implementation of KC (4.3). In Chapter 5, I will go more deeply into specifics concerning the focal learners and their families. Table 8 gives an overview of the focal learners and the data sources.

Table 8

Overview of the focal learners and relationships. All names of children, parents, and teachers are pseudonyms.

	Parent	Teacher	Facilitator
Arman	Dad	Molly (5 th)	Charley (Week 06, 07 - Choice Day 01) Beth (Week 10 - Choice Day 02)
Ben	Dad	Terrie (4 th)	Charley (Week 06, 07 - Choice Day 01) Beth and Emily (Week 09 - Choice Day 02) Jason (Week 10 - Choice Day 02)
Freddie	Mom		Terrie (5 th)
Donna	Mom	Terrie (5 th)	Tammy (Week 06 – Choice Day 01) Jason (Week 07 – Choice Day 01) Beth and Emily (Week 09 – Choice Day 02) Tammy and Emily (Week 10 – Choice Day 02)

4.1 Profile of the Green School and Classes

The Green School is a pre-K-12 independent Montessori school located in a suburban area. The elementary school is divided between lower elementary (grades 1–3) and upper elementary (grades 4–5). Children in grades pre-K–5 are enrolled in a Montessori program in which they call, “an experiential approach to learning”. The Montessori program consists of learners in what the teachers call an “open curriculum”. In this curriculum, the activities are structured to be interdisciplinary and connecting. During interviews, when I asked the question, “What are science classes like at The Green School?” both children and teachers were quick to correct me that separate science classes do not exist here. Instead, science activities are integrated into the other learning areas of the curriculum. And the children have a range of tasks they must complete for the week which include a wide variety of learning areas. Science activities might include learning how to use a microscope and earning a certification for its proper use, understanding the parts of a cell and coming up with specific role to play for that organelle, and working with a teacher to learn about the different parts of a mushroom. Explorations outside the classroom in the school areas are also common occurrences.

At The Green School, children are given a series of tasks to complete independently or with a group. Tasks range from hands-on manipulatives, worksheets, reports, and independent projects. Each child is given a check-off list of the tasks to complete. The children do not receive homework; however, if the children are unable to complete the work schedule that is presented, the schoolwork is sent home for the weekend for completion. Children often work together with their

teachers in smaller lessons when they need help. Schoolwork consists of projects, reports, worksheets, and hands-on activities. For more independent projects, teachers give the children opportunities to choose what they want to research in. For example, in a report about animals, children can choose to be the expert at which animal they are most interested in researching and presenting in a report. The Green School offers report cards, but not letter or numerical grades for the learners. For assessment, children are given percent correct and incorrect in notebooks. They are given the chance to make re-corrections to worksheets and other tasks. All work is kept track of in a portfolio. At the end of the school year, teachers will summarize in writing how each child are doing. Testing is not a priority at the school. The children do not receive grades, but they get a thorough evaluation from their teachers. Every week the children meet together in a group meeting with their teachers to discuss any pressing classroom issues.

The classrooms are setup so that both 4th and 5th graders are in a mixed-age classroom with one or two teachers present. The philosophy of the school is that having the children in a multi-age classroom (ages 9 – 11) allows for better interaction and support between older and younger children. The Montessori philosophy of the upper elementary is to allow children to provide children with a work schedule, but the children can choose when and how they would like to complete it. Therefore, the upper elementary children independently work at their own pace, appropriate to their learning needs. Although a teacher is present, the classes do not have formal didactic lessons. Instead, teachers act as guides and work individually or in small groups to guide learners through the tasks. The teachers are

referred to by their first names, instead of their surnames. Teachers move from group to group to check in with the progress or conduct small independent lessons with the children. Students in the classroom I observed worked either in pairs and were talking with each other or working quietly by themselves. Some children would sit in one place for a couple minutes, while other would be moving around in all directions. After the 5th grade, the children transition into more traditional structures where a single teacher instructs a classroom of the same grade students.

4.2 Profile of the Teachers and the Focal Learners

In order to facilitate this style of classroom management, the classroom needed to have a wide-open space. I visited two 4th/5th grade classrooms where my focal learners were present. The classroom layout is not in the traditional grid style of desks and board. Instead, the room and the furniture are spread out into smaller stations. The classrooms have devoted areas for computers, personal shelves, sink, microwave, and a teacher's desk. The rest of the classroom has couches, tables, and chairs all distributed in random fashion. The walls are adorned with posters of flags, children's artwork, history, quilts, and guidelines and rules. Large ceilings and windows give a sense of openness. During the tasks, children independently move throughout the classroom and work wherever they feel comfortable. They can sit on couches to work, move to table stations, and go to the computer area.

The teachers I interviewed for this study were Molly (Arman – 5th) and Terrie (Ben – 4th, Freddie – 5th, and Donna – 5th). Molly is a veteran teacher from a family of educators. She was introduced to Montessori education when her daughter enrolled in preschool. She has a Montessori certification for children aged 2.5 to 6 and 6 to 12

years. She has taught over 30 years in many Montessori classrooms, with 26 years at The Green School. At the time of this study, Terrie has been at The Green School for 8 years. She is a Montessori trained teacher with multiple certifications. She has the same credentials to teach as Molly. She has been teaching for 24 years both domestically and internationally. She has also help to start her own Montessori school abroad.

4.3 Summary of the Kitchen Chemistry Weeks

In this afterschool implementation of Kitchen Chemistry, we began with a sequence of semi-structured activities to familiarize the children with the activities and the technologies (Weeks 1–4). Afterwards, we worked on *Choice Days* when participants would develop and implement their own food investigations. We had two rounds of Choice Day (Weeks 5–7, 8–10). First, learners spent time coming up with their ideas and designing an investigation. Next, learners would implement their ideas and designs. After Choice Day was over, children got a chance to present and share some of their results. The final week was a culmination of the work to the community and the parents.

Week 1 – Introduction. We planned the first day of the program to first introduce ourselves and help the learners get familiarized with the program. We explained the goals of the program in that learners would act as chefs, investigators, designers, and scientists. Each child used an iPad and StoryKit to write a short description of themselves and what they thought about science. Children shared these stories with us. Towards the end of the session, we gave children an opportunity to try Zydeco and have them tag starchy foods (e.g., breads, cookies) through observations.

We attempted to get them to make measurable observations (e.g., taste, touch, texture) as opposed to general opinions (e.g., it tastes good, it tastes delicious).

Week 2 – Pizza dough and yeast. On this day, we introduced the pizza activity. We gave the children balloons, yeast, sugar, and water bottles. Yeast acts as a leavener. As a one-celled organism, yeast breaks down sugar and produces the gas carbon dioxide. The children made observations of the rising of the balloons with yeast in water and yeast in sugar water. Afterwards, children made pizza dough with yeast and without yeast and made comparisons between the different setups. The children recorded their observations and implementations using StoryKit.

Week 3 – Brownies and eggs. In this session we worked with the children to develop a hypothesis of what they thought would happen in brownies if different variations of eggs amounts. After the discussion, we gave the children soda bottles, oil, water, eggs, and funnels. Each group mixed the same amount of oil and water, but varied the amount of eggs (one, two, three, and four eggs). Eggs act as emulsifying agents that help to distribute oil and water evenly through a mixture and prevent separation. We had the children use StoryKit to make observations of the different bottles of egg, oil, and water mixtures. Afterwards, the children baked brownies using the same number of eggs as they did with the egg, oil, and water bottle mixtures. We had the children compare the different variations of brownies and come up with a reflection on what they thought the eggs would do in the brownies mixture.

Week 4 – Cookies and baking powder and baking soda. We began the session to reminding the children about last week's activities with brownies and eggs. We asked the children to 1) describe what eggs do in brownies; 2) come up with an idea

on how the eggs worked with the brownies; and 3) talk about what they wanted to learn about. After the group discussion, we had the children think about what a leavener was in cookies and what they might think the difference is in baking soda and baking powder. Baking powder is a combination of baking soda (base) and a dry weak acid (tartaric acid). Water acts as an agent that distributes the weak acid to baking soda. This combination of weak acid and base produces carbon dioxide. Water alone with baking soda will not produce any leavening effect. We split the children into a group that would make cookies with baking powder, baking soda, and tartaric acid with baking soda. The children used Zydeco to record and tag what they thought about the results of the cookies. While the cookies were baking, we had each group of children mix baking soda and baking powder into warm water to observe what would happen. The children also mixed lemon juice into the baking powder and baking soda to observe what an acid does with a base. Using Zydeco, the children tagged what they observed.

Week 5 – Discussion and planning with SINQ. In this session, we started with a group discussion about the results of the cookies with baking powder and baking soda. We demonstrated the baking soda, baking powder, and warm water setup to show the generation of bubbles. We had the children try to come up with explanations in how they thought the carbon dioxide bubbles were being produced. Afterwards, we had the children begin to plan their Choice Day investigations using SINQ. As mentioned before, SINQ is a social media tool for scientific inquiry. Children can input ideas for questions, hypotheses, and project ideas. They can make contributions to other's ideas and vote up and down the ideas. Dr. Ahn and Michael Gubbels came

that day to enable the children to try a new prototype called: SINQ. As mentioned before in Chapter 3, SINQ is a social media app for science inquiry learning (Ahn et al., 2012). Learners can input their questions, hypotheses, and investigation ideas and also vote up and down the contributions. Using a combination of iPads™ and a laptop, we had the children use SINQ to record their food questions, develop a hypothesis to test out, and come up with an investigation to test this hypothesis.

Weeks 6 and 7– Choice Day 1. Based on the responses in SINQ and their interests, we split the children into the following groups for Week 6:

Puffy cake investigation – Anthony (a learner) and Donna with Tammy and Jason: What do we need to do to make a cake very puffy?

Pizza ball – Arman and Ben with Charley: What is the best dough type (yeast, egg, baking powder) to make a pizza ball?

Greenies (green brownies) – Freddie with Emily: How do we make brownies green?

Whities (white brownies) – Eric (a learner) and Elizabeth: How can we make brownies white?

Each group worked together with an adult to determine what the goals were and how they were going to design the investigation. The adults used a goals sheet, a scaffolded worksheet to help the children think about what the goals of their investigation were, what variables they would select to manipulate, and what materials they would need. After filling out the goals sheet, each group began their investigation. During these two days, new variations of the investigations occurred. For example, Arman wanted to use the dough made in his group to investigate whether cinnamon rolls should be made with cinnamon mixed into the dough or spread in between the dough. Donna, has to eat gluten-free foods, and had to make a

variation of puffy cake using gluten-free cake mix. Freddie, who could only be present on Week 06, decided to try to make brownies with white chocolate and green food coloring. In Week 07, we conducted another session with SINQ to prepare the children for Choice Day 2 (Weeks 9 – 10). Again, the children input their questions, hypothesis, and investigation ideas into the iPads. Afterwards, children continued work on their Choice Day investigations.

Week 8 – Examination of results, SINQ session 03, and co-designing technologies. This week presented a variety of activities. Prior to Week 08, we had a two-week hiatus from Kitchen Chemistry because of Spring Break for the school and a prior activity. Because a two-week gap existed between Weeks 07 and 08, we either had to freeze the food or remake new ones for comparison. We split the children up into groups. We created three stations of food: one for the puffy cakes with gluten (Anthony), one for the non-gluten puffy cakes (Donna), and one station for greenies (Freddie). We did a round robin in which children would go around and taste the different foods and explain what they thought about them and the investigation. We used StoryKit to record the children's thoughts. Second, we ran a third and last run of SINQ to see what the ideas would be for Choice Day 2. Lastly, as part of another project, we had the children work together with us to co-design the new mobile technologies for a future implementation of Kitchen Chemistry. Specifically, we had the children examine low-fidelity paper prototype interfaces of "ScienceKit", a mobile app the HCIL is developing for other life-relevant learning environments. Using the Layered Elaboration technique (Walsh, Foss, Yip, & Druin, 2013), we had the children mark up the interface and have them share their design ideas.

Week 9 – Choice Day 02a. For these two weeks, we rotated the leads so that every child had a chance to prepare an investigation. For Week 09, the following groups developed an investigation:

Caramel investigation - Donna and Ben with Emily and Beth: What sugars make the best and smoothest caramel candies?

Milkshakes investigation - Anthony (lead), Eric, and Freddie with Jason and Charley – How do milkshakes made with yogurt compare with milkshakes made with vanilla ice cream? During this time, Eric mainly worked with Charley, while Jason lead Anthony and Freddie.

Arman was absent from Week 09 due to illness. Timmy, although he was part of the original group, had to also depart early. Therefore, Timmy worked with Charley alone.

Week 10 – Choice Day 2b. For this session, we had to create new grouping because Arman had not a chance to create his own investigation, Ben had to miss the first half of Kitchen Chemistry, and Eric was absent on that day. The new Choice Day 02b groups were:

Cookie investigation – Arman with Beth: What can we do to make cookies spread far out?

Pudding investigation – Freddie and Donna with Tammy and Emily: What do different powders do to make puddings?

Trashcan brownies – Ben with Jason: What do I need to manipulate to make brownies so that they resemble bowls (Ben called these “trashcan brownies.”)

Lava cakes - Eric with Charley: What do I need to do to get the middle soft in a lava cake?

Week 11 – ScienceKit prototype and preparation for Week 12. As Kitchen Chemistry was winding down, we asked the children try two activities. First, at the HCIL, we developed a low-tech prototype of ScienceKit and we asked the children to

try out the app in making puddings. During this time, some children began a discussion about how the pudding was binding together. After the testing of ScienceKit, we had the children plan out their presentations to their parents for Week 12. Eric and Charlie wanted to talk about their milkshakes. Arman worked with Timmy on how to present Timmy's lava cake findings. And Donna and Ben paired up to explain what happened in their caramel investigation.

Week 12 – Preparation and presentation. In this last day of Kitchen Chemistry, we had to quickly get the children to prepare their foods for the parents and practice the presentations. Each child got a template for StoryKit that had the following pages:

These are the questions we had and started out with.

This is what I did.

This is what I found.

This is my conclusion.

This is what I learned.

Each group created a story using this template and presented their findings to their parents. Arman and Eric presented work on Eric's project on lava cake findings. Ben and Donna presented their work on caramels and sugars. Freddie and Anthony gave a summary of their work on the milkshakes.

4.4 Summary and Conclusion

In this chapter, I described the background and context of the case study of KC. I provided details about the The Green School and the science, including background of the teachers that work with the focal learners of this study. Next, I specified details of this implementation of the KC program. I included descriptions of the facilitators of KC and the 12-week implementation of KC.

In Chapter 5, I outline my findings of the case study. I present my four cases of Arman, Ben, Freddie, and Donna. For each focal learner, I will present a series of vignettes from Choice Day during Weeks 05 – 10 of Kitchen Chemistry (KC). For each vignette, I will provide an analysis of the learner's ownership using the four sub questions I outlined in Chapter 3. I use Wenger's (1998) framework of imagination, engagement, and alignment to explain how learner's ownership was evolving in Kitchen Chemistry. The analysis will include my observations and interpretations from the learners' home, school, and KC experiences and how these factors impact ownership of learning.

Chapter 5: Arman's Case Study

At the time of this study, Arman was a 5th grade boy that attended The Green School since kindergarten. Arman's father explained that he sent Arman to KC because Arman's mother heard about the program. While having no expectations of KC, Arman's father wanted his son to have more exposure to STEM programs and develop greater interest in math and sciences. Arman expressed that he liked cooking and science; this combination made KC a good match for him. I chose four vignettes as representations of Arman's ownership of science learning (5.1). The first vignette (Week 05) highlights Arman's progress in coming up with an investigation question on cinnamon rolls (5.1.1). The second vignette (Week 06) represents Arman's role as a follower in the pizza balls (5.1.2). The third vignette (Week 07) focuses on Arman's engagement in the investigation (5.1.3). Finally, the fourth vignette (Week 10) emphasizes Arman's difficulties in decision-making when he leads his own investigation on spreading cookies (5.1.4). I present a discussion of these vignettes together and make the claim that Arman's imagination of science and perception of adult authority influence how his ownership of science learning took place (5.2).

5.1 Vignettes from Choice Day and Analysis

5.1.1 Vignette 1: Choice Day #1 - Week 05

Arman needs to come up with a question

On Week 05 (Clegg et al., 2013), we asked Arman and his cohorts to use the SINQ app (Ahn et al., 2012) to come up with an idea for Choice Day. In the first SINQ session, Arman worked with Mike (visitor facilitator) to devise an

investigation. Initially, Arman did not have an idea for his investigation and instead asked Mike for an idea. Mike randomly told Arman, “cinnamon goo,” an idea Arman latched onto.

Arman: Uh, how about you come up with an interesting [?] just what's on top of your head that's - that's kind of straight forward?
Mike: Cinnamon goo[?]
Arman: Cinnamon rolls! I love cinnamon rolls (Arman looks down at iPad).
Mike: How can they be even more cinnamony!
Arman: And then uh, how does cinnamon relate to cinnamon rolls?
Mike: Yeah!

At this point, Mike generated a question for Arman, “How can they (cinnamon) be even more cinnamony?” Curious, Arman probed into the cinnamon question further with his own question, “Isn't like cinnamon like that stick?” Mike explained how cinnamon sticks are grounded into powder. During this explanation, Arman began to type his first question into SINQ, “How does cinnamon relate to cinnamon rolls?” As Arman worked, SINQ’s interface prompted him: “Do you wonder about this?” Using this prompt, Arman vocalized his thoughts on cinnamon, “Because cinnamon, actual cinnamon is a solid thing.” Mike interpreted Arman’s response as a comparison of cinnamon sticks to cinnamon powder. Arman and Mike then discussed the nature of cinnamon and where it came from. Concurrently, Arman scanned some of the questions other learners posted. Arman typed in his second question, “How do they make cinnamon sticks?”

Arman further developed a question on cinnamon

While Mike responded to technical SINQ issues, Jason and Charley (facilitators) recommended to Arman that he use SINQ to vote on other children’s

questions. As Arman did this, Charley asked Arman about his question. Arman explained his transition from the first and second question. Charley began a series of prompts to learn more about why he chose to explore cinnamon sticks and cinnamon rolls. Arman explained that cinnamon rolls are very sweet and “cinnamony”.

- Charley: Do you like things that are like really really sweet? Or just like (inaudible). Like is there such a thing as too sweet?
- Arman: Ummm, yeah.
- Charley: I disagree (jokingly), I think there's not anything you can't make too sweet.
- Arman: Well I've never had anything really sweet before. I've just had stuff like, you know, just like everything's sweet.
- Charley: So one thing, like if we could play with stuff, so like maybe we could make things more sweet or less sweet.
- Arman: So like (inaudible)
- Charley: Because it like, sometimes it's in-between like the dough and sometimes it's not in-between the dough. It's like sprinkled between the layers.
- Arman: Yeah. (Arman is quiet for 14 seconds)
- Charley: And you could test it out and like cinnamon in different kinds of dough (needs to walk to the other side of the table for a moment)
- Charley: And we could try regular sugar, or brown sugar, and compare like which ones maybe stay together, and which ones taste really sweet.
- Arman: That could be an interesting one.
- Charley: And also like you wanna (inaudible), what's the brown stuff called again, the powder and the cinnamon, you could mix them up in the cinnamon and see like which ones also taste also cinnamony and which ones taste (inaudible).

Searching for more detail, Charley asked, “Is there such a thing as too sweet?” Both of them discussed what foods they thought were sweet and their experiences with cinnamon rolls. At this point, Charley asked Arman to consider working on a recipe for the rolls that would determine the amount of sweetness in the roll. Arman entertained the idea and entered a third question into SING: “How do they add the cinnamon to a cinnamon roll?” Charley asked Arman about this third SING question.

Charley: Um, so you know how they add cinnamon into cinnamon rolls?
 Arman: Uh huh.
 Charley: Um, but we should sort of, like have a science experiment about it. Like how to prepare it (a cinnamon roll). Like sort of in-between the layers or cinnamon in the dough.
 Arman: Like that? Like what you just said?
 Charley: So like, you know sometimes they have cinnamon in-between the layers?
 Arman: Yeah.
 Charley: So sometimes they have it (cinnamon) in the dough. We could test out one we could mix in and one we could put in-between the dough to see which tastes more cinnamony.
 Arman: Ok. (looks at SINQ) No this would be a project.
 Charley: Or it could be a hypothesis. Like um, well you could ask a question like, which would taste more cinnamony, cinnamon in-between the layers or cinnamon in the layers?

As Arman added his question, Charley shared how cinnamon was sprinkled between layers of dough. Building on this, Charley also suggested different ways to think about how to add the cinnamon into the dough (e.g., different flours or sugars, in-between layers or outside the layers). Arman took Charley’s idea to develop another SINQ question: “Which would taste more cinnaminy: cinnamon in the dough or cinnamon in between the layers.”

Analysis of Arman’s Vignette #1

1. In general, Arman did not prefer open-ended tasks.

In this vignette, Arman was getting his first chance to write his own investigation question. While many of the other children immediately knew what kind of project they wanted to do, Arman came into this exercise not knowing what exactly he wanted. His teacher, Molly, mentioned that Arman tended not to like open-ended tasks. At school, Molly described Arman as “a really cautious student. He's one that likes everything kind of set up methodically.” When describing this cautious

nature of Arman, she stated that Arman was often determined to understand the tasks at hand and asks many questions to make sure he is clear. Molly explained that, “He kind of prefers the more standard, tell me what do and I'll do it approach. He's a little bit more black and white.” His teacher noted that Arman particularly liked when work is prescriptive and structured. This open-ended exercise in science inquiry question development may have been more difficult for Arman. In one of the interviews, Arman expressed that he had a sense of initial anxiety for the investigation development: “...I got really worried about what I should do” (*SQ3 – characteristics*).

2. *Facilitation and SINQ may have helped to build Arman's confidence.*

One explanation of this vignette is that working together with Mike and SINQ, Arman expressed more confidence for the task: “And then somebody brought up cinnamon and I brought up cinnamon rolls. And then I had my questions for that.” Both the technology and the facilitation may have helped Arman develop confidence in building a question (*SQ4 - factors*). Using SINQ, Arman was able to also see other learners' questions and how his friends were contributing. The prompts from SINQ sparked learner and facilitator conversations about scientific questions and evidence. For instance, the structure of SINQ required that the learners to vote up questions by requesting them to consider, “Do you wonder about this?”, “Is this a novel question?”, and “Can you relate to this question?” As Arman followed these prompts, Mike asked him if he ever considered questions about cinnamon, which prompted Arman to ask about cinnamon's composition, and how cinnamon sticks relate to cinnamon powder. From one prompt to another, Mike and Arman were able to

elaborate on cinnamon's transition from stick to powder, a line of reasoning that led to more discussions about how cinnamon is added to the rolls.

However, another possibility is that Arman continues to follow the lead of the facilitator in combination with the technology. He could be framing the task as adult driven and school learning. For instance, in an interview, Arman stated:

Jason: What kind of science right now are you getting right now of just designing yourself?

Arman: Um, guess really using my head because I got really worried about what I should do and then somebody brought up cinnamon and I brought up cinnamon rolls. And then I had my questions for that.

The cinnamon idea originated from Mike; Arman just goes along with the conversation with Mike. As well, Charley brings up the idea that Arman should consider turning his interest in cinnamon rolls into an investigation. Arman expressed that he was "really worried" about what he "should" do, which may suggest that he is framing the task as finding a correct line of questions.

The vignette is unclear whether or not Arman had another line of ideas he wanted to follow rather than the cinnamon rolls. When Mike switches off with Charley as a facilitator, Arman does continue the line of thought with the cinnamon as the theme for his Choice Day investigation. Rather than be fully independent, Arman may appear comfortable going along with an idea that sparks the interest of the adults.

3. Arman may be following what he thinks the adults want.

In these stages of development, Arman went from uncomfortable with the exercise to developing a question for an investigation. Arman began to gain a sense of ownership over the cinnamon question (*SQL - target*). This can be seen as Arman

began to invest into the idea that a question could be developed about cinnamon. The point in which Arman started to take ownership of this question was when Arman and Mike and Charley began to banter about cinnamon (*SQ2 - points*). Both facilitators did not denigrate his idea or tell him it was impossible to do (*SQ4 – factors*). Instead, both facilitators entertained the idea that a food investigation question can be developed from an interest in cinnamon rolls. One explanation is that working with Arman, the facilitators continued to add on different parts to the discussion, such as questions, cooking experiences, and prompts. As Arman began to see that his ideas are valued, he developed comfort and trust to keep working with the SING prompts to come up with a food investigation on cinnamon (*SQ3 - characteristics*). However, another rival explanation is that Arman was following the lead of Mike and Charley. Specifically, Arman’s last question about cinnamon in-between the layers and cinnamon in the dough was initiated from Charley. The ownership that Arman was developing may not be about the idea for the cinnamon rolls investigation, but about following what he thinks the adults want.

5.1.2 Vignette 2: Choice Day #1 - Week 06

Arman started to work on pizza balls

On Week 06, the facilitators Arman with his friend, Ben to work together on Choice Day 1. Arman had originally chosen to do an investigation on determining which cinnamon roll would have more cinnamon flavor, a roll with cinnamon mixed into the dough or a roll with the cinnamon placed in between the layers. Ben had chosen to investigate, “What would happen if you made a pizaball (pizza ball) when the dough rises and also when it doesn’t” (SING question). Since both children

wanted to complete a food investigation with dough, the facilitators decided to pair Arman with Ben. Ben would take the lead on developing an investigation with dough and leavening agents. If Arman had enough time and interest, he could use the remaining dough to investigate his cinnamon roll question. Charley worked with Ben and Arman as the facilitator.

The two boys began by working with Charley to develop the investigation on the dough and leaveners. Charley had the two boys sit down with her to fill out the goals sheet, a guide to help the children determine what leaveners they might choose and what outcomes (texture, mouthfeel, smell, handfeel, and taste). Although Arman had originally wanted to do an investigation on cinnamon rolls, the entries into the goals sheet focused on Ben's pizza ball investigation. I observed that Arman appeared fine with not focusing his original project and following Ben's lead.

The children began to work together on developing an investigation for the dough and leaveners. Charley asked what recipe they planned on using. Ben recorded into the iPad™, "Pizza balls, *my* pizza balls." As they continued to input into StoryKit, Charley asked, "What's the question?" Arman responded, "It's a question we should be able to answer, it should taste interesting." However, Charley noticed, "That's a fact, that's not a question." As they refined the definition of the question, Arman contributed, "Will it (pizza balls) taste good when we use leaveners?" Charley prompted, "When we use leaveners versus...?" A moment of frustration occurred since the children did not really understand the design of an experimental setup or trying to just simply make the food.

Arman does not defend a decision on the amount of eggs

Despite the frustration with the task, Charley continued to work with the boys on helping them develop an investigation on dough and leaveners. At some point in the exchange, I came over to check on the progress of the group. I asked the children what they decided to do. The group had decided to create dough with comparisons of the leaveners as eggs, yeast, and baking powder. I later asked them about the quantities they would be comparing. At this point, the children had to have another discussion with each other about the amount of leavening agent they would use, but also how to conserve the amount of ingredients so that the group did not make too much dough. Arman suggested to “cut it (recipe) into thirds.” Ben agreed with this suggestion; however, not all of Arman’s ideas worked out well for Ben:

- Charley: So instead of using yeast, when we do the baking powder, how much baking powder do we wanna use?
Ben: Um, same amount (as original recipe).
Charley: Same amount, so like (inaudible) of baking powder? How many eggs?
Arman: One-third of the egg?
Ben: What the heck? No! (directs to Charley) Um, about two eggs.
Arman: Two eggs, (jokingly) what are you crazy?
Ben: (jokingly) Yes.

Arman continued to work on pizza balls

Although Ben dismissed Arman’s suggestion, Arman continued to act cheerful and helpful towards the investigation. Once the children had a plan, they set out to go and make the three different dough types for the pizza ball recipe. During this time, while Ben was distracted and playful, Arman would constantly volunteer to get items for the group. Arman was also the one that mainly used StoryKit to document the investigation. In the making of the dough, each person had a specific bowl labeled with a different leavener (Figure 3). During this mixing, Arman rarely

left the middle position, except to gather more materials for the group. At some point in the work, Ben acknowledged Arman's effort in a humorous manner: "You did everything."

While Arman complete many tasks to make sure the dough was properly made, he also asked permission towards Ben to interact with the bowl. During the mixing, Charley gave instructions on how to mix and what to observe as the dough becomes leavened. Arman asked Ben, "Can I stick my finger to see what happens?" Ben responded, "Yeah, sure." Each person continued to stir and mix the dough, knowing that they would not be able to use this material until Week 07. As the time drew to a close, Arman continued to mix and stir the flour and even helped to put the dough away at the end with Charley into plastic bags.



Figure 3: The group makes the dough. Ben (left) – yeast and sugar, Arman (middle) – baking powder, Charley (right) – eggs.

Analysis of Arman's Vignette #2

- 1. Arman gives up ownership of the recipe to avoid conflict. However, by not taking ownership, this may have led to some later problems in the investigation.*

In this particular vignette, Arman, acted as the supportive role for Ben's pizza ball investigation. In the interview, Arman stated that the investigation was fun and "I mean I don't mind doing other (learners') projects." However, Arman took a more

passive role and did not want to take ownership of the negotiation process or the recipe in the investigation. Arman was known as being easy-going, but also had difficulty taking his own stance. As mentioned before, his teacher Molly stated that Arman did not often take chances in collaborative efforts. She stated, *“He can be willing to let someone else make his decisions for him.”* Arman may have good ideas and resources to add into collaboration, but Molly noted, *“Sometimes he might give them up and want someone else to answer.”*

Similar to his social workings in school, Arman did not take ownership in the negotiation process of the eggs and let Ben make the final decisions of the investigation (*SQ3 – characteristics*). Originally, Arman wanted fewer eggs than Ben, but ultimately, Ben went with his own decision of using two eggs. Instead of pushing for fewer eggs, Arman jokingly questioned Ben’s decision and did not pursue any further argument about it. However, the decision to use two eggs may have been haphazardly committed. Charley noted that adding two eggs was too much liquid and, *“Well, that dough was so heavy cause we compensated for the increased liquid with extra flour. Because you add flour till it turns to doughy.”* In the video, the children had to spend more time adding flour to this mixture to get it to the right consistency, but the egg dough became much drier and harder as a result. Charley noted that Arman was unwilling to stand by his opinion, *“So, the decision process was, you know, Ben saying his opinion, Arman saying his opinion and then Arman saying (making an interpretation), ‘but, it's really your (Ben’s) recipe, so if you wanna, if you wanna do two (eggs), we'll do two.’”* So although Arman was involved in the

choice-making practices and negotiations, he ultimately deferred his ownership of the task and mainly allowed Ben to make the final decisions (*SQ3 - characteristics*).

2. *Even as a follower, Arman does exhibit characteristics and aspects of ownership over some aspects Ben's investigation.*

Despite Arman's role as a follower, this did not make him any less invested or involved in the development of the mixtures. As part of his engagement in the community, he was often quick to volunteer for small tasks, such as gathering materials, spending time recording the investigation, or helping to put the dough away for the second half of the investigation while Ben was not present. Although he had thought about the cinnamon rolls investigation in Week 05, the conversation about that project never came up with Ben. However, Charley explained that the cinnamon roll idea was still on Arman's thoughts. She stated, "Arman wanted to make sure that we were going to still do his recipe when he realize when we weren't going to finish, um, Ben's today." Even through he enjoyed working on Ben's investigation, she explained, "*His (Arman's) recipe was important, he had personal investment in doing it and personal interest.*"

One possibility for Arman's investment into the pizza ball investigation was that Arman knew his turn would come up in a later Choice Day (*SQ1 - target*). Arman's target of ownership may still have been the pursuit of his cinnamon roll investigation or just making the cinnamon rolls. The facilitators had offered to Arman the chance on Week 07 to either continue to work on the pizza ball investigation or to use the dough he was making for his cinnamon roll investigation. In this case, the facilitation gave Arman the option to pursue his own choice or continue his follower

role (*SQ4 - factors*). Arman ultimately chose to do the cinnamon investigation for Week 07. Even though he was making the dough and supporting Ben, Arman still had his cinnamon rolls idea in the back of his mind (*SQ1 - target*). However, another reasonable explanation is that Arman identifies himself as a “helper” that does not mind following his friend’s project. In this role, Arman may be comfortable knowing that he is being supportive and being risk averse. In this role, he does not have to argue with Ben about the number of eggs or make strong opinions. In this explanation, Arman takes ownership of a role he tended to always gravitate towards in the classroom. I believe it could be a combination of the two ownership explanations, rather than a single motivation, that explains Arman’s decision to take on the supportive role.

5.1.3 Vignette 3: Choice Day #1 – Week 07

On Week 07, Arman worked with Charley to explore his cinnamon food investigation with the three kinds of dough (baking powder, eggs, yeast) they prepared in the prior week. The dough was sealed up in plastic bags on Week 06 and was frozen and thawed for Week 07. Charley was switching back and forth between helping Arman and Ben. In contrast to the week before, Arman and Ben mainly worked separately on their own projects. Ben continued to work on his pizza ball to see which leavener made the fluffiest pizza dough. Arman was investigating if cinnamon within the dough or cinnamon in the layers of a sweet roll would have a sweeter taste.

Arman needs to come up with an organization scheme

Before the children began, Charley suggested to both of them to come up with an organizational scheme for their products. The children used paper plates to arrange the products. She asked Arman, "What's going to indicate what's going to have cinnamon inside the dough versus cinnamon in the layers?" Ben, listening in on the conversation, suggested, "C I, C I." Charley continued to ask, "So what do you want to write on the plate?" While Arman was thinking, Ben suggested, "C I, C I, put like C I." Arman responded, "C R is cinnamon rolls. Cinnamon rolls." Charley prompted him to think, "What will that mean?" Ben chimed in again, "How about C I, cinnamon in?" At that moment, Arman had a realization, "Cinnamon in... Oh! Cinnamon in! Cinnamon partially in. Cinnamon inside." At this point, Arman added, "dough" into his labeling. Ben added to the scheme, "Cinnamon inside dough." Charley finalized the labeling, "Oh so maybe C I D, cinnamon in the dough." Arman completed his organization as, "C I D and then, cinnamon in layers, C I L." The final scheme that Arman created is in Table 9.

Table 9

Organizational scheme for Arman's investigation

Yeast – C I D N = 4	Egg – C I D N = 4	Baking powder – C I D N = 4
Yeast – C I L N = 4	Egg – C I L N = 4	Baking powder – C I D N = 4

Working together with facilitators

Once the scheme was completed for Arman, he needed to figure out many parts to building the rolls for this investigation. First, Arman had to come up with a way to put the cinnamon in the dough and within the layers. He worked with Charley to come up with a way to mix the cinnamon into the dough and how to get the cinnamon in between the layers of the dough. Once Arman has this plan in mind, he began to work on his own to make six different types of cinnamon rolls for the investigation. Charley was switching back and forth between Ben and Arman for support.

During this time, other facilitators would approach Arman and ask him questions about his investigation. For example, Dr. Clegg asked Arman to explain this cinnamon investigation to her. He explained the basic gist; he was testing to see which would be tastier for a roll, cinnamon between the layers or cinnamon within the dough. Dr. Clegg pressed him further, "Which one do you think it's going to be?" Arman expressed, "Hard to say" and that he would try to figure this out through a blind taste test. Dr. Clegg asked if he thought a blind smell test would work. She had Arman close his eyes and held one of the uncooked rolls up to his nose, "I'm going to let you smell it. I'm going to hold it up to your nose." Dr. Clegg did an initial "smell" blind test to see if Arman can distinguish between the two cinnamon rolls. Arman made a guess as to which one is which, but had a tough time distinguishing the two types. Dr. Clegg conjectured that smell might not be an indication. She also wondered if Arman just got too much cinnamon mixed into the dough. Arman thought, "It might also depend on how much dough I smelled. I was rating it on how much dough I smelled."

Working quietly and carefully measuring

In this whole session, Arman tended to work quietly by himself, but he was focused on getting this project accomplished. He acted very methodical in the development of this investigation. For example, Charley and Arman wanted to make measurements of the cinnamon rolls before and after they baked to determine if a difference occurred in the size. Charley suggested Arman needed a “starting point” to figure out which ones rose and which ones did not. Meanwhile, Ben needed Charley to help him on his project. Charley left Arman to wait. Instead of just waiting for Charley to do the measurements with him, Arman took the initiative to begin measurement. Using a ruler, he got down on his knees, and measured the height of the pre-baked rolls at eye level. Meanwhile Charley was still talking with Ben to help him out (Figure 4).



Figure 4: Arman working closely to measure the height of his cinnamon rolls; Charley is speaking to Ben.

Charley eventually came down to eye-level to help Arman with the measurements. She worked with him for only a minute and guided him on what measurements to take. Eventually, she stood up and watched Arman take the lead on

the measurements of the rolls. Arman still needed some guidance for the measurements. Arman was wondering what the measurements were and pointed to the ruler. Charley explained, “That’s three quarters,” and “This one here is a quarter.” She guided him on what a quarter, half, and three quarters is on a ruler. For the next three minutes, both Charley and Arman went down together at eye-level with the table to continue measuring the rolls.

Arman had stayed on this project for almost two hours straight with no break for rest. However, because others were using the oven and Arman was taking his time to work closely with this investigation, he was unable to put his cinnamon rolls into the oven before needing to go home. The facilitators promised Arman that they would bake the rolls for him in the evening, freeze them, and have them ready for testing and measurement in Week 08.

Analysis of Arman’s Vignette #3

1. Arman’s ownership over the investigation was supported when he could take on smaller tasks.

For Arman to make investments and ownership into his project, he needed guidance and support from the facilitators and learners (*SQ4 – factors*). For the entire two hours, Arman methodically and carefully enacted his food investigation with minimal distractions. While persistence could be interpreted as increased responsibility and self-efficacy, it can also be evidence for ownership over the project. O’Neill and Barton (2005) describe the investment of personal and precious time as an indication of ownership. Afterschool time is often a period in which learners can choose what they want to do and where they want to go. For Arman, he

chose to spend two hours of his own time on the project at the expense of giving up personal and social time.

However, even though this was his own independent project, Arman needed guidance to push forward his investigation. For instance, Arman worked with Charley and Ben to develop his organization scheme. Each of them gave him an idea for his organization that helped lead him toward the overall scheme Arman developed. He also constantly checked and confirmed his tasks with Charley. When he wanted to measure the cinnamon rolls, he took the ruler and got down on his knees to make careful measurements of height and diameter with Charley. In particular, Charley's facilitation and prompting enabled Arman to take more responsibility for this project. In part, Charley helped Arman take on the smaller tasks for his investigation, which allowed him to move forward into his investigation. Without a way for him to take apart his investigation into these smaller pieces that he could take responsibility for, it could have been difficult for him to develop ownership over the whole investigation.

2. *Arman welcomed social supports for his investigation, which could support his ownership over the investigation process.*

Arman also allowed others to come into his food investigation and help him with it (*SQ3 - characteristics*). He worked mainly with Charley and took in a lot of her suggestions. Dr. Clegg also came into the investigation and helped him consider if the smell of the rolls was an option he wanted to explore in determining his question. In this case, Arman has a sense of selfless ownership, which allows him to want to share the ownership of the investigation with others. Although he is the main lead in this project, he was willing to take on the suggestions and ideas from others (*SQ3 –*

characteristics). In essence, he gave up some form of control, knowing that collaborating with others may later help his project. These social interactions were important for Arman. In school, Arman tended to work with others that could support him. Arman's teacher Molly noted that he liked participating with a friend in larger projects.

Another perspective of Arman's social interactions is that he gives up ownership of this investigation. Instead of seeing his interactions as selflessly sharing the investigation with others, it is possible that Arman is simply following the lead of his facilitator to make sure Charley is happy. Evidence for this is shown as Arman may be framing the afterschool interactions as "school-like" and making sure no one is rocking the boat and causing disruptions.

5.1.4 Vignette 4: Choice Day #2 – Week 10

In Choice Day #2, Arman was only able to participate in Week 10; he was absent on Week 09 due to illness. Prior to his absence, Arman entered into SINQ a question about cookies: "What affects the spread of a chocolate cookie?" Since Arman had been absent on Week 09 and since he had not led his own food investigation from start to end, the facilitators wanted Arman to have his own Choice Day. Over the course of KC, it became apparent Arman tended to be quiet and not always pushed for his own opinions. The facilitators wanted him to have his own time designing his food investigation on his own.

Working with Elizabeth

On Week 10, Elizabeth was the facilitator working with Arman. Both Arman and Elizabeth started by looking through websites on cookie recipes. They decided

that a simple sugar cookies recipe would be the easiest to investigate and manipulate. Using the iPad™, Elizabeth came across a website that discussed how shortening type may be a cause of helping cookies spread faster. Arman and Elizabeth also discussed about a prior experiment in Week 03 when they made cookies using baking powder and baking soda. At this point, Elizabeth and Arman worked together on filling out the goals sheet. Elizabeth suggested to Arman that they write some ideas down in what they want to compare. During this time, Elizabeth used StoryKit to interview Arman on his thoughts about the investigation. Arman thought that butter as a variable affected the spread of the cookies. Elizabeth suggested that they do an initial experiment to see which melts first, butter or vegetable shortening. Elizabeth initiated a conversation concerning how acidic baking powder was and that this leavener might set faster for spreading. In the use of StoryKit, Elizabeth did a lot of the recording, while Arman was watching and making contributions.

As Elizabeth wrote down their goals and some thoughts, Arman was reading a website called Baking911. The site claimed that acidic batters and doughs (such as using baking powder, with a dry acid) would set faster and make the cookies puffier. Elizabeth took what Arman read and focused on two goals: cookies that spread and cookies that do not spread. They created a setup in which they hypothesized those cookies that spread would use butter and baking soda and cookies with less spread would use baking powder and vegetable shortening. Elizabeth and Arman also made decisions about what pictures to include in the StoryKit story.

Coming up with an investigation setup

Once the duo wrote up a plan, Elizabeth went and got the baking soda and baking powder. She encouraged Arman to look for the acid in the baking powder ingredient list. Elizabeth walked around looking for vegetable shortening and butter, while Arman was looking at the ingredients in the baking powder. Unfortunately, the pantry in KC did not have any vegetable shortening to test out. So the group needed to alter their plan. Elizabeth began to talk with me about the rate at which shortening may spread out. I suggested to them that perhaps melted butter could spread out faster since it was already in liquid form. Charley walked by and suggested to try oil instead of liquid butter. Elizabeth explained that they wanted to see if shortening melts slower than butter. At this point, Elizabeth and Arman decided to compare liquid butter and solid butter.

As they talked more about how to adjust the investigation, Arman showed Elizabeth a website that might describe what the acid is in baking powder. They read it over and found a section on the creation of carbon dioxide gas as a by-product of the reaction between the acid and the base. Arman, jokingly stated that they should “breath on it (the cookies)” to help it leaven. Elizabeth laughed and they began a conversation about how acids and bases contribute to bubble formation. She stated, "So without this, without the acid that is in this (baking powder), it should not rise." Arman pointed out, "So this should be flat (baking soda), flat cookies (points to baking soda) and not flat (baking powder)." Elizabeth agreed and wrote down, "We should try one experiment with baking powder and one with baking soda and compare. We predict these will be flatter (BS) and we predict these will be fluffier (BP)." For the final setup, Elizabeth called it a “double or nothing” arrangement.

Predicted more spreadable cookie: Liquid butter + baking soda
Predicted less spreadable cookie: Solid butter + baking powder

Arman's confidence issues

After this decision was made, the duo needed to figure out the proportions for the recipe. Elizabeth asked Arman, "Can you do the math and I'll type it in?" However, Arman looked hesitant and said, "You type it in, I'm not good at math." Being supportive, Elizabeth said, "Oh well, we'll figure it out together." The two of them began to work on changing the proportions. At some point, Elizabeth asked:

Elizabeth: So one-third of a tablespoon equals...?
Arman: A teaspoon?
Elizabeth: (Hands raised) Exactly! Yeah!
Arman: (Smiled and replied) I'm learning math.

Once the proportions had been determined, Elizabeth and Arman began to make two batches of cookies to see which would spread the furthest. They organized the bowls (spread, no spread) to make sure the mixtures are placed separately. Each of them took turns adding the ingredients in. During this time, Arman was using the iPad™ to take photos of the setup. At one point, I came and observed how Elizabeth and Arman are doing. Elizabeth began to explain the setup, but she encouraged Arman to show me the story about the investigation he created in StoryKit.

Closer towards the end, Arman and Elizabeth placed the two types of cookies into the oven. The cookies baked in the same oven, for the same amount of time. When cookies were brought out, Arman and Elizabeth used a ruler and thermometer setup to measure the diameter of the cookies. What they found was that while the baking soda and melted butter did spread more, the difference between the two was negligible (Figure 5). At some point, while Arman was wrapping up, his father came

to pick him up from KC. Arman showed off his cookies to his father. His father told him that it's a "good cookie" and they left for home.



Figure 5: The result of the cookie investigation is shown above. The center photo is the baking soda and melted butter and the right photo is the baking powder and solid butter. The end result was that very little difference in size occurs between the two types of cookies.

Analysis of Arman's Vignette #4

1. *Arman's confidence and self-efficacy influenced how willing he wanted to own and control the cookie investigation.*

At this final Choice Day investigation, Arman was given the chance to follow through on an idea that he had initiated with help. In the interview, he said "it was fun making the cookies and tasting them" (*SQ1 – target*). However, I observed that Arman's ownership of learning is not as clear and transparent. Arman may have engaged and aligned with the practices of the investigation, but he might have had difficulty imagining himself as taking complete charge of it. Specifically, Arman exhibited lower confidence and this might have affected how much control of the decisions he wanted. For instance, Elizabeth claimed that although Arman's decisions were simple, it was difficult getting him to make firm decisions (*SQ3 – characteristics*). Even though Elizabeth broke the tasks down into smaller pieces

(similar to Charley and Mike in Weeks 05 – 07), he was not completely confident in making the decisions himself.

In particular, when Elizabeth asked Arman to help her with the proportions and Arman's immediate response was that he was not good at math (*SQ2 – points*). He did not feel confident at this point and time to take on this part of the investigation by himself. Arman may also be framing the cookies investigation as a school task to learn lessons (e.g., "I'm learning math). While Arman engaged with the investigation and aligned with the practices of KC, he might have still been uncomfortable making decisions and taking a lead role on this project (*SQ3 – characteristics*). While some learners quickly established ownership and the need to make decisions in their projects, for Arman, this process was slow and could have been attributed to lower confidence.

2. *Arman's ownership was difficult to gauge since he did not often voice his opinion.*

Elizabeth expressed that of all the children in KC, Arman was the hardest learner to interpret and the most likely to defer his choice to others. Elizabeth became concerned about her role as a facilitator (*SQ4 – factors*). She stated that she was worried all the time about "taking over too much" or that he was not excited about the investigation. Elizabeth claimed that, "*Arman might be opinionated, but you don't hear him voice his opinion.*" Since it was difficult for Elizabeth to interpret Arman's ownership, she acted cautious and did not want to overstep her bounds (*SQ4 – factors*). Because Arman had a difficult time voicing his opinion, Elizabeth conveyed that she felt a tension in leading and supporting him. She was not sure how the adult power dynamic could play out (*SQ4 – factors*).

3. *Arman's perceptions of authority and adults may have influenced how much ownership he wanted over the investigation.*

Arman might not have been comfortable taking a strong commitment to the investigation because he might end up disappointing the adults. So even though Arman spent time on this investigation and worked methodically to make sure it was done well, he might not have had as a strong commitment or devotion to it because ownership meant owning up to risks and mistakes. Elizabeth expressed that while Arman was happy that his cookie question was going to get investigated, he might have still had a difficult time leading the investigation because of an adult-child power dynamic. Elizabeth commented that Arman may have not wanted to make the decisions in his investigation because she was there as an adult and the adults have knowledge about science. This did not mean that Arman was not concerned about the investigation. Elizabeth conveyed that even though Arman had a muted response, he acted a little disappointed that the hypothesis they had planned out about the spread of the cookies did not go according to plan. Although, science inquiry is not about determining a right or wrong answer from an experiment, Arman might have wanted his spreading prediction to come true.

One possibility is that Arman does not see this activity as an authentic investigation and testing a hypothesis. Instead, he may want to prove this prediction to be true. Arman's interactions may show that he is framing the activity as school like, and that experiments should generate simple predictable answers. What might have made Arman happy was seeing a positive reaction about the cookies from his

father (*SQ4 – factors*). In this case, Arman had control over the product he created and chose to give one of the cookies to his father (*SQ1 – target*).

4. *Arman had a difficult time later explaining what happened in his cookie investigation.*

I found in my interview with Arman that he had a hard time describing his cookie investigation experience to me (*SQ3 – characteristics*). Arman explained that he could not remember much about the investigation and what affects the spread of cookies. During this discussion, Arman had trouble explaining the motivation of the investigation, what choices he made, and what he thought about the outcome. One possibility as to why Arman had difficulty recalling is that Arman had a tough time owning this investigation. As mentioned before, Arman may have spent more time trying to follow Elizabeth's lead in the cookie investigation. If he did not spend the time considering the choices and the outcome of the decisions, he may have had a difficult time remembering what he did on that day.

5.2 Overall Discussion on Arman's Ownership of Science Learning

5.2.1 What did Arman own?

In my examination of Arman's experience from Week 05 to Week 10, I believe several targets of ownership of his learning may have existed.

First, Arman had weaker ownership over his ideas, but stronger ownership over being a helper. Arman may have appreciated that the facilitators honored his choice of ideas. As mentioned before, Arman often was not vocal in his opinions. He stated in an interview that working with adults can be difficult, particularly his mother:

Jason: So you said they (facilitators) were nice and funny. How was it helpful for you?
Arman: Probably because it's just better if you learn with more friendlier people than not so nice people.
Jason: Have you ever had not so nice adults working with you?
Arman: Sometimes.
Jason: Sometimes, what's that like?
Arman: It's hard.
Jason: Why's it hard?
Arman: Because like when I work with my mom if I don't understand something or I fail to answer a question properly she gets mad.
Jason: Oh she gets mad? Have you ever gotten mad?
Arman: Yes.

The facilitators attempted to make sure that he was given a chance to create his own food investigations. In Week 05, Mike and Charley worked with him on his idea for the cinnamon rolls investigation. Charley noted on Week 06, he asked if he was still going to do his cinnamon rolls investigation. On Week 07, he was given the choice to either follow Ben's pizza ball investigation or go on his own and try his cinnamon rolls recipe. Ultimately, he decided to go independent and work on his own investigation. On Week 10, he also wanted to try out the spreading cookie investigation with Elizabeth. Even though Arman had a tough time making independent decisions, he ultimately made choices and investments that appeared to gravitate towards his own ideas for investigations. However, it seemed that most of the time his ownership over pursuing his own ideas about investigation and projects were weaker as he tended to follow the lead of others (e.g., facilitators, friends). Instead, I contend that he was more invested into taking on the helper role. For instance, in the interview Arman noted that it was Ben that chose his pizza ball project:

Jason: Ok. And what about the pizza itself? Why did you guys choose pizza?
Arman: Um, well Ben kinda picked it. I don't know why he picked it.
Jason: Ok. You wanted something else?
Arman: I was going for cinnamon rolls.
Jason: And how does it feel working with Ben since he picked pizza.
Arman: It's fun. I mean I don't mind doing other projects.
Jason: Ok. And so, um, what kind of interactions are you having with Ben?
Arman: Uh, they're kinda funny.

Second, *Arman had control, pride, and investment into the accomplishment of his projects.* Arman's target of ownership was the implementation and accomplishment of the projects. During all Choice Day investigations, Arman did not appear distracted. Arman engaged in the investigation and aligned his practices to the community. He worked closely with the facilitators to bake the foods. Instead of just cooking, Arman aligned his practices towards experimental design. He developed and implemented a careful organization scheme, made thorough measurements of the ingredients and final products, used StoryKit to record his investigation, and engaged in dialogue with facilitators and participants about his investigation. In the video recordings, I found that it was rare to catch him off task. Arman focused on developing a personal product to share. Although his prediction for the cookie investigation did not pan out, he was still proud enough of them that he gave his father a cookie to try. One of the goals Arman had was to make food from "scratch." Based on Elizabeth's observations, he appeared happy that his father liked the cookie that he made. However, the alternative explanation is whether or not Arman truly saw himself having possession of this project. His interactions could still denote a learner who just wanted to follow what he thought the adults wanted.

5.2.2 How does Arman's Ownership Evolve Over Time?

In this section, I consider the role of Wenger's (1998) engagement, alignment, and imagination in explaining how Arman's ownership evolved over time. Arman's outward behavior indicated that he was engaged, focused, and invested on his own investigations and the investigation of others. Many supporting factors in KC helped to advocate and support Arman's ownership through engagement. However, outside of the KC community, Arman had difficulty developing alignment, particularly in expressing to others what he had done in KC. Based on his imagination, Arman views his progress as being a scientist, investigator, chef, and designer as "slow progress."

Engagement and Ownership

Wenger (1998) described engagement as the active involvement in mutual processes of negotiation of meaning. During Choice Days, Arman made choices, such as choosing to accomplish his cinnamon and cookie investigation, following through on the choices he made, volunteering his time and effort towards menial tasks that would finish his project, and collaborating with others so that his investigation could be complete. Arman engaged in KC through his investment of time and energy towards these projects and stayed quite focused on them. Arman's engagement allowed him to take part in meaningful activities, sharable artifacts (e.g., food products, stories), develop community-building conversations with facilitators and participants, and negotiate new situations (Wenger, 1998). However, Arman's engagement and ownership in KC needed support from facilitators and friends.

Advocacy for his ownership. First, the facilitators needed to advocate on his behalf to make sure that he had the chance to establish ownership. Even though

Arman was fully focused and attentive in KC, Arman did not always vocalize his ownership over the investigation or project. The facilitators really wanted him to have his own Choice Day with no interruptions. Although he was engaged in the investigation and had no objections to following another participant's Choice Day investigation, the facilitators all agreed that they had to make concessions to allow him to experience his own investigation. The facilitators worked to build his confidence. Without the advocacy from the facilitators, he might have just continued to stay quiet and followed along with the choices of his group. In Arman's case, ownership over his project was not something that was quickly established in isolation, but required nurturing and support from members of the community. However, it is also important to note what ownership Arman already took on. He wanted to invest and spend personal time into being a good member of the community and doing what was expected of him. In this case, ownership in science learning may not just be the pursuit of learning goals, but also other aspects such as social roles in the community.

The need for mutual engagement to develop ownership. Second, Arman needed mutual engagement to help build his ownership. Wenger (1998) described mutual engagement as a core principle in sustaining practice. Being involved in activity with others helped to shape the community and influenced how learners developed. Open-ended investigations are often difficult for learners because so many choices and distractions exist (Kirschner et al., 2006). Part of the role of mutual engagement gave Arman the support and guidance to help him develop ownership of science learning. All three facilitators (Mike, Charley, and Elizabeth) appeared to

work with Arman in helping to turn his ideas into plausible investigations. The facilitators broke down the larger idea into smaller and more approachable tasks for Arman. Each facilitator tried to be positive and work with Arman to achieve his goals, such as wanting to cook from scratch and seeing how cooking related with science. When Arman could see that the facilitators were supporting his goals in conjunction with his personal ideas, he was able to independently take control of aspects of the investigation. Even some participants in KC helped out. In Week 07, his friend Ben helped out Arman in the development of the organization scheme. Arman stated that it was always “better if you learn with friendlier people than not so nice people.” Alternatively, another explanation is that once Arman determined what he thought the facilitators wanted him to do, he was quite happy to follow their lead.

Technology and mutual engagement. Even the social media app, SINQ also allowed Arman to develop mutual engagement with others. The combination of the prompts, seeing the contributions from other participants, and working with the facilitators allowed him to see that he could contribute to a question. In both investigations, Arman inputted his investigation ideas through SINQ. The micro-contributions of SINQ allowed the facilitators and others to see what was on his mind and make ways that he could follow through. Even though he expressed anxiousness about putting his contributions into SINQ, getting his ideas out into the open and talking with the facilitators helped to increase his ownership and pursuit of his investigations.

Mutual engagement through mistakes and failures. Arman expressed in interviews that making decisions about the main goal of the investigation was

difficult. For a more reserved personality like Arman, the times in which he began to take on ownership of his investigation and choices in ideas were when he was had social supports from the people around him. For instance, since Arman had more responsibility in his cinnamon and cookies investigation, he also wanted to make sure he was doing a good job. Arman had already expressed that designing an investigation on the first Choice Day was not an easy task. However, in the afterschool environment, he expressed that it was fine to make mistakes.

Arman: *I mean we make a mistake, it's gonna be good because then we can learn more stuff. Like whether not to do this again or if we did do this again, it would be good.*

The ability to make mistakes allowed him some more confidence and comfort to take on more responsibilities for his projects. Even though Arman was not used to the open nature of creating an investigation, he did not feel the pressure of assessment and penalization. For Arman, he may have needed a chance to try out new ideas he had without the feeling of mistakes or pressure from time constraints. He expressed that KC was a different place than his school, “So, the problems here (KC), it's more like kinda what we don't know and what we want to solve. And over there (classroom) it's in various probably. It's kinda different cause I don't know how to explain it. It's different.” Since Arman already had issues of confidence and reservation, having mutual engagement with others that allowed for mistakes influenced his ownership towards the investigation and choices. In this way, ownership of science learning for Arman evolved slowly and needed cultivating from facilitators and the learning environment.

Imagination and Ownership

Even though Arman engaged in the investigations in KC, the facilitators constantly expressed that they were concerned that Arman was not taking full ownership of his investigations. Both Charley and Elizabeth indicated that since he did not always voice his opinions on decision-making, they were worried about overstepping their bounds and leading him in directions he did not want to go. Wenger (1998) claimed that understanding imagination allows us to develop a more full picture of alignment and engagement. While Arman outwardly invested into his projects and his choices, his imagination of his role and identities did not shift greatly. Towards the end of KC, I asked him if he could identify himself as a cook, designer, investigator, and scientist. He kept saying these roles were “*slow progress*” for him. I asked him what he meant by this term. Arman identified his progress towards these roles based on his imagination of what people in these identities can do. In this case, Arman perceived these roles as being able to “explain” some knowledge or information to someone else.

Designers, chefs, and investigators. Arman summarized the main theme of his imagination of the role of a designer, chef, and investigator, “*like I can't explain things really well.*” In the interviews, Arman stated that he had trouble remembering in general and making explanations. As a designer, Arman had difficulties seeing himself as this role because he could not transform the ideas he has into an actual product. He explained that designers needed to be able to have artistic skills and be able to “draw” out their ideas. He expressed this was a skill he could not do. As for a chef, Arman expressed that he often had a hard time remembering the recipes and ingredients. Arman expressed that the role of the chef is a person that is able to not

only cook, but to remember and communicate all that they are taught. For the investigator, Arman stated a view of learning content knowledge. The investigator can explain to others what the findings are, but Arman was not ready to explain to others what he has done in his investigation. In all three imagined roles, Arman explained that he did not develop enough competencies that he could even imagine himself embodying these roles.

Scientist. For the role of the scientist, Arman had an interest in science at home and school and proclaimed that he generally liked science. However, Arman was also quite hesitant to define himself as a scientist. For example, during a group discussion on the first week of KC, I asked the children, “Do you think that you guys are scientists or do you guys think of something else?” Arman quietly and hesitantly responded, “*Legal scientists?*” I asked for more clarification and Arman replied that a legal scientist is someone that is legally employed in a job to be a scientist. Here, Arman defined being a scientist as an occupation that one performs. In a later interview, I asked Arman the same question again of whether or not he thought of himself as a scientist. Arman said no because, “Well, I don't really *do* a lot of scientist, actually sometimes I do like if I, mainly I look up things, questions I have.” Arman defined his relationship to science as what a person does and can do in comparison to how he imagined a scientist acted. A key point here is that being a “scientist” is what others declare you to be based on competencies, rather than something you declare to yourself and others.

The importance of imagination. Wenger (1998) explains that the importance of imagination is “looking at an apple seed and seeing a tree. It is playing scales on a

piano, and envisioning a concert hall” (p. 176). As part of “learning as identity”, a learner’s perception of improvement in a performance gives a degree of trajectory in sorting out what matters and what contributes to his or her identity. For Arman, he had difficulty imagining himself (e.g., slow progress) as a chef, scientist, designer, and investigator; this may have influenced his reluctance to take on full ownership of the investigations. In Arman’s case, his outward behavior may have indicated a learner that took on ownership of the investigation, ideas, and decision making such having control over decisions in the food investigation and aligning his works through investments into the practices. However, his imagination of the roles may have limited his ability to want to take stances, take ownership, and voice opinions. I contend he might have needed more time to see his practices as improving before he could identify himself strongly in any particular role.

Alignment and Ownership

I suggest that Arman’s engagement explains how he was able to take part in meaningful activities and interactions. However, Arman needed advocacy and support into order to develop ownership over the investigation. Imagination clarifies reasons as to why Arman may be hesitant to take on full ownership over his investigation. Wenger (1998) notes that people may engage with others in a community of practice without managing or caring to align this practice within a broader enterprise. Imagination alone also does not necessarily result in coordinating actions. In short, a key to understanding Arman’s ownership is examining Arman’s motivations for coordinating efforts.

Alignment with KC practices. Arman aligned his actions towards the KC

community standards. Arman chose to invest his energy into coordinating towards the practices of KC and aligned his practices and perspectives towards a common purpose (e.g., developing a food investigation) (Wenger, 1998). Instead of just cooking and baking, Arman took on the KC practices for investigation development. Arman chose to use StoryKit to record his investigation. He made careful measurements of height and diameter of both his cookies and cinnamon rolls. Arman also inquired and worked with the facilitators to try to make sure he was adhering to the practices of KC. From Weeks 05 to 10, he chose to engage and invest into the discourse of investigation development with Mike, Charley, and Elizabeth. However, it is not clear whether Arman's alignment to the KC practices is motivated solely by his own interests or wanting to follow and please the adults.

Alignment through ownership is risky with social interactions. However, alignment to KC practices was not often present in his home and school life. Both Arman's father and his teacher commented that Arman spoke very little about KC to them. While he could talk about KC with the other participants in the program, Arman hedged his ownership, specifically expression of pride, towards other peers and adults. Arman expressed that his peers might not appreciate KC, which may have made a negative influence on his ownership. For instance, Arman stated that his accomplishments in KC were learning how to make foods from scratch and being able to learn from his investigations. However, he also stated that he was hesitant to share anything of his food investigations in KC with others. If people were interested to know, then he would tell them, but people had to be proactive and ask. Arman did not think people would care, *"I just think like if I tell them and they don't really care,*

I don't know if they will really listen.”

Wenger (1998) suggests that alignment concerns power, that is, the power over one's own energy to inspire alignment with others. For Arman, he may not be convinced that he has a sense of power or confidence to tell others about KC or align his actions towards the KC practices outside of the community. Similar to O'Neill and Barton's (2005) examination of ownership, expression of pride is a component of ownership of science learning. However, while Arman may have been proud of his accomplishments, he was unwilling to tell others about it because of concerns of their dismissal. Arman's imagination of his social interactions may have hindered his development of ownership over the investigations and his alignment outside the KC community. If Arman identified himself strongly in the roles of a chef, scientist, investigator, and designer, he may have had to prove to others at home and school that he was able to match the competencies of that imagined role. I believe that for Arman, ownership of science learning can be socially risky for him. Strong ownership towards his KC investigation meant that he might have to be vocal about what he did in KC or show an alignment towards KC practices. Other people in his life may not fully appreciate what he was doing in KC. Based on his imagination of roles and self-identity he still did not feel comfortable being able to explain his involvement in the investigations.

In contrast, his father stated that Arman talked about video games and his YouTube™ dance videos all the time. His teacher also observed that Arman was very social with other children. Here, Arman is both proficient in these hobbies and he has found people with common interest. He can also be social with other children and

play with them. However, in the case of KC, since the imagination of his roles was focused on a comparison of what he thinks the role entails and his assessment of his own skills, Arman may have a harder time expressing pride and what contributions he made to others and developing a self-identity within science, design, and investigation.

Arman's views on adults and authority may impact how much ownership he developed in his investigations. Similar to social interactions, Arman had very respectful views towards adult authority in home, school, and KC. Arman also talked about his views on adult authority. For instance, Arman compared the facilitators to the Google™ search engine, “You're (facilitators) teaching me and I'm taking it in. Or trying to take it in as much as I can.” Here, Arman takes an epistemological view that the adults in KC are “the Google”, that is, the keepers of knowledge and the experts at science. He described knowledge as an object that is passed down from adult to child. Arman took this similar view of adults with his comparison of himself with “legal scientists.”

Although Arman's perspective on adults in his home and school life was deferential, this might have made the choice making process difficult for him. He may have wanted the “right” decision in KC or at the least decision he thought would make the adults would be content with. In this sense, his alignment through ownership over his choices and investigation wavers. On the one hand, he has selfless ownership. Arman was willing to listen to the perspective of the adults and the learners to make sure that he was making good decisions for his investigation. On the other hand, his ownership may be weaker towards the science of the investigations

and the ideas; Arman was not willing to take a stance towards independent decision-making or hold strongly to a particular idea. He may have chosen to align to the KC practices because he wanted the approval of the adult facilitators. Elizabeth conveyed, “But I bet, I bet Arman would defer much quicker than Ben... Um, Ben, um, is very reasonable, but he can definitely voice his opinion. And Arman, might have an opinion, but you kinda have to, have to figure him out.” However, he may have stronger ownership over his role as a supporter and helper in investigations.

5.3 Summary of Arman's Ownership of Science Learning

In summary, Arman's outward behavior alone may look like he was in control and fully invested into his projects. As part of engagement and alignment, he worked very hard and meticulously with the investigations. He used the technology to document and record, he took on the practices of KC, and he was not distracted. However, I believe his imagination of roles (i.e., chef, scientist, investigator, designer) as being slow progress, perceptions and relationships with adult authority, and fear of social rejection prevented him from taking direct control over choices and decisions and expressing pride in his investigations. The previous analysis shows how even though a learner shows engagement in a community of science, ownership can be difficult to establish. For Arman, he may have difficulty taking control over the investigation; however, he is quite comfortable investing into the role of a supporter. Learners can diligently engage in a community, but if they are unable to imagine their roles as part of science and develops ways to coordinate their actions to a broader effort in alignment, stronger ownership of learning may not take place. Ownership of learning is also difficult to cultivate, even though we attempted to foster shared

spaces for ownership (e.g., O'Neill, 2010) in KC. For instance, even though the facilitators wanted Arman to engage in the design of an authentic investigation, Arman may be framing and perceiving the tasks as an aspect of formal learning from school, rather than his own personal investigation. The facilitators setup KC to be a supportive environment for Arman (e.g., guidance through facilitation, allowing mistakes), but he might have needed more time to see his transition and growth before he could develop a stronger sense of ownership over his food investigations.

Chapter 6: Ben's Case Study

At the time of this study, Ben was a 4th grade boy at The Green School. He has been at this school since the age of four. Ben's four-year-old sister also attended the school. As for his family, Ben's father was an Upper School math teacher at the school. Ben also has a mother that I was unable to interview. Ben and his family all live within walking distance of the school. I chose four specific vignettes to represent Ben's case (6.1). The first vignette (Week 06) shows his initial development of the investigation into pizza balls (6.1.1). The second vignette (Week 07) indicates the increasing ownership over the pizza balls investigation (6.1.2). The third vignette (Week 09) highlights Ben taking on a follower role (6.1.3). Finally, the last vignette (Week 10) focuses on Ben's dedication to coming to KC (6.1.4). In my discussion of these vignettes (6.2), I make the argument that the combination of Ben's engagement, alignment, and imagination lead him to develop a strong and positive ownership of his investigations.

6.1 Vignettes from Choice Day and Analysis

6.1.1 Vignette 1: Choice Day #1 - Week 06

As mentioned in Chapter 6 (Arman's case study), Ben had wanted to work on his pizza ball investigation. Although I have previously outlined portions of Ben's Week 06 investigation in the Arman's case study, in this section I will mainly emphasize the highlights of Ben's decisions and choices with this group.

Coming up with an investigation and a question

On Week 05, Ben collaborated with Charley on getting an idea for a food investigation. Charley began by asking Ben what questions he had about food. With very little hesitancy, Ben talked about this idea for a “pizza ball.” He explained that a pizza ball was a baked dough ball with sauce and cheese in the middle. Ben posted this question into the SINQ social media app and was extremely proud of his idea. As this session was towards the end of the day, Ben’s father arrived to take him home. However, Ben asked him to wait around for a couple minutes since he wanted to finish up entering his question. During this time, Ben invited his father over to come look at the posted SINQ question, “What would happen if you made a pizzaball when the dough rises and also when it doesn’t.” Ben also came up with a conjecture, “The pizzaball with the yeast in it will squeeze everything into the middle and come out when you bite into it, and the pizzaball without the yeast will do the opposite.”

During the Week 06 planning of Ben’s investigation, his group (Arman, Ben, and Charley) needed to decide how to create an investigation for the pizza balls question. Charley asked, "So remember you asked a question about like the pizza balls. Like what would happen to the cheese and the sauce. So what question is that?" Ben answered in a goofy manner, "What happened to the cheese and sauce and stuff?" Charley reminded him again about the "leaveners" and asked, “So what was the question?" Ben was reminded, “Oh questions we will be able to answer. So we have to ask how will it turn out? Yeah, how will it turn out?” Charley pushed again, "How will it turn out when I do...?" Ben, reminded of Week 05, stated, "How will it turn out when I use yeast?" and “*How will it turn out when I use different leaveners, eggs, and yeast?*” Charley, "There you go."

Charley continued to work together with the boys on helping them develop an investigation on dough and leaveners. She asked Ben why did he want to adjust the leaveners in the first place. Ben commented that he wanted the pizza balls to be fluffy and soft. Charley continued to prompt him with questions, “In order to be fluffy, what kind of leavener should we use?” Ben immediately thought of baking powder as another comparison.

Distractions and reminders of ownership

Next, the group had to make decisions on the quantities of the leaveners; in particular Ben chose to use two eggs instead of the lesser egg amount that Arman had suggested (See Arman’s case study, Chapter 6). Although Ben was leading the investigation with Charley and Arman, Ben became distracted from the unstructured nature of the task. For instance, because he did not know the specific direction of the investigation, Ben would deviate and made jokes, created odd sounds, rocked back and forth in his chair, and played around with the cooking equipment. Arman often volunteered to get up and go get the materials and ingredients. Ben, distracted, sat down in his chair and started beating the rubber spatulas as drum sticks on the table (Figure 6).



Figure 6: Ben is slightly distracted during the investigation task.

While Ben acted unfocused, Charley was giving out instructions on what they should do in the investigation. However, at some point in the investigation, Charley called out Ben for his distractions:

- Charley: Wait, wait, wait this isn't my idea to make the pizza balls, right? So how come I'm reminding you guys what to do? What are you suppose to do next if you're gonna make them?
- Ben: Wait, I was the one that thought of pizza balls?
- Charley: Yeah, it wasn't me. So then maybe you should tell us what we are doing next?
- Arman: (Towards Ben) Yeah.
- Ben: Well we are going to do that because you said so and...
- Charley: So what are we suppose to do?

After Charley reminded Ben about who created the idea and who was supposed to be giving out directions, Ben was still distracted and continued to use the spatulas to drum on the table. However, as time went on and the participants took on more specific tasks, Ben became more involved in the investigation. During parts of the mixing of the dough, he would take on the role of recorder and used StoryKit to capture the mixing of the ingredients in the bowls. For the investigation, Ben had started mixing the dough with the yeast, while Arman took on the baking powder dough. Most of the time, Charley helped the boys organize how they were going to produce the different doughs and gave the children instructions on the ingredients that needed to be added.

A transition towards responsibility

After a while, Ben started to take on the role of giving instructions out to the group. For example, in Figure 7, Ben and Arman are mixing the two different bowls

of yeast and baking powder, but the egg dough had not been made. Ben looked right at Charley and asked her, “*How about you work on the next one?*” Charley agreed and started to work on the egg dough with the boys. While this happened, Arman reached over and grabbed the wrong measuring cup. Ben noticed and quickly directed him, “No, that’s mine. This is yours.” Ben physically grabbed Arman’s hand to prevent him from pouring flour into Arman’s bowl. Ben then grabbed another measuring cup by him and said, “This is yours.” Ben proceeded to pour Arman’s measuring cup into Arman’s bowl.



Figure 7: Ben giving out directions to Charley, while Arman reaches out for the wrong measuring cup.

Analysis of Ben’s Vignette #1

- 1. Ben’s ownership over the product idea of pizza balls may be easier to develop than ownership over the implementation, processes, and science questions of the investigation.*

Portions of Ben’s interactions in Week 06 were of him being distracted. For the most part, Ben’s distraction may have come because the task became more open and largely unfocused (*SQ2 – points*). In her interview, Charley reflected on Ben’s distraction was not a lack of ownership, but frustration in seeing the big picture of the investigation. He may have had unfamiliarity in managing his own time and schedule

for an open-ended project. In Ben's case, ownership of his investigation was not just about the product idea of pizza balls, but also how he will plan and manage his project. Ownership of his idea to make pizza balls can be seen as Ben declared, "Pizza balls, my pizza balls" into StoryKit (*SQ1 – target*). Both Charley and Arman also acknowledged this was his project to run and let him make the final decisions of baking powder, yeast, and eggs as the comparisons. Arman often looked to Ben to make many decisions.

However, ownership over the whole design process may have been more difficult for Ben, especially when it was not clear what the goals of the investigation were (*SQ3 – characteristics*). I asked Ben what the hardest part about Choice Day was. Ben described the process of selecting the ingredient variables and the quantities to examine as two largest difficulties he encountered in Choice Day. So while it may have been easier for him to grab quickly at the opportunity to come up with an idea for a product in the more focused SINQ task in Week 05, making decisions and choices for an open task was tougher.

2. *Ben's ownership over the investigation needed reminders and guidance; this may indicate weaker ownership when the task is difficult.*

Because of these difficulties in the investigation, Charley needed to guide and prompt him with many questions along the way to get Ben to work through the design of the investigation (*SQ4 – factors*). In particular, her guidance was not just about breaking the task down into smaller pieces, but actually reminding Ben of his ownership of his investigation (*SQ2 – points*). Charley stated:

But then, I was like, "*This is really like, your guys' thing, so why am I like telling you guys what to do?*" Like, we should be like, "you now know what to do in getting the stuff, and so, I still had to like help them remember, but there

wasn't any like, I just had to remind them, "*It's yours really.*" And then they were on it.

For Charley, instead of constantly giving out directions to Ben and Arman, she needed to remind him where the idea came from and whose responsibility it is (*SQ2 – points*). Although Ben established ownership of the idea for a product design very quickly in Week 05, Ben needed reminding of the ownership of the design and implementation of the project (*SQ3 – characteristics*). Ownership, therefore, may be quickly established in the initial idea development, but harder to stick with when it comes to the implementation. One explanation might be that Ben has strong ownership with the idea of creating his pizza balls, but has a harder time establishing control and possession of the project when difficulties arise.

3. *Authenticity and genuine inquiry-based tasks are important aspects in developing ownership of the investigation for Ben.*

While Ben had distractions along the way, he displayed characteristics of ownership of this investigation. First, Ben knew what was “genuine” and was not in terms of science inquiry activities. In particular, the development of the pizza ball investigation appeared to be a more genuine science task for Ben than prior KC activities. During Week 03 of KC, we had the children engage in a structured experiment to examine how eggs emulsify water and oil mixtures. Dr. Clegg and I tried to give the instructions on how we were trying to figure out what eggs do and what hypothesis we could make. At this time Ben picked up on this activity and asked us, “Shouldn't you already know cause you've already done it? To figure out the answer?” and “Why are you guys asking us?” Here, Ben determined that this activity

did not appear genuine to science because the adults have already done it and seen what the results were.

However, while Ben may have argued that the semi-structured activities were not as authentic in its science inquiry, his investment towards the pizza balls that “work” may be more focused on engineering product design, as opposed to hypothesis testing. In his interview, Ben expressed the following:

- Jason: So can you tell me about some of the decisions you are making in Choice Day? Like what you are deciding to do? What choices you are making?
- Ben: I'm usually thinking of making new ways to do stuff.
- Jason: Such as?
- Ben: Uh, the pizza balls. Instead of eating pizza with crust, that you hold it, why don't you just have it like a meatball and stab it with a fork and stick it in your mouth.
- Jason: How did you come up with this idea?
- Ben: Um, like I said hey, it would be cool if pizza was in a meatball.
- Jason: So what are you hoping to find out in your investigation?
- Ben: Ummm, how hard it is to do stuff sometimes.

In this explanation, Ben wanted to come up with a product design in pizza balls that was innovative and original. Ben did not know what would happen in this design (*SQ2 – points*), which led him to want to invest more into creating the pizza ball. In comparison, the task of the pizza ball investigation was a more genuine design task than following a pre-determined experimental procedure with an already known result. He had talked about Choice Day as allowing him to expand on design ideas he had always wanted to try (*SQ4 – factors*).

4. Ben's ownership was expressed through vocal opinions

In contrast to Arman (Chapter 6), Ben was known to be vocal about his opinions and not shy about what he was thinking. As mentioned before, Ben stood

firm about the two eggs decision. However, taking charge and ownership of the project did not always produce the best results (*SQ3 – characteristics*). One possibility was that Ben was just making an arbitrary guess for two eggs as the leavener. He did not provide any evidence or reasoning for this decision to his group, but he still wanted to use two eggs. Neither Charley nor Arman was willing to take a strong stance about this choice since they both expressed this was Ben's investigation. Another explanation is that Ben just wanted control of the project because he considered this to be his project and he should be making decisions. However, as mentioned in Arman's case, using the two eggs proved costly to time and resources; the mixture was extremely wet and the children had to keep adding more flour to get the right consistency. Ben was also quite vocal when Arman grabbed the wrong measuring cup. He physically grabbed Arman's hand and directed Arman to how he wanted the investigation done. Ben even made statements about territory and who has current possession of the materials ("No, that's mine. This is yours.") (*SQ1 – targets*).

6.1.2 Vignette 2: Choice Day #1 - Week 07

On Week 07 of Choice Day #1, Ben was ready to build and design his pizza ball investigation. Charley was moving and switching between Arman's cinnamon roll investigation and Ben's pizza ball investigation. In this section, I focus on Ben's development and ownership of the investigation.

Developing the organization scheme

Before Ben was able to start the investigation, Charley wanted him to begin developing an organization scheme for what he wanted to do. Initially, she directed

Ben to label one plate as “egg, pizza – cheese” and “egg, pizza – sauce and cheese.” However, Ben stated he wanted one “without cheese.” Instead of going with this initial plan, Ben wanted to create a sauce only pizza ball and a sauce and cheese pizza ball. He created the following 3 x 2 experimental design (Table 10).

Table 10

Ben’s 3 x 2 experimental setup

Sauce + Yeast dough N = 3	Sauce + Two egg dough N = 3	Sauce + Baking powder dough N = 3
Sauce / Cheese + Yeast dough N = 3	Sauce / Cheese + Two egg dough N = 3	Sauce / Cheese + Baking powder dough N = 3

Consulting and compromising with Ben

Ben soon started to develop independent work on his pizza ball investigation. However, despite working alone, he always consulted with Charley and Arman. For example, Charley came up to Ben to see if he needed any help. She noticed that Ben decided to add some pepperoni slices into his pizza balls. Ben asked Arman, "Do you want some pepperoni in some of them?" Arman responded, "No, I can't eat pepperoni." Ben quickly realized this and quickly explained to another learner, "No, he's not allergic. His religion doesn't allow him to have pork." Based on his conversation with Arman, Ben decided, "No pepperoni for us." Arman, being concessionary, stated, "You can put pepperoni, just leave one un-pepperoni for me to eat it.”

Careful measurements and organization

Once the decision was made not to put pepperoni into the pizza balls, Ben started to roll out the dough and fold in the sauce and cheese according to his investigation setup.

He started to talk with Charley about measurement and how he wanted to record the data. Charley asked him, “So what do you think is good to measure about this?” Ben wanted to measure, “Up and across” meaning he wanted to measure both the height and diameter for the pre-baked pizza balls. Charley suggested that, “so maybe you want to do like up and then over and then across.” Unfortunately, Ben did not capture his measurements onto StoryKit. However, based on my field notes, Ben had measured the height, length, and width of the pizza ball (Figure 8). What is not shown in the video was that Ben demarcated his measurements using a series of “U” (up) and “S” (sideways) designations. Ben also described his process in an interview:

- Ben: Uh, most of them were one and a half up (means inches); the egg and the yeast were mainly three inches.
- Jason: I noticed that you were using the ruler in different ways. Can you tell me about that?
- Ben: I was going this way (gestures: hand up); I put U equals, which is up. Then I put S equals, which is sideways.
- Jason: Why did you do that?
- Ben: Uh, to figure out if they got bigger when we finished them.

Ben also had to calibrate the ruler to make more accurate measures.

- Jason: Ok, and was there anything difficult about using the rulers or was it pretty ok?
- Ben: Umm, I just picked the longest point. So like if it was that long (gestures: fingers showing length) and there was a little part here, and it was that wide there, and a little part here, I would measure this way.
- Jason: Ok, so you were just measuring how high things got?
- Ben: Yeah, how high it got and how wide it got.

When he described, “a little part here”, Ben was referring to the extra piece of material that is left over in a ruler at the 0 mark. Since he was on his own to measure, Ben determined how to compensate for the ruler. Without Charley’s direction, Ben noticed the poor instrumentation of the worn out ruler, but was still able to figure out how to measure the pizza balls with it.

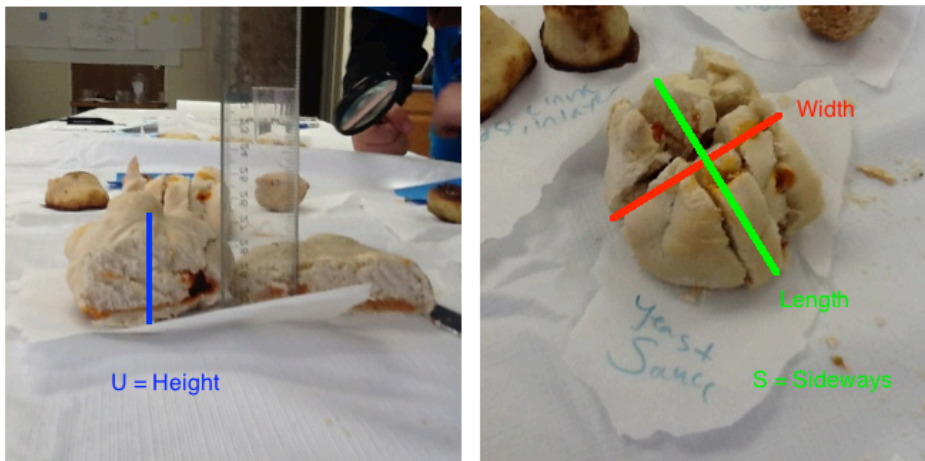


Figure 8: Ben measured the width, length, and height of his pizza balls. I generated the green, red, and blue markings here to show how Ben did the measurements.

After the measurement, Ben worked with Charley to determine the amount of time the pizza balls should go into the oven. They determined that roughly about five minutes at the same temperature their pizza recipe would be appropriate. During this time, Ben waited and carefully monitored the product. When the pizza balls were complete, he was the one who called Charley over to come help out. After baking, Ben was also the one that went around to grab materials to place the pizza balls on. He also went to help Arman on some of his tasks.

As the pizza balls were finishing up, Ben's father arrived to come and pick him up. The entire two-and-half-hours was used up. However, Ben asked his father if he could stay longer to finish wrapping up; his father stated they had to go soon. Therefore, Ben was unable to take final measurements of his pizza balls. He did, however, take a couple pizza balls home to give to his family. Ben also observed that although the egg dough may have given his pizza balls more flavor, the dough was not as soft as the yeast version. Specifically, Ben argued that although the egg, yeast, and baking powder doughs may have leavened, the amount of sauce and liquid in the middle mattered more in how moist the pizza balls came out.

Analysis of Ben's Vignette #2

1. Ben's ownership of the project was expressed through negotiation and sharing.

Ben was more willing to negotiate and listen to others for choice and decision-making (*SQ3 – characteristics*). Although Ben could have put the pepperoni into the pizza ball, he consulted both Charley and Arman for their opinions. Arman stated that he did not eat pork food products and for Ben this was reason enough not to put the meat into the pizza ball. Ben could have chosen not to follow Arman's dietary restriction and told him this was his investigation and his product. However, Ben chose to comply and adapt to his friend's request. Charley noted, "Um, so, I don't know, so, so again there was that like, just sorta of this fluid compromising. *Even though, like it was Ben's dish, that like, that, but like, he wanted to make sure that we, could like eat them.*"

One part of the aspect of ownership of the project here is the ability to share the personal product with others (*SQ3 – characteristics*). For Ben, sharing the

personal product (*SQ1 – target*) was just as important (or maybe even more important) as conducting the investigation. Charley recalled, “So, but yeah, his first thing was about wanting to be able to share what he made with other people.” For many learners like Ben, they took their products home to share with their families and friends. If Charley (who kept kosher and could not eat pork) or Arman cannot try out the pizza ball, the motivation to share and receive comments became limiting. The importance of sharing the product may also be evidence of his ideas for design, as opposed to hypothesis testing.

2. *Ben invested into micromanaging his project.*

Ben’s choices and decisions on measurement and organization of the design project are also important features of his ownership of science learning. In KC, Ben was given a chance to develop and work with the facilitator to come up with an organization and measurement procedure (*SQ4 – factors*). First, Ben needed to come up with an organization to make sure everything was in order. Ben was going to attempt to do a 3 x 2 experimental setup (Table 10) similar to Arman’s. With this specific goal in mind, Ben had to manage a lot of little pizza balls by himself. During this time, instead of just making the pizza balls in complete disarray and just eating them, Ben created a systematic setup for both the creation of his product and the baking. Charley commented that Ben thought about both scenarios; how the pizza balls were made and how they would be positioned inside the oven. Ben had to micromanage a number of tasks for this investigation. He had to create the organization so that 18 small pizza balls were not in disorder, make sure to be organized, and determine the best way to position the pizza balls in the oven so that

they remained separate. Ben's micromanagement towards many small tasks expressed devotion, investment, and control (*SQ3 – characteristics*) into his investigation (*SQ1 – targets*).

6.1.3 Vignette 3: Choice Day #2 - Week 09

On Week 09, Ben and Donna engaged in Choice Day #2. In Choice Day #1, Ben took the lead on his pizza ball investigation. For Choice Day #2, he took the follower role and worked alongside Donna. Donna came up with an idea to make caramel candies. This investigation sounded interesting to Ben, so he decided to collaborate with Donna on this project. Elizabeth and Emily acted as the facilitators for this group.

Watching a video to get ideas

Before beginning the caramel investigation, the facilitators wanted the children to come up with an investigation question they could explore. Prior to the development of this investigation, Elizabeth found a video on YouTube™ on the making of caramel. Elizabeth began to explain that sugar has a crystal structure that can be disrupted through heat; Elizabeth called caramel “melted sugar.” Ben immediately showed interested in what Elizabeth had to say and replied, “It's kinda like ice where you melt it and it turns into a liquid.” From this, Elizabeth explained that when sugar melts it gets grainy and wants to crystalize again. When the melted sugar cools down, crystallization occurs and the caramel can become hard and similar to rock candy. Elizabeth continued to talk to the group and suggest that they will need to add butter and corn syrup as a way to prevent the caramel from becoming too hard. She asked if the children wanted to watch that YouTube™ video. Both children

agreed to this and they spent another ten minutes watching how caramel was prepared.

Coming up with an investigation on caramels

After the video, the children and facilitators returned to work on what investigation question they would attempt to answer. Ben wanted to know how to make the caramel creamy. Donna wanted to add both white chocolate and vanilla. Elizabeth said that was fine, but that they would add the vanilla at the end. Ben, knowing about vanilla, claimed that it would evaporate too quickly if you added it in too early. Elizabeth continued to help the children fill out the goals chart on what they wanted to do. At some point in the conversation, the group needed to figure out if they should use jaggery butter (or sugar). This sugar was brown, soft, and comes from sugar canes. Elizabeth explained the differences between jaggery and other butters. She also talked with the children about sugars with impurities (e.g., refined white sugar) and that if you use them for caramels, the product will give an off color brown. She suggested, "If we want, we can also test that, see if it has a burnt taste instead of this taste." Ben was curious about the jaggery butter and said he wanted to open up and taste it, however, Elizabeth said that they can do that later. Elizabeth made a suggestion to make a dry caramel with only sugar and butter (Version 1) and a wet caramel with corn syrup, cream, butter, and sugar (Version 2). The children agreed, but they were more excited just to attempt to make the caramel than to understand the setup of the investigation.

Burning the dry caramel

As they began to work, Elizabeth suggested to the group they should record their startup on StoryKit. Donna immediately responded, "I don't want to do it; (pointed at Emily) she can do it." Ben, however, asked if it was possible to link the video on caramel they watched onto their StoryKit story. The children broke off into two groups. Donna was preparing the wet caramel (Version 2), while Ben was working on the dry caramel (Version 1). Elizabeth continued to explain to Ben why his version was simpler than Donna's and what they are attempting to examine. The group decided to do a third variation using the jaggery (Version 3), but they would complete this later.

Both Versions 1 and 2 of the caramel were on the stove. At first, there was momentary excitement for both children. As the mixtures began to cook, Ben exclaimed, "Wow, look at that! Now it's bubbling!" Elizabeth realized, "Wow, I think we have to stir." What the children did not know was that making caramel could take up to 30 minutes to prepare over the stove. The caramel could not just be set on the stovetop without supervision; otherwise the caramel would burn. Each child had to stir constantly for 30 minutes and watch the caramel. During this time, Donna grew impatient and distracted. She began to lose interest and moved away from the stove and let a facilitator stir for her (see Donna's case study, Chapter 8).

However, Ben continuously stirred the mixture without distraction. Ben, Elizabeth, and Emily talked about what the proteins in the cream do and how sugar was a crystal. He began to engage in conversation with Elizabeth about the Version 3 caramel they should try. Elizabeth asked Ben, "Do you want to try to do a half, instead of using sugar, we use the jaggery and corn syrup, then we'll do...?" While

Elizabeth and Ben were in conversation, Elizabeth realized they had burned the dry caramel (Version 1). She exclaimed, "Look at it! Oh my gosh! Look at this as it gets harder. Look at it, it's black." The dry caramel mixture burned and crystalized too quickly.

The smell of burning caramel began to overtake the group. For this dry caramel, because no wet ingredients were present in the mixture, the group had to watch carefully the rise in temperature for the dry caramel. However, because the temperature rose too rapidly, the sugar burned. The adults had to quickly intervene to close down that portion of the investigation. Elizabeth instructed Ben to go help Emily with the Version 3 jaggery setup as they had talked about while she took care of the burned caramel. Meantime, Elizabeth was still stirring the Version 2 wet version of the caramel and carefully monitoring it. Ben transitioned between helping Emily setup Version 3 and stirring the Version 2 at the stove. Emily eventually came by the stove to prepare Version 3, a wet caramel composed of corn syrup, cream, jaggery, honey, vanilla, and chocolate. This version was an unstructured mixture that Donna had chosen to prepare.

Ben's excitement over the burned caramel mixture

Once all three caramels were completed, the adults brought the burned dry caramel, and the two wet caramel versions back for the learners to make observations. Elizabeth made the first attempt to taste the burned one. After Donna saw Elizabeth taste the burnt caramel, she yelled out, "Put it in the trashcan!" Donna also took a bite of the burned caramel and immediately spat it out. She yelled at Ben, "It's yours, you are the one who started it!" Ben quickly grabbed a spatula and started to tap on the

burned caramel, “Listen to this!” At some point, Ben tasted the burned caramel and came out with a disgusted look on his face. However, Ben excitedly exclaimed, “We totally burned it! Wow, it’s like solid rock! It’s like solid rock!” He went around to others, “It is solid rock, look at this!” Ben continuously tapped on the burned caramel to show others how hard it was. Donna also became excited about this, “No way! Let me try.” With enthusiasm, Ben called Elizabeth over, “Elizabeth, listen to this!” He continuously tapped on the burned caramel. Elizabeth quickly came over and recorded their interactions on StoryKit (Figure 9).



Figure 9: Ben tapping on the burned caramel. The sound icon is of Ben tapping the burned caramel.

Comparing and contrasting the different versions

The children began to cut into the two wet versions of caramel and to taste them. Immediately, they could see a clear difference between the wet and dry burned version. The wet versions were softer and edible, while the dry burned version was extremely hard and unpalatable. Both children gravitated towards tasting the two wet

versions. Ben, excited about what his group has made, exclaimed, "I love this stuff." Dr. Clegg came up to Ben and asked him for his thoughts on what other versions could be made that would be comparable to what he tasted and liked. Ben answered that he thought more honey, chocolate, and jaggery could make it creamier. Dr. Clegg, however, argued against Ben's conjecture, "But I think that you can't really say that adding the honey makes it creamier. That can only be a hypothesis. It could be the chocolate or it could be the jaggery sugar. We don't know right?" Ben wanted to start another test immediately, but the facilitators stated that no more time remained. As the group wrapped up, Elizabeth had a conversation with Ben and stated, "There's two good ones, one failed, which is a lesson. I mean, when you fail at something, what do you do? When you fail at something, that's learning."

Analysis of Ben's Vignette #3

For Week 09, Ben took on aspects of ownership in this task. Even though he was not the one who came up with this idea or the lead, there were many aspects of ownership in his interactions.

- 1. Ben exhibited investment and ownership into someone else's project idea and chose to stay with the activities.*

Although the project was first developed from Donna's ideas, she wandered away most of the implementation time (see Chapter 8). Ben was the one that came forward and took on responsibility for the menial tasks (*SQ3 – characteristics*). For instance, Ben spent a long time stirring the mixture and engaging in dialogue with the facilitators. Donna, unable to concentrate on the task, decided to transition in and out of the responsibility of stirring. Ben, however, chose to stay with the facilitators to

watch and stir the mixture. He stated the stirring the caramel this was one of his favorite aspects of KC.

- Ben: I like stirring the caramel. That had to be one of my favorite ones.
- Jason: Can you talk more about that?
- Ben: Well one, it's really quick and easy. Two, the only hardest part about it is the fact that you needed a candy thermometer or a thermometer that doesn't touch the bottom of the pan. Or a thermometer that you don't have to hold the whole entire time. And then you also have to hold it over. Ok, so there's a lot of negatives about that. But there's way more positives than there are negatives.
- Jason: So what was the way more positives you felt?
- Ben: Well, the fact that again there's really easy to make, really quick, ummm, there's different variations that you can make. There's creamy, there's like a sauce, there's crunchy, there's candy, there's all that stuff you can make out of caramel. You can even think about putting in dessert if you really wanted to.

Here, Ben explained that the process of making the caramel was important. For Ben, creating the different products from scratch was one of his main goals in KC (*SQ2 – points*). He imagined himself as becoming more like a chef because he was able to make food products from scratch that he could be proud to show off (*SQ3 – characteristics*). Even though the idea came from Donna and she directed some of the group's activities, Elizabeth commented that Ben did not care about this. "And it wasn't like we said, he didn't, he didn't claim, ownership of that idea, and he didn't seemed concern it wasn't his idea, he seemed to be enjoying, or at least engaged with the process that was going on."

In essence, although Ben did not come up with the idea, he exhibited characteristics of ownership over the process (*SQ1 – target*). One possibility for Ben's interaction was that he might have already been used to Donna coming in and out of the task. At The Green School, children work on their own tasks at their own

pace (*SQ4 – factors*). Elizabeth noted, “Um, he stayed by the stove knowing that he had to stir or getting something or um, whatever, he stayed engaged with the process, whether Donna was engaged or not.” In my observation of Ben in the videos, he stayed with the investigation the entire two-and-half-hours and did not move around to socialize or get distracted by the chaotic environment. During this time, Ben kept going back and forth from the stove to help setup the other variations. Ben owned the responsibility for making the caramels; he was not interested in being passive part of this investigation (*SQ1 – target*). In contrast to Arman, who may have been following the lead of the adults in doing the menial tasks, Ben was more likely to disengage and rebel if he was not interested or motivated.

2. *Ben chose to align himself with some of the practices of Kitchen Chemistry.*

Ben did not simply just stir the mixture and remained quiet the entire time. Ben also continued to take on the inquiry practices of KC while Donna was not around. He used StoryKit to document the investigation with the facilitators and asked for more opportunities towards the end to keep trying new ingredients. Elizabeth described Ben as being methodical and engaged in the discussion of how the caramel was produced while they were stirring for 30 minutes (*SQ3 – characteristics*). She observed that Ben “seemed like he was very interested in the science of it all.” During this time, Ben would ask questions about the process of making caramel, such as, “Like, by heating it (the sugar and cream mixture), won’t that speed up the process (of making the caramel)?” However, most of the time, Ben’s questions and observations remained on making the caramel product.

3. *Mistakes and failures are an aspect of Ben's ownership in the caramel project; so are successful accomplishments.*

Ben's ownership of the project focused on mistakes and failures in the design (*SQ1 – target*). One pervasive theme I observed in Ben's interviews was his positive view on mistakes.

- Ben: Well, if you make mistakes, you should clap. If you do it correctly, clap, but not as much. Cause you still haven't learned on WHY it's correct. What your saying is correct.
- Jason: Why do mistakes help you learn what's correct or not correct?
- Ben: Um, well, um, well if you fail, things won't go as planned. But at least you know something now.

Ben was not shy with others about burning the dry caramel and the failure of producing a caramel from dry ingredients. He went around the entire room showing everyone the burned caramel and tapping on it to show how hard it was. Although Donna wanted to immediately throw the failed dry caramel away, Ben wanted to take photos of it with StoryKit and show others what happened when corn syrup and cream were not used. He showed off pride and exuberance about the burning caramel and how hard it became.

From the failure of the dry caramel, the excitement of the burning, and the lessons learned for the other two versions, Ben talked about mistakes and failures as exciting and a part of his experience in KC (*SQ3 – characteristics*). The facilitators and learners in KC were genuinely interested in the failure of the dry caramel (*SQ4 – factors*). For example, Dr. Clegg and the facilitators came to Ben and talked to him about hard candies and how this solidifying and crystallization of the sugars is similar to how they make other hard candies. Here, Ben might be supported in making

mistakes since others in the community shared his enthusiasm for the failure (*SQ2 – points*).

Another aspect of Ben’s ownership of Donna’s investigation was the reaction he received from the people in the group for the positive outcome (*SQ2 – points*). The reaction of the group was mainly positive and there was a lot of excitement in the air when the wet caramels came out successfully. He was extremely proud of the result he got and told many people about it and was even willing to replicate the recipe again with the little time left (*SQ3 – characteristics*).

6.1.4 Vignette 4: Choice Day #2 - Week 10

Developing an idea about trashcan brownies

On Week 10, the final Choice Day #2, Ben had come in rather late from an all day field trip. KC usually started at 3:30 pm; however, Ben was on a field trip that included a two-and-half-hour bus ride back. Despite the long day, Ben eventually came in at 5:00 pm and still wanted to run a brief Choice Day investigation. I worked with him directly as the facilitator. The facilitators and I knew from a prior SINQ entry in Week 08 that he wanted to try something out called, “trashcan brownies.” In Week 08, he posted two questions into SINQ: “how to i make my own edible small trashcan” and “how do i make frozen gray trashcan looking brownie”. I asked him later about where he got this idea. Ben stated that he had gotten the idea from a trip to Florida and thinking about a specific ice cream he ate with many ingredients mixed together (e.g., chocolate, vanilla, candy). This random mixture reminded him about “trash” and he wanted to complement an ice cream like this with a “trashcan.” The trashcan brownie would be brownies shaped as a round container that could hold a

certain amount of liquid. Mainly, though, Ben wanted to do “something funny and out of whack, something crazy, something that someone wouldn't do.”

Coming in late to Kitchen Chemistry

When Ben arrived at 5:00 pm on Week 10, I immediately got to work with him on the trashcan brownies. However, we had very little time to plan a detailed recipe. We worked together to figure out how to manipulate a brownies recipe from Week 03 into an investigation that would satisfy the container goal. We decided to try the two-egg brownies recipe as the control and manipulate the rest of the ingredients. I had Ben document the recipe through StoryKit, while I went to prepare the chocolate and eggs quickly. We made the two-egg recipe first and then I divided the control into three half-cups. The first one-half cup acted as the control and went into the pan. To create the container shape, we fitted balls of aluminum to depress into the batter before baking (Figure 10).

Using StoryKit, I interviewed Ben on what he thought would happen with the controls.

Jason: What's going to happen to the control right now?
Ben: Um, probably going to turn out like every other one, fluffy.
Jason: Fluffy, ok. And what do you think these aluminum balls are going to do?
Ben: They're probably going to make the indents.
Jason: Indents. Ok. Do you think it's going to rise up with the indentation?
Ben: Yes. Yes, I do.

Next, using the second half-cup (Figure 10, Row 1), Ben decided to add one-cup of flour directly into the mixture. I asked him why he did that, but he just said he wanted to try it to see what happens. The mixture with the extra flour became incredibly stiff

and hard to mix. I later asked Ben why he thought the flour mixture became this way, but he did not know how to think about it. Finally, for the last half-cup (Figure 10, Row 2), we added about two ounces of chocolate. Again, I asked Ben what his predictions were, but he had a difficult time articulating a response. However, Ben made observations that Row 2 brownies were much thicker than the control batch.

Staying late and making observations

Because Ben came late, we were unable to start baking till 5:50 pm. His dad eventually came around 6:00 pm, but Ben wanted to stay and finish up. His dad let him stay and allowed Ben to walk home alone. We baked the brownies with aluminum foil balls as a mold. I asked if Ben had any predictions, but he said, “no idea.” When the brownies were complete, they were difficult to pull out, except the flour mixture. During this investigation, there were a lot of observations to make. I worked with Ben to focus on three aspects: overall taste, brownie sidewall strength, and the capacity to hold liquids (in this case, pudding from another group) (Figure 11). Ben noted that the control did not work out at all. He described the control as “collapsey” and unable to hold any kind of liquid because it was “too creamy”. For the Row 1 trial, the trashcan brownies with extra flour had the stiffness to hold up the walls and could contain the liquid pudding easily. As for taste, Ben described it as “hard” and “crispy.” Lastly for the Row 2 trial, the two-ounce chocolate brownie trial, the taste was chocolaty to Ben, but the walls were too weak and the liquid pudding began to leak out. In the end, Ben chose the flour one as the most successful of the trials, even though it did not have the taste he wanted.



Figure 10: The control is setup using a two-egg brownie recipe. Row 1 has an extra cup of flour and Row 2 has an extra two ounces of chocolate. Aluminum balls are placed to create the indentations for the trashcan brownies.

Analysis of Ben's Vignette #4

From my observations and experiences of Week 10 with Ben, this task seemed very much like an engineering task, rather than an investigation about inquiring about the mechanism of the phenomenon. Here, the goal of the Choice Day for Ben was to determine the possibility of building a brownie container that could hold a certain amount of liquid and taste chocolaty enough. Even though Ben was able to only spend an hour and a half with KC that day, I argue his ownership of the investigation was quite apparent.

- 1. Ben chose to come to Kitchen Chemistry and stay with the investigation after a long bus ride home.*

Ben looked exhausted from his long bus ride home from an exhausting field trip. Not only was the bus ride long, he got to KC late at 5:00 pm. While all the children that got off the bus left with their parents, Ben simply walked up from the

bus stop straight into the kitchen lab. Not only did he choose to participate in KC, he made the decision to stay even longer after his father showed up to pick him up at 6:00 pm. He told his father directly that he would walk home himself and that he wanted to complete the investigation. Ben stayed an extra 40 minutes after KC was complete so that he could see if he was able to be successful in making his trashcan brownies. For Ben, he had two opportunities to leave, go home, and get rest. Instead, Ben chose to start a design project and see it through completion (*SQ2 – points*).

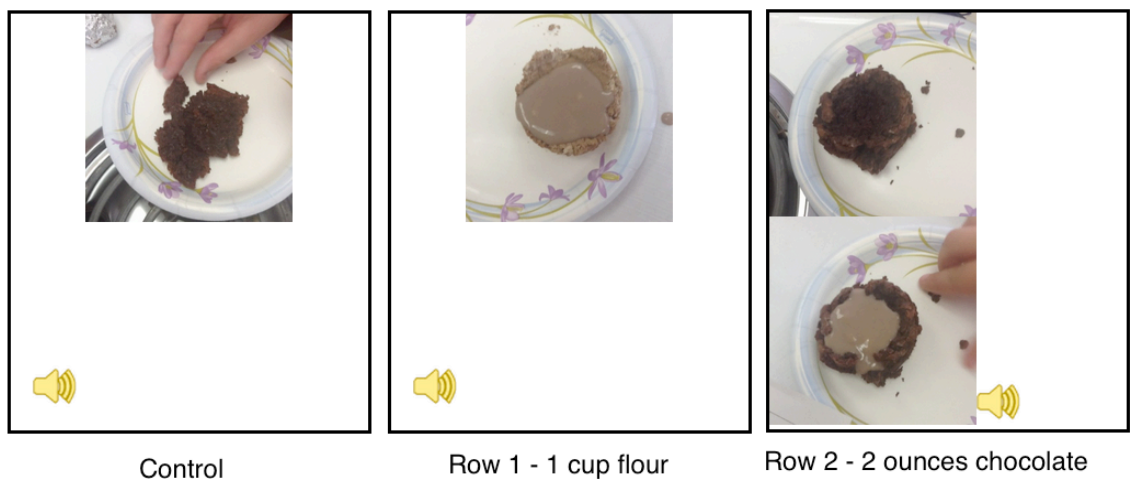


Figure 11: The final results of the trashcan brownies.

While making trashcan brownies was fun, one possibility is also that he might have been obligated to come to the afterschool program, despite the long trip. However, this seem unlikely given that Ben lived very close to the school and he could have gone home or went to his father’s classroom. Ben also expressed that opportunities to conduct these kinds of investigations are not always present at his home (*SQ4 – factors*). Ben also expressed that KC was very different than school and that the experience of making food was not present at school (*SQ4 – factors*). If Ben had chosen to go home on Week 10, he would likely not been able to participate in

the design and implementation activity at home or school. Part of the reason he may have chosen to come for this opportunity at Choice Day was because it was the last time he could have designed and implemented a food design task on his own.

2. *Ben exhibited pride in being about to accomplish his trashcan brownies and described creativity as a contribution.*

In a later interview, I asked him about his thoughts on the trashcan brownies investigation. He expressed that his contributions to KC was on the creation of strange and creative ideas (*SQ1 – targets*). Ben commented that his time in KC was “fun”, but also that having fun is part of being a chef. He expressed that he had fun when he could think of “creative things to do” and by “figuring out things to do.” He saw his creativity as making an impact in how the investigations were run and implemented. For the trashcan brownies, we as facilitators had to come up with a way to transform this unorthodox idea into something he could both investigate and bring to life (*SQ4 – factors*). Ben imagined the role as a chef and that what he was doing in the investigation was acting in that role. Ben also saw himself as a designer, as someone who could create ideas that were “new” and that no one else thought of. Part of the ownership of the investigation he expressed was in the creativity of the idea and the sense of accomplishment at being able to achieve what he sought after. I asked Ben if he shared what he did in KC with others.

Ben: Um, well John, my friend, Kris my friend, Nat my friend, Adam my friend (Interviewer: Lots of friends). Matthew my friend, Lucas my friend, and almost all my other friends (names are all pseudonyms).

Jason: So you told all these people you ate a trashcan?

Ben: And I told them about KC.

In this portion of the interview, Ben showed ownership of the trashcan brownies through many aspects (*SQ3 – characteristics*). He was proud and shared about his experience to multiple friends. In contrast to Arman (Chapter 6), who was very shy about telling others, Ben told many in his social circles about the experience and KC. He is also very proud of the fact that he “made them.” Ben’s ownership of this project extended towards the personal product and the creative process of making them (*SQ1 – target*).

6.2 Overall Discussion on Ben’s Ownership of Science Learning

6.2.1 What Did Ben Own?

First, Ben had ownership over creative design ideas. Ben did not just want to own simple ideas for his investigation; he wanted creative design ideas. For two of the Choice Day activities, he chose to create pizza balls and trashcan brownies. Both of these are creative to Ben because 1) they are new designs of traditional foods; 2) no one else in KC thought about them; and 3) he never had the chance to make these kinds of food before. For Ben, he latched onto the inherent challenge of developing foods with the creative designs. He also enjoyed hearing about more ideas from others and commented, “The more you see ideas, the more you get ideas.” In this quote, Ben is referring to design ideas, such as the pizza ball and the caramel. However, the vignettes do not give strong evidence of Ben attaching onto these projects as a science investigation for hypothesis testing or developing ideas and explanations about the phenomena behind cooking foods.

Second, Ben had ownership over his personal products. Like many of the other learners, Ben had goals for making tasty food products from scratch. This was

an important goal for him and a motivating factor for his development of ownership. In all three vignettes, Ben took the products home and shared them with his family. Ben talked about the difference between science in KC and other science experiences as making “awesome food.” Equally important to Ben was also the ability to share these foods. He enjoyed the praise he received from his friends, family, and facilitators whenever he would share these food products with them.

Third, Ben had ownership over the process of implementation. For Ben, controlling and investing into the process of implementation of these food projects was important. Although he had moments of distraction in Week 06, for the most part, Ben was very active in the decision-making of his projects. He controlled what ingredients to use as variables (e.g., two eggs in the pizza balls), how to organize and manage the investigations, how to measure the products, and what roles others might play in the investigation (e.g., asking facilitators to help out). In addition, his ownership over the process of implementation could also be seen in his negotiation between him and the other participants. He chose to ask others what they thought about the products (e.g., pepperoni in pizza balls) and wanted their opinions. Even though the caramel idea was not his, he chose to spend time observing the caramel and engaging in discussion with the facilitators while stirring for 30 minutes. In the pizza ball and trashcan brownies investigation, he specifically asked his father if he could stay longer to finish the products and see the investigation completed. Overall, Ben did not take a passive role, but found himself in control and investment into the process of the investigation.

Lastly, Ben owned the mistakes and failures he made. The production of the failed dry caramel and the dry pizza ball created an opportunity for Ben in terms of ownership of mistakes and failures. Instead of blaming external circumstances (e.g., poor equipment, bad facilitator choices), he embraced the mistakes he made in KC. When the burning caramel came out, he did not want to throw it away. He grabbed a spatula and began hitting it, telling everyone how hard it was, recording the burned result on StoryKit, and engaged in discussion with a facilitator about it. For the pizza ball, when it came out drier than he thought, he acknowledged there was something to learn from it (e.g., adding more sauce) and that failure was an opportunity to learn. Ben was not shy about his mistakes; he even engaged in conversation with his father and others about them.

6.2.2 How Does Ben's Ownership Evolve Over Time?

In this discussion, I explain how Ben's ownership of science learning evolved through the work of engagement, alignment, and imagination (Wenger, 1998). I suggest that Ben's strong ownership over his projects involves a combination of these three modes of belonging. Even though engagement, alignment, and imagination require different conditions, understanding Ben's interactions in this framework can help better understand how ownership evolved for Ben.

Engagement and Ownership

Wenger's (1998) depiction of participants' engagement in communities as sharing in practice, contributing to the pursuit of an enterprise, and utilizing shared usage of symbols, tools, language and documents. Ben's characteristics and outcomes of ownership can be examined through his engagement in KC.

Ownership as a negotiation of meanings. In the engagement process, Wenger (1998) depicts one aspect as the management of boundaries and the negotiation of meanings. For Ben's ownership, he wanted people to know what aspects he owned and he negotiated the meaning of that ownership with others. On Week 05, Ben asked his father to come and "look at my question" on the SINQ app. For Week 06, Ben recorded into StoryKit, "Pizza balls, my pizza balls." Week 08, he wrote into SINQ, "how to i make my own edible small trashcan". And in Week 09, when Donna stated that the dry caramel failure was his version, he went around proudly in KC showing off how hard and burned it was. Here, Ben created delineations and boundaries for the ideas, processes, products, and mistakes he owned.

Taking ownership of failure. Another aspect of engagement through negotiation of meaning was accepting making mistakes and failures. As part of Ben's engagement, he chose to accept mistakes and transformed them into a positive view. The dry pizza ball and the burned caramel did not turn out exactly as he had planned, but he was fine with this. Instead of accepting mistakes as a bad outcome in design, Ben changed the meaning of failure through his shared discourse with the facilitators, excited expression to the other learners, and his conversations with his father. Ben accepted that mistakes and failures are what you do in science and you learn from them.

Ownership as mutual engagement in shared practice and facilitation. For Ben, the initial ownership over his investigation was difficult to establish. Even though he came up with the idea in Week 05 to do the pizza ball rather quickly, the beginning of Week 06 showed that he had attention issues on what to focus on,

particularly when he did not know what exactly to do and how to start. Similarly, Arman in working with Ben also did not know what practices they should have engaged in. Since this was the first time both Arman and Ben were developing a food investigation, they did not have mutual engagement. Wegner (1998) described mutual engagement in the following way.

Mutual engagement involves not only our competence, but also the competence of others. It draws on what we do and what we know, as well as on our ability to connect meaningfully to what we don't do and what we don't know – that is, to the contributions and knowledge of others (p. 76).

In Ben's case, both him and Arman had little experience in developing food from scratch. Although Charley was there to help guide the group, it still took time for them to understand what was going on. Without a sense of shared practice and mutual engagement, Ben had a difficult time paying attention to how exactly he was going to transform his pizza ball idea into something real and tangible.

For Ben, having structured and focused tasks in mutual engagement helped him develop ownership over his investigation. When tasks were unstructured and open, Ben tended to have a harder time taking responsibility. Ben described being impatient during these times as getting “a little giddy” and starting “to get a little crazy.” At some point Charley even had to remind Ben this was “his” design project, not hers. Although Ben came up with many creative design ideas, he acknowledged it was very difficult to think about the ideas. The facilitators helped him slow down to think about the questions (instead of the creative idea), provided discussion about the scientific processes he observed, and narrowed the investigation into a focus for Ben to latch onto. Without shared practice and facilitation through mutual engagement,

Ben's ownership over the project was hard to establish because open-inquiry can be overwhelming for novice learners (Kirschner et al., 2006).

Ownership as a mutual engagement in relationships. A second aspect of mutual engagement was Ben's meaningful conversations with the facilitators. Through engaged discussion, he experienced about how failures can lead to more learning with Elizabeth and how to build a pizza ball with Charley. Part of the ownership for Ben was the social nature of sharing and seeing other people's reactions. When he got excited, many others around him got excited. Terrie, his teacher noted, "his enthusiasm makes the other children excited about the activity too." I observed the same reaction from other learners as well. After the burning of the dry caramel, Ben became very excited and took the burned residue to other learners. Vice versa, when others got excited, he got more enthusiastic and wanted to record and capture all of his observations on StoryKit. In this case, Ben's engagement through ownership of his product, mistakes, and process all increased when he saw a positive reaction from other people.

Alignment and Ownership

Ben's interactions through mutual engagements, negotiation of meanings, relationships, and shared practice helped him to develop ownership over many aspects of science, such as his ideas, end products, process of implementation, and failures. In contrast to Arman (Chapter 6), who kept his interaction with KC quiet from family and friends, Ben was much more outspoken with others outside the KC community. Ben's alignment to the community showed how he was able to coordinate his energy and activities to fit within the broader structures of KC. Several

themes of alignment exist for Ben that expressed the initial characteristics and outcomes of his ownership.

Alignment and ownership characterized through shared discourse. Wenger (1998) described discourse as communicating shared meaning and creating forms of community and can be shared by multiple practices. Sharing discourse allows participants to invoke control and negotiate meaning in a community; a notion that Wenger described as the “ownership of meaning.” Here, participants hold some meanings as their own and some meanings as part of the community. For Ben, he was able to take elements of discourse and meaning across different settings. For example, his father expressed that after KC, he noticed Ben started to ask more questions about cooking, design, and food while they were cooking and eating at home.

- Jason: Can you talk to me if Ben's interest in science has changed since KC or has it stayed about the same?
- Ben's Dad: He's definitely more interested in the science of cooking. In terms of flavor taste and texture. Maintained and emphasized his love of chemistry.
- Jason: How do you know this?
- Ben's Dad: Working with him in the kitchen, he's clearly more engaged in conversations about why certain things mix, why certain things don't, why certain things are particles, why do certain things break into crystals. Inquisitory curiosity in the kitchen.

Ben chose to align in the kinds of discourse found in KC with his father. He asked questions and made observations, assertions, and arguments in the kitchen about the cooking process with his father. However, I believe that most of the questions for Ben remained on the product design aspect of cooking (e.g., process, steps, why certain things mix) than hypothesis testing or explanation generation.

The facilitators often had take on the role of authority and push for alignment in KC. We might ask learners to follow certain practices and ask them to comply with

our requests. For instance, in Week 09 when Ben was stirring the caramel, Elizabeth attempted to have a discussion about how the proteins in the cream and the crystallization of sugars affect the outcome of caramel. Wenger (1998) states that asking for alignment can be a way in which instructors show and guide learners what is possible in order to hand over control later. However, when the facilitators are not present anymore, it is up to the learners to choose whether or not to participate in those established discourse practices. In terms of alignment and ownership of science learning, Ben began to participate in the some of the practices of KC at home without a facilitator present.

Alignment with home practices. Many aspects of KC already aligned with Ben's own science learning experiences at home. Ben's father described Ben as engaging in science at home through a variety of ways, often much of it without structure. Ben often worked with his father on a series of informal science activities, such as a volcano with baking soda and vinegar and creating a whirlpool simulation using two 2-liter bottles of soda. The kitchen was not only where Ben tried experiments, but a place he spent time cooking with his family twice a week. KC may have just been an extension of that home experience he already had. Ben's ownership of his product was influenced how his ownership took place because he already envisioned himself doing science in the kitchen. However, he recognized home had many limitations in being able to do full investigation. The afterschool environment acted as an extension for his personal goals of trying new investigations in the kitchen. His activities at home already prepared him to want to take on the larger independent tasks in KC.

Ownership expressed as an expenditure of energy. Ben's ownership over his investigation can be seen in where he directed his energy towards the investigations. Wenger (1998) describes commitments as not dependent on commonality or differences, but on alignment towards a community. In this case, Ben's own direction of energy focused in on his investment into his projects. First, in terms of participation, Ben made efforts to either come or stay in the KC environment. On Weeks 05, 07, and 10, he told his father to wait for him as he finished up his investigations. Ben had the choice to leave as soon as his father arrived. On Week 10, Ben could have also skipped KC. He sat through a two-and-half-hour bus ride from a long field trip and arrived late at 5:00 pm. In order to become engaged, Ben had to expend his own energy and investment to come. For ownership of learning, Ben made the choices to stay and continue. I asked him why he continued to come back. Besides the tasty snacks and seeing his friends, Ben commented that developing design ideas and hearing new ideas from others was very important to him. Here, Ben's alignment developed as he wanted to actively engage in idea and investigation generation processes.

Ownership expressed through relationships across communities. Ben's characteristics and outcomes of ownership of learning could be seen through his relationships. Wenger (1998) explains that alignment spans distances socially and physically. As participation increases, our identities form trajectories, both within and across communities. In this case, Ben shared his pride and contributions to the people in his circle both in and out of KC: family, friends, teacher, and facilitators. In Week 05, Ben invited his father to come see his question on pizza balls. In Weeks 07, 09,

and 10 Ben took home all the products he made and wanted to share them with his family. For Ben, showing off his products and ideas to his family was very important and influenced his ownership over the investigation. Ben mainly wanted to share his creative ideas with people that were close to him. He told many of his friends about how he made a “trashcan” and figuratively and literally ate it. He was incredibly proud that he could turn his creative ideas into an actual product. Even his teacher, Terrie, commented that on Wednesdays, Ben would be very excited about KC and tell others about that day. Here, Ben’s alignment through ownership expanded KC to his home and school communities.

Imagination and Ownership

Through engagement and alignment, Ben took on ownership over aspects of the KC, both within and outside the community. In the work of engagement, Ben took on meaningful activities and interactions in the production and implementation of his investigation. As Ben engaged in the KC practices and could see that his ideas were taken serious and could used to develop end products and idea generation, he started to align himself to KC in home and school. He expressed to others about his enjoyment and wanted to go into discussions about cooking and science more with his father. The work of imagination requires participants “to explore, take risks, and create unlikely connections” and “demands some degree of playfulness” (Wenger, 1998, p. 185). For Ben, his imagination was both the source of his engagement and alignment through ownership and the resulting change.

Scientist. Ben described scientists as just another form of “explorer” that “find(s) out new ways to do stuff and new things in life.” He explained that scientists

are people that discover new cures to diseases: “they figure out how to make the uh, serums and all the medicines and stuff. And then they give those to the doctors and stuff.” His ideal view of a scientist was Albert Einstein and Stephen Hawking. Although Ben’s conception of scientists appears to be abstract, he articulated many personal and relatable traits that he exhibited to be a good scientist.

As part of his ownership of science learning, he could imagine himself and relate to these traits. His imagination of scientists supported a mode of belonging within the investigation he was conducting. First, Ben imagined that scientists needed to be patient in their tasks. Instead of giving an abstract example of patience in a scientist (i.e., scientists must be patient in waiting for a chemical reaction to occur), Ben gave an anecdote about how he lost a Lego™ piece in a building set and had to be patient to find this missing piece. He explained that this kind of patience makes a good scientist. Second, Ben stated that multitasking was an important trait of his view of scientists, but that he had difficulties with handling all these tasks. Ben imagined scientists needing to be careful and work with multiple tasks at hand. Part of Ben’s ownership of science learning was seeing himself as a scientist in a lab, or in this case the kitchen. However, Ben also commented this first Choice Day was difficult because he had to multitask so much. Indeed, in the weeks he engaged in KC, he worked independently and had to watch over many parts of his investigation. For Ben, his imagination required opportunities for engagement and alignment and Ben took the opportunity to enact his view of multitasking as science.

Finally, Ben imagined that scientists learned from their mistakes. After the mistakes he engaged in on Weeks 06, 07, and 09, Ben expressed that scientists learn

from their mistakes and that engaging in science meant failures were going to happen. I asked Ben what kinds of things he thought we did in KC that reflected science. He immediately started to talk about mistakes as part of science learning experiences. Instead of seeing mistakes as a shameful thing in science, he talked about them in a positive light. He focused on the possession of the mistakes (e.g., my mistakes) and what personal lessons he learned from them. In this case, he later talked further about how he would have improved his prior pizza ball investigation. Here, through the ownership of mistakes in engagement, Ben could imagine that professional scientists could learn from mistakes.

However, Ben's view of science appears to switch between explanations about nature and engineering design. For instance, in the following interview, explained that he thought of himself as a scientist trying to think about the universe and determining a prediction for the future:

Ummm, me and my friend John, we just like, like, whenever we have free time in our class, we just like to sit down and talk together. And one of our things was, one of our ideas was, maybe the Big Bang might start again. When everything is gone... Cause we were thinking, so there could be one black hole. And that black hole sucks everything in, and since it's too big, it explodes and makes three black holes. All those suck in everything else (gestures: hands show black hole). And then you have a massive black hole. And then since it's so big, it sucks in itself. And then it turns into that small ball of mass again. And then it explodes again! (gestures: hand shows explosion).

Here, Ben discusses aspects of himself in science coming up with explanations of the universe. However, when Ben talks about doing science in the context of cooking, it is focused more on product design.

Jason: What's the difference then between cooking at home and cooking at Kitchen Chem?

Ben: Again, I don't do science with it (cooking at home). I don't figure out why that worked, or why this didn't. Um, also that I can do chemistry, it's not me and my family. It's me and a group of people. So, yeah, it's kinda different.

In KC, Ben perceived that doing science meant figuring out “why that worked” or “why this didn't.” One explanation is that science is about understanding how the world works, but this is in the context of school. However, science in KC is about determining how to best create the creative food ideas a learner comes up with. In this view, science is similar to engineering, that is, “definitely figuring out the variations. Um, figuring out how things should go to make it actually work.” It could be that Ben's definition of “doing science” meant to “figure things out”, either figuring out about explanations of phenomena or figuring out how to make a pizza ball or caramel from scratch. Ben also acknowledged the social supports he received in KC for helping him.

Investigator. In “doing science” Ben wanted a sense of the unknown; he wanted to what would happen if he attempted to make these creative food designs. Even the facilitators should not know the results. Ben stated that the science in school was different than the science in KC, “*I don't do much science at The Green School other than at Kitchen Chem.*” Ben recognized that aspects of science in his schooling experience were changing. The school only does the Montessori portion till the sixth grade. Ben expressed that project-based and hands-on science experiences changed from when he was in first and second grade to third grade and that he was unable to engage anymore in his own explorations. I asked Ben what did it mean for him to “do science”? To Ben, being an investigator meant exploring “without the clues.”

One of my interpretations of Ben's "clues" is that they are hints or small bits of guidance for investigations.

Ben imagined doing science as being an investigator and trying to find out what the answers and findings are along the way. In all the food design projects, Ben did not know exactly what would happen. All the facilitators (including myself) also expressed that we did not know what the result would be of these projects. Ben's imagination of the investigator role gave him reason to want to invest and make choices into these food design endeavors. For Ben, if no one knew the answer, this meant his food projects were genuine and authentic probes into science inquiry, even though they are more product design tasks. This meant that he had to make investments into his investigation; otherwise he would not be able to find out what he was looking for. Imagination of the unknown discoveries helped to fuel Ben's investments and engagements into KC.

Designer. Ben also imagined himself as someone who could come up with "big and impossible ideas." I asked him what he thought about himself in the role of a designer. Ben imagined himself as a creative designer and wanted to show off his creativity in the investigations. He did not just want to make simple food; he wanted designs that were out the ordinary. Ben was proud of these designs and this supported his self-identity as a designer. His experience about designing these investigations was not just about making food or understanding experimental design processes. He wanted to take on these challenges and make investments to make sure he could accomplish them.

Chef. Finally, Ben could imagine himself as a chef. He stated that he felt like he progressed to being a chef because he had been craving to make food from scratch. Making the food from scratch was an important part about the investigations. Ben imagined himself enacting the role of the chef in Choice Day. He was very proud to make and share the food. His ownership through control and investment of these personal food products increased as he imagined his identity in the chef role.

Imagination bridges ownership through engagement and alignment. Through imagination, people can envision themselves in the world and can develop identities through other possibilities and meanings (Wenger, 1998). As part of the modes of belonging, imagination is a balancing act between the possible and the impossible. With Ben, his imagination of the roles and himself links his engagement and alignment through ownership. Ben could see himself enacting the roles of scientist (or engineer), investigator, chef, and designer in KC. Wenger observes. “in terms of participation, imagination requires an opening” (p. 185). KC’s Choice Day gave Ben the personal freedom he needed to express his creativity and explore genuine design questions in which no one knew the answer to. For the pizza ball and trashcan brownies, these two ideas came to Ben very early on and spontaneously. None of the facilitators discouraged him, but instead tried to figure out ways that these random ideas could be integrated into a science investigation. Ben would suspiciously question tasks the he felt were not authentic, such as experiments that had pre-determined results.

The opportunity to transform unorthodox ideas into an investigation with a question was paramount to confirming his imagination and ownership. He needed to

make sure that his choices and investments would help him design his food products and help him answer the questions that he had. He also needed a place that allowed him to make failures into inquiry and food that did not always turn out right. Vice versa, as Ben engaged and aligned his practices to KC, his imagination of scientists shifted. For instance, after negotiating the meaning of failure as a positive aspect of learning, Ben expressed in our final interview that professional scientists constantly make mistakes and learned from them.

6.3 Summary of Ben's Ownership of Science Learning

Ben's evolution of ownership of learning is complex interaction between his engagement, alignment, and imagination in the communities he takes part in. Over time, his engagement in the community showed that his ownership over his creative design ideas, investigation processes, mistakes, and products manifested through his interaction with his relationships, negotiation of meanings, and shared mutual engagement. His alignment in the community was shown through his shared discourse and expenditure of energy across home, school, and KC. With imagination, I believe that his perception of what it meant to "do science" is based on the notion of "figuring things out." Even though Ben expressed early on that in school, doing science meant figuring out explanations of phenomena (e.g., how the Big Bang may have happened), doing science in KC meant figuring out how to make creative ideas come to life. The combination of Ben's engagement, alignment, and imagination all worked together so that Ben's ownership of his investigation, products, ideas, and mistakes were supported and could support community building. Overall, Ben's

ownership towards his targets took on a stronger attachment towards control, pride, investment, and contributions.

Chapter 7: Freddie's Case Study

Freddie is a 5th grade boy at The Green School. He has been to The Green School since the third grade. Freddie expressed that he wanted to come to Kitchen Chemistry because of use of iPads and cooking. For Freddie, the use of technology was not simply a hobby or interest, but a large part of who he is and how others identify him. I chose three vignettes to represent Freddie's case (7.1). The first vignette (Week 05) shows his development of an investigation called Greenies (7.1.1). The second vignette (Week 06) gives a snapshot of conflicts and tensions that exist in ownership (7.1.2). Finally, the last vignette (Week 09) highlights how Freddie ignored another child's investigation and went off to create a water investigation on his own (7.1.3). Using my analysis of the vignettes (7.2), I contend that Freddie's ownership of science learning is influenced from his imagination, engagement, and alignment in science from his home life.

7.1 Vignettes from Choice Day and Analysis

7.1.1 Vignette 1: Choice Day #1 – Week 05

Turning Greenies into an investigation

On Week 05 of KC, Freddie worked with Dr. Clegg to develop his ideas for Choice Day in the SINQ platform (Clegg et al., 2013). Although Freddie was initially distracted (i.e., playing with the research video cameras), he became intently focused on the activity once Dr. Clegg prompted him to consider an idea he had previously expressed interest in: making green brownies or "Greenies". Ever since Week 03, Freddie had expressed that he wanted to make brownies that had a green color. The

idea came from the pun that “brownies” are brown cakes in color; therefore “Greenies” could be chocolate cakes with green color. Freddie became so enamored with the idea of Greenies that he drew the word “Greenies” in his Week 03 StoryKit story (Figure 12).



Figure 12: Freddie writes “Greenies” on the left panel. Donna, his partner, became so irritated, she wrote a text saying they are making brownies, and sings that they are not making Greenies.

As Dr. Clegg read Freddie’s initial question in SINQ, “How should I make green brownies?” she prompted him to develop an experimental question to answer, as well as a hypothesis for the experiment. However, Freddie exhibited many attention difficulties, such as yelling out, playing around with the iPad™ cover, and being overall inattentive. Dr. Clegg, being patient, asked him if he wanted to add regular brown chocolate chips for these greenies. Freddie was under the impression that green chocolate chips existed and this was all he needed. Dr. Clegg indicated green chocolate chips did not exist and that melting the chocolate alone was not suffice to make a green brownie.

At this point, Dr. Clegg and Freddie decided that green food coloring was going to be a necessary ingredient in this investigation. Freddie already predicted that green food coloring was not going to change the taste. He took this idea and typed into SINQ as a hypothesis, “Use brownies w/ green food die.” Since the goal of KC was to help children develop food investigations, Dr. Clegg asked Freddie if they were going to have a comparison batch (i.e., an experimental control). Freddie chose not to make a comparison batch of brownies because he already had made a “regular” batch of brownies in Week 03 (Figure 12).

As the SINQ activity was wrapping up, Freddie still had not thought about exactly what chocolate he would use. His father arrived to come pick him up. At this moment, Freddie called out to his father about how he was going to make chocolate brownies with green food dye. However, Freddie’s father brought up a point; green food coloring would only darken the brownies if he used regular chocolate chips. Freddie realized this conundrum and changed his mind about the blondies idea. The conversation changed to how to not only make the brownies green, but how to lighten them up to absorb the green food coloring. Dr. Clegg still wanted Freddie to try a comparison between the Greenie and a standard, in this case, a blondie recipe. At some point before this conversation, I added a response into SINQ for Freddie, “Maybe you should use white chocolate and let green food coloring get absorbed into the white chocolate.” While Freddie was scanning through SINQ, he saw my response and called out, “I think I saw this one, I think I found what you recommended! (Holding up SINQ hypothesis in air on iPad™) I think I found it!” At this point, Freddie had to leave home with his father. When he arrived at home, he

logged into SINQ and typed a message for us, “may you please buy some brownies and blondies for me? –Freddie”.

Analysis of Vignette #1

1. Through the development of ownership, Freddie transitioned from distracted to focused

Freddie was one of the learners who, in whole group discussions, had to be reprimanded often for non-productive contributions, such as disruptive comments and noises. However, as we worked on SINQ, Freddie was more focused on the goal of the activity than he was during whole group discussions. Although he became distracted at points, he was easily prompted back to the activity or he brought himself back to it. The main target of ownership for Freddie was his Greenies design idea (*SQ1 – target*). Freddie developed early ownership of this idea in Week 03 (*SQ2 – points*). Although Freddie had issues in maintaining attention in KC, when we focused on the idea of the Greenies, he became more interested. One of the characteristics I observed in his ownership of the Greenies idea was his pursuit to making it a possibility (*SQ1 – target*). Even though Dr. Clegg wanted him to make comparisons as an investigation, he was much more interested in seeing the possibility of making this food product than comparing them to regular brown brownies (*SQ3 – characteristics*). Here, he appears more focused on the design and creation of the green brownies. Another aspect of his ownership of the Greenies idea was his immediate response to his father about it (*SQ3 – characteristics*). Similar to other children in Kitchen Chemistry, he quickly shared what he had written in SINQ to his family. Sharing the design idea to his father gave him a sense of pride and excitement (*SQ3 – characteristics*).

2. Freddie is vocal about his ownership over the Greenies

Freddie was also not shy about sharing the Greenies idea to everyone in the room. Starting from Week 03, most of the facilitators already knew that he wanted to create the Greenies for his Choice Day investigation before the SING activity. Dr. Clegg, using SING, helped Freddie envision how to create the Greenies and narrow the focus (*SQ4 – factors*). Freddie first initially thought there was such a thing as “green chocolate chips.” When Dr. Clegg informed him no such thing existed, he decided that green food coloring would make the most sense to use. He also saw in SING that I posted a suggestion to think about with white chocolate for his Greenies. Here, he started to increase his ownership from just an idea in the making to an actual process that could be developed through decision-making. SING also allowed Freddie to post his Greenies ideas with his name on it and declare authorship over the product. In this case, Freddie attached his name to the message, “may you please buy some brownies and blondies for me? –Freddie”.

7.1.2 Vignette 2: Choice Day #1 – Week 06

Slowing down causes frustrations for Freddie

Freddie was extremely excited to begin Week 06; this was the first Choice Day for him. Freddie and Eric were going to be making brownies. Since both boys had issues with attention and Eric was quite young, we split up the two boys and had them work separately on their own projects. Freddie would take on the green brownies with Emily, while Eric would work on white brownies with Elizabeth.

As soon as we announced the day to begin, Freddie immediately went to his station to begin. However, his enthusiasm soon deflated as he found out he had to fill

out the goals chart. Freddie, frustrated at even the notion of slowing down, raised his hands in the air to show his irritation, “Why don’t I, I don’t get this piece, cause it says what leavener should we use for taste and stuff? Like for texture? Seriously?” Emily, being patient, asked him, “What leavener should we use to make cakey brownies?”, “Texture?”, “Smell?” For Freddie, none of these were really pertinent questions; all he wanted was to make brownies with a green color.

As soon as Emily focused on the green goal, Freddie immediately perked up and started to plan for that part. He asked for a pencil to add into their recipe that they would need four ounces of white chocolate as a substitute for the brown semi-sweet chips. He exclaimed that he wanted to get started quickly, “I want to get ingredients!” Emily still wanted him to slow down, “Let’s hold off on that.” Freddie looked for something to do that would let him stop planning and get him to make green brownies faster. He even asked Emily if they could just pre-heat the oven. Emily stated that this was not a good idea because other people needed the oven first.

Instead, Emily wanted Freddie to consider how his green food coloring would show up since all the other ingredients had different colors and tones. She suggested that they change something in the recipe to make sure the green food coloring shows up more. Freddie just wanted to add the green food coloring, “Let’s just add it, just because it’s (white chocolate) white, it will show up more.” Emily again slowed him down, “Well hold on, that’s the thing. Not everything in the recipe is white.” Freddie argued back, “Brownies are brown because of the chocolate!” Needless to say, Freddie started to grow impatient with waiting and thinking. On the video, Freddie started to breathe heavily; he wanted to go and just grab the ingredients. Emily asked

him, “Are you getting frustrated?” to which Freddie nodded yes. She suggested they go get some fresh air. Emily also reminded Freddie they were a team and there was no rush to what they were doing.

Starting the Greenies design

Once Freddie calmed himself a bit, Emily reminded him the Greenies might not be perfectly green and they need to consider how much white chocolate they would put in and how much green food coloring goes with it. She held up a white chocolate chip and showed him it actually had a yellow tint. Freddie stated that it does not matter how green it gets, “Anything green is good.” He was also not particularly interested in re-enacting the Week 03 eggs, oil, and water experiments with food coloring (Chapter 4). Emily went through an entire list of ingredients from butter, eggs, salt, sugar, and vanilla and pointed out that some ingredients are not as white in color. Freddie agreed, but stated, “I know, but it’s (the sum of the ingredients) mostly white.” His claim was that the yellow and white ingredients would still absorb the lighter green color. It is difficult to tell if Freddie had a particular mechanism in mind; his intuition may have been that the dark green food coloring could sufficiently mix and color the white mixture. Freddie was still excited, “I just can’t wait to start!” Emily was quickly wrapping up; she wanted a smaller amount of batter to try out. Meanwhile, Emily had been using StoryKit to keep track of their investigation and arguments (Figure 13). Towards the end of their planning, they made their final decisions on the amount of chocolate, butter, and vanilla to put into recipe. They choose to enact the original two-egg brownie recipe.

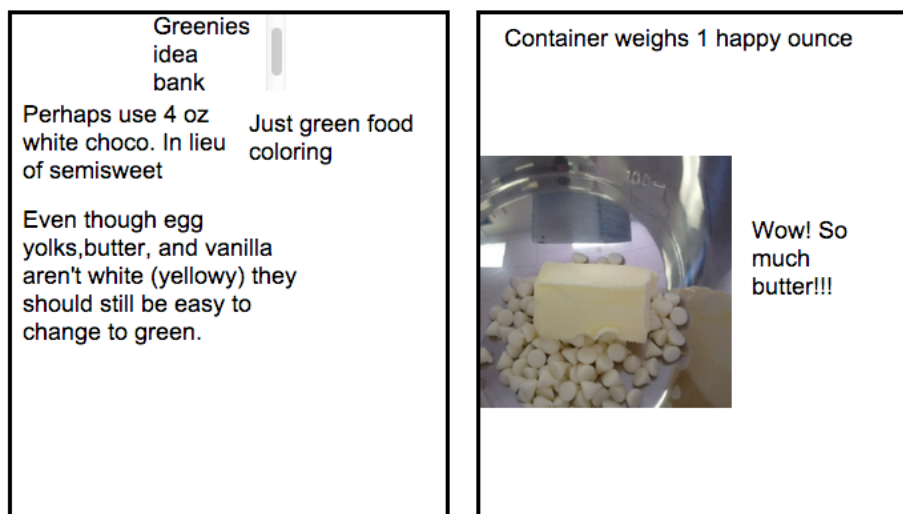


Figure 13: StoryKit panels of Freddie’s Greenies. His argument about the color of the ingredients is posted on the left panel.

Unanticipated results in melting white chocolate

The two of them started the process of the making the Greenies for the investigation. Following the same procedure as the two-egg brownies, they took butter and white chocolate and go to the stove to double boil the mixture. While they were at the stove, Freddie wanted to use StoryKit to record the observations. Both of them realized that melting white chocolate was not the same as melting semi-sweet chocolate chips. When the white chocolate melted, gritty sugar started to appear; this was not the same observation they made with the previous brown semi-sweet chocolate chips (Figure 14). Emily noted that it would be impossible to pour out this gritty sugar from the white chocolate mixture and that they would have to keep going on.

Freddie and Emily both commented that the white chocolate mixture did not look right. Emily suggested waiting for the green food coloring till the last step. She thought it would be best to add the eggs next and then the dry ingredients (e.g., sugar,

flour) into the white chocolate butter mixture. However, Freddie at this point may not be taking over all aspects of the design decisions. As the dry ingredients were put in, they hoped that the flour would absorb the green food coloring better. The final step in the investigation was to add the green food coloring. They closely read the instructions on the box and decided to add $\frac{1}{2}$ a teaspoon into the batter. Freddie got excited and started to repeat, “Greenies! Greenies!” Emily added the first $\frac{1}{4}$ of a teaspoon in first as the test run while Freddie stirred this in. He called out, “Let’s not add anymore than this, I like how it looks.” Emily suggested stirring further before making a final decision.



Figure 14: White chocolate chips and butter did not melt with the same consistency as brown semi-sweet chocolate chips.

Baking with a red rubber muffin pan

At this point, Freddie grabbed a red rubber muffin pan and stated, “We can have little brownie cups.” As Emily continued to stir, he yelled out to the group, “Look at our batter! Arman, Ben, look at our batter, it’s green!” He held the bowl and

tilted the bowl towards the direction of Arman and Ben. Another child, Anthony, came over to look and complimented Freddie on how green the batter looked. Emily asked Freddie to go and grab the iPad™ to take photos (Figure 14). Dr. Clegg came by and smiled at him. Freddie, proudly stated, “I told you they would be green!” He took a photo of the batter and started to sing about his Greenies into the iPad™.

Once the batter was green and stirred, Emily poured the green mixture into the red rubber muffin pan. They baked the Greenies at the same time and temperature as the Week 03 brownies. Freddie was excited to use the muffin pan because he envisioned them coming out of the oven like cupcakes. At this point Freddie’s mother showed up to pick him up. Freddie wanted to start the investigation over again, but his mother said they had to go home. He appeared disappointed because due to a prior engagement; he would not be at KC for the following week. His mother suggested they replicate the investigation at home. Emily started to give instructions to his mother on what they did.

Terrible, absolutely terrible, results

When the timer went off, Freddie yelled out, “Times up! Hey, times up!” Emily took the Greenies out of the oven and noted that they did not look very good. Freddie inquired whether they were even done, “Do you think they’re done?” Emily used a thermometer and observed that the middle did not seem to be cooked all the way and that perhaps they should not have used the red rubber muffin pan, “Maybe they needed to be cooked all together.” Freddie wanted to redo the investigation with the same metal baking pan as Week 03 when he returned. Emily also noted, “We used white chocolate, but it didn’t have any cocoa content. It was all just sugar and fat. So

even as we were all mixing it, we noticed it wasn't melding all together right."

Freddie chimed in, "When I get home, I want to make Greenies with pre-made brownie mix. Or buy white chocolate brownie mix." After they sampled the Greenies, which tasted very sugary, hard, and buttery, Freddie recorded into StoryKit (Figure 15), "The end result is terrible, absolutely terrible. Green, but terrible, absolutely terrible."

Analysis of Vignette #2

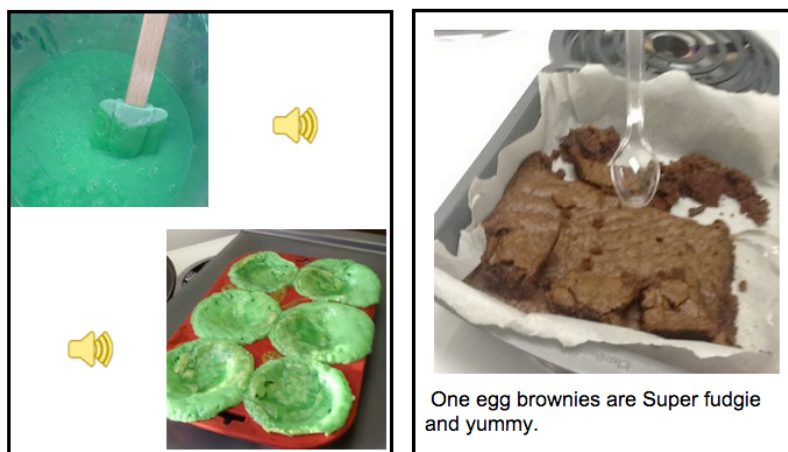
- 1. Freddie had a very impulsive personality . His impulsivity to make the green brownies fast conflicted with Emily's slower methodical inquiry development process. However, Freddie was fine when Emily took responsibilities to make sure they were baking the green brownies.*

Freddie's mother, his teacher (Terrie), and the facilitators of KC all pointed out to me that Freddie tended to be very impulsive in his decision-making practices. Freddie's mother commented that while Freddie was very bright, creative, and perceptive, he had issues with slowing down, paying attention, and listening to other's opinions. One of the traits that his mother and his teacher wanted Freddie to work on was being able to be more patient and take his time in solving a problem. Often, Freddie wanted to follow through on his ideas without contemplating it over or even understanding if others wanted to listen. As well, when others did not want to listen to him, Freddie would grow frustrated and agitated.

In contrast to Freddie's impulsivity, Emily's role as a facilitator slowed him down (*SQ4 – factors*). One likely explanation is that Freddie views the Greenies project as a design engineering task. A problem exists (how to make brownies that are green) and he was attempting to find a solution to this. Freddie's ownership over this

engineering task initially came into conflict with Emily's role. Freddie's goal was simple; he just wanted the brownies green and this may have been more of design activity than a reflective task (*SQ1 – target*). He wanted to start fast, get his hands into the cooking quickly, and not reflect on the investigation at hand; he views this as a trial and error activity. Clegg and Kolodner (2007) describe Freddie's style of learning as a "bricoleur", one that investigates and designs by manipulating objects and letting the product and learning emerge. Bricoleur learners often do not plan extensively and learn through trial and error. In contrast, Emily took on a planner role; she preferred a more reflective and rule-based perspective. Dr. Clegg also had wanted Freddie to have a control for comparison.

Although Freddie had ownership over the product, he did not have full control over the process. Emily attempted to negotiate with Freddie and try to resolve their differences. However, Emily's adult role allowed her to take over some control as she thought she needed to (e.g., slowing down, planning, reflection). As a result, Freddie grew frustrated and often sighed and breathed heavily to show his discontent (*SQ3 – characteristics*). In this sense, children's ownership over the design processes can come into conflict with the goals of science learning processes that require planning and reflection (*SQ3 – characteristics*). First, treating the task as a design rather than inquiry conflicted with the goals of KC. Second, Freddie wanted to only to *do* rather than reflect, and whether or not this *doing* conflicts with the learning goals of KC. And third, the goals of KC can be difficult to be met when the learner frames the task as a design and has strong ownership over that design product, but not the design or inquiry processes.



Week 06 - Greenies

Week 03 - Brownies

Figure 15: The picture above shows a comparison of the Greenies in the red rubber muffin pan (Week 06) to the Brownies in the metal baking pan (Week 03). The top sound icon in the left panel is a song that Freddie sings proudly. The bottom right sound icon is a statement of how “terrible” the Greenies actually taste.

2. *Interventions and reminders did not help Freddie to engage in KC activities.*

Freddie’s ownership over the design target of Greenies was quite strong, however he showed little evidence of ownership over the KC activities. Instead of wanting to slow down to reflect and build an investigation, Freddie’s ownership focused on just making the green brownies. Emily could sense the tension over this issue of Freddie’s impulsivity to quickly start and ownership over the process and design of Greenies. On one hand, she wanted him to have control and investment over the process of making these Greenies. But on the other hand, jumping in too quickly without reflection and planning was antithetical to the norms and values of creating inquiry-based investigations in KC. Emily tried to remind Freddie that they were a team and that she was trying to support his green brownies endeavor (*SQ2 – points*). His teacher commented that Freddie often needed these kinds of interventions, “You

go to him and say, ‘Freddie, I see that you are upset. Let’s remove you from the situation. Breath.’ However, reminding him that she wanted to support his goals did little to get him to want to take on science inquiry practices.

3. *Despite his impulsivity and impatience, Freddie’s ownership of the Greenies helped him stay focus on the investigation.*

Although Freddie’s ownership and impulsive nature may have conflicted with Emily’s reflective process, Freddie did make a great deal of investment into this investigation (*SQ3 – characteristics*). Starting from Week 03, he started to sing about Greenies and shared his idea over SINQ in Week 05. Freddie had put a lot of upfront value in to this project. Even though Freddie exhibited issues of inattention and impulsivity, for the most part, he stayed very focused on this investigation. He rarely wandered away from Emily. When he grew frustrated at Emily, it was mainly due to the fact that he was not allowed to gather the ingredients, turn on the oven, or start the project. I believe his desire to simply take on these menial tasks showed how much he really wanted these Greenies products to be made. He wanted to lead and Emily noted that there were times she took on the follower role with Freddie.

Freddie was also very proud of his Greenies products, despite saying multiple times that they tasted, “terrible” at the end. One turning point for his ownership was Freddie seeing the batter turn green (*SQ2 – points*). When this goal was achieved, he immediately called people over to come take a look at his work and wanted to record the outcome using StoryKit (*SQ3 – characteristics*). Prior to this goal being met, he made no invitations to others to come over. When his goal was achieved, his ownership over the Greenies product became even more public. He wanted to share with the facilitators and learners about the goal he had accomplished. Freddie’s pride

and control gave him the ability to invite others in to share in his joy. In this case, being able to share his product outcomes allowed him to become more motivated to get the green batter into the oven and make observations with StoryKit. Even after his reported failure, Freddie wanted to reattempt making the Greenies.

4. *As Freddie's goals and learning changed, Freddie developed ownership over the failure of Greenies and was able to develop reflective critiques of his own design.*

Similar to Ben's case, Freddie was proud of his mistakes and failures (*SQ1 – target*). After the Greenies were made, I conducted an interview with him on his thoughts about the process. During the interview, I asked him what he thought was an accomplishment he made in KC. He said he was most proud of the “*epic failure*” of the Greenies product. I inquired him more about this.

- Jason: Why was that something to be proud of? Or why is that something you find to be interesting?
- Freddie: Um, because we put the greenies that were suppose to be made like brownies in the muffin things (the red rubber muffin pan). So it makes it like that.
- Jason: So you mentioned about the greenies last time as well. So you'd want to do that all over again, but instead you'd want to put it into the brownie pan, not the muffin pan.
- Freddie: Yeah.

Here, Freddie exhibited pride in his mistakes in two ways. First, he acknowledged that the Greenies was an “*epic failure*” and that although he got the batter green, it might have been a mistake to put them in the muffin pan to cook. Second, Freddie did not want to completely give up on the design of the Greenies; he wanted to redo it again with a brownie pan. One possible explanation is that Freddie's ownership over these Greenies was not ephemeral, but longer lasting (*SQ3 – characteristics*). For instance, in Week 03, he was singing about Greenies into his StoryKit. Even after making them, he was still thinking about them even outside the KC context. In this

case, Freddie could imagine himself redoing the design of the Greenies. To do this, he would have to think more about the problem of why the Greenies did not turn out. I asked him what he thought about this, why the red rubber muffin pan could have been the problem in his investigation.

- Jason: Well what do you think happened to those little muffin tins and the way it came out in the brownie pan?
- Freddie: Um, I think it didn't let it cook, you know from the inside. The heat was being trapped by the outside.
- Jason: So you have thoughts about heat?
- Freddie: Yeah. The brownie pan with like, another brownie pan, when so, wait, so the aluminum's heat gets in it and then it can travel through the thing better because it's bigger on the inside.
- Jason: Oh, so you think that the bigger pan makes it so that the heat goes like that.
- Freddie: Yeah, traps it better.
- Jason: What about the muffin tin, what's going on over there?
- Freddie: Oh it's not traveling fast enough.
- Jason: Oh it's not traveling fast enough. So the heat....
- Freddie: And also the, it's more thin on the outside when it bakes when you try to make brownies in a muffin pan. That's note of that mom! (Points to his mom).
- Jason: (Laughs) Can I ask, how did you come up with that thought? How did you come up with that claim?
- Freddie: Um, cause brownies are made from brownie pans and muffins are made from muffin tins.

Freddie developed various ideas about of the phenomenon (*SQ3 – characteristics*). He is throwing out ideas about blocking the heat (e.g., heat trapped on the outside), spreading the heat (e.g., heat is not traveling in the muffin pan), and the rate of the heat (e.g., traveling fast enough). He explained that the brownie pan spreads the batter out farther, so that the heat from the aluminum can cook the batter more thoroughly.

What I believe is notable was that Freddie did choose to reflect more on the Greenies and why they turned out the way they did than many other learners in KC. Initially, Freddie was quite resistant to plan, think, and slow down with Emily in the

development of the investigation. I suggest that Freddie's ownership and goals of the design may play a part in this. When Freddie's initial cooking goal was to produce the green color, he was not as concerned with the conditions of the cooking. Therefore, slowing down to reflect came into conflict with his personal impulsivity and ownership over the design. When he saw that he made an "epic failure" with the Greenies, one possibility is that he may have realized that he needed to think this out in this interview context (*SQ2 – points*). Here, we could talk about what happened to his Greenies without impeding his cooking processes. Another explanation is that he did not think this through because he does state, "brownies are made from brownie pans and muffins are made from muffin tins" and that he is only basing his thoughts on semantics. However, he does give indication that he has an explanation with heat flow and surface area for the resulting Greenies and is willing to engage in explanation construction.

Nasir (2002) states that as initial goals are met, new learning occurs, which then creates new goals and new learning (goals \leftrightarrow learning). One possibility is that in this case, as Freddie's personal cooking goal of making green brownies was met, he learned that one of the possible issues in the investigation was the red rubber muffin pan. A new goal emerged and Freddie may have started to reflect on why this problem occurred. Initially, Freddie's ownership of the Greenies idea and need to quickly act impeded the reflection process. As Freddie's green goal was met, Freddie's ownership extended toward accepting the epic failure he made, investing into developing a mental model of what might have happened, and creating a new

idea for an investigation. However, it is difficult to say whether his ownership is over the design target of Greenies or also including inquiry in pursuit as well.

7.1.3 Vignette 3: Choice Day #2 – Week 09

Working together to make milkshakes

On Week 09, Anthony and Freddie were going to make milkshakes. Since Freddie had his pick on the Greenies investigation, he followed Anthony's lead on milkshakes investigation. Prior to this investigation, Anthony's mother wanted him to eat healthier. In coming up with an idea for an investigation, Anthony wanted a way to make healthier milkshakes. We worked with Anthony to think about the difference in making milkshakes with vanilla ice cream or lowfat vanilla frozen yogurt. Since Freddie had not worked with Anthony before, we put these two together and I acted as their facilitator.

We started out trying to fill out the goals chart to get Anthony to plan out this project. During this time, we also had them try out different ice creams and frozen yogurts. They gave their thoughts on texture, smoothness, taste, and visual observations. At some point, I wanted them to think about "viscosity" as something to consider in their measurement of this investigation. In particular, both children talked about the smoothness of the milkshake, but both had a hard time describing differences. At this point, I thought a demonstration by the sink could show them differences in how liquids flow. I poked a hole into a cup and had the children measure out the difference in flow rate between milk and water. We called this cup with a hole, "the viscometer." We filled up the viscometer at the same volume of milk and water with a finger covering up the hole. Once I released my finger from the hole,

we measured the time it took for the liquids to drain out. Freddie grew excited and wanted to try yogurt to observe its drain rate. The children began to talk about average time and what the term average meant. They discussed how many trials they should run for the water.

Distractions and divergence

At this point, Anthony and Freddie began to diverge in their goals. Anthony, who was more interested in making the milkshake product, was not keen on watching water and milk flowing out of a cup. Anthony decided to move away from the sink and play with an iPhone™ game. Freddie, on the other hand, was much more interested in observing the drain rate of water out of the cup (Figure 16). However, he also became distracted with his friend Eric and they started to play around with the iPad™. I noticed this disinterest from Anthony and Freddie's distraction and pulled them back to the table to plan out the investigation of the milkshake.

I was able to eventually gather them all together to determine what to do. Anthony did not want to test out the viscosity of the frozen yogurt or ice cream as separate ingredients. He wanted milkshakes. Freddie, slightly focused now, still wanted to examine the viscosity and flow rate of the yogurt. I had to remind both of them of the main investigation at hand and that they needed to make decisions. The two finally began to make choices on how to make the milkshake. They decided to create a vanilla frozen yogurt version first. Anthony and Freddie decided the amount of yogurt, milk, sugar, ice cubes, and other ingredients (Figure 17). While the two were making decisions on Trial 1, Freddie kept asking to try the viscometer again. Anthony, while trying to make Trial 1, kept being distracted by Donna, who was

walking around singing and avoiding stirring her caramel at the stove (see Donna – Chapter 8 or Ben – Chapter 6).



Figure 16: Anthony chose to move away from the sink to play with his iPhone, while Freddie stayed at the sink to check out the draining rate of water. At some point, both children are distracted at the task.

Freddie's excitement over drainage and flow

Once the decisions of the ingredients, quantities, and procedure had taken place, both Freddie and Anthony blended the mixture for Trial 1. After the blending and the tasting, I prepared Trial 1 to go to the sink for use with the viscometer. Freddie, excited at this prospect, went to the sink before I even arrived with the liquids. We began the first time trial of the frozen yogurt milkshake drain into the sink with the viscometer (Figure 18). Freddie grew excited with anticipation and started to yell out, "Pour more! Pour all of it (milkshake) into the cup!" Anthony, with less excitement, stood behind and ducked out. Freddie still stayed at the sink, waiting to use the viscometer on the Trial 1 milkshake. When Anthony walked away, I had to call him back in to help out. I passed the iPad™ to Anthony to have him time the drain rate, while Freddie was ready to release the milkshake into the sink.

Before we tried the milkshake drainage, I let Freddie do a trial run of water in the viscometer and have Anthony practice timing. As he released his finger from the hole, Freddie looked directly at the water flowing out the cup and called out to Anthony.

Oh that's so cool! That's so cool! Anthony, Anthony, Anthony, Anthony, Anthony, Anthony, Anthony (seven times) this is so cool! Anthony, Anthony, Anthony, Anthony! There's a vortex inside. Do you see the vortex?!



Trial 1
1/3 cup low fat vanilla yogurt
1 cup milk
1/8 cup sugar
1 Tspn vanilla
1/4 cup syrup chocolate
2/3 banana - 80 grams
6 ice cubes



Trial 2 more thick
1/8 cup chocolate syrup
1 cup frozen yogurt
1 cup milk
1 Tspn vanilla
1/8 cup sugar
6 cubes ice

Figure 17: Trial 1 and 2 of the milkshakes. Trial 2 is an attempt to make the milkshakes thicker.

After Freddie made this observation, Anthony wandered away again. I had to ask Anthony to come back one more time. Meanwhile, Freddie and Dr. Clegg began to talk about Freddie's observation of buoyancy, holes, and sinking. Once everyone had gathered around the sink, we began to test the Trial 1 milkshakes to observe the drainage rate. However, Anthony was not in the mood to run these trials. Instead, he asked for a break to sit down. I have Anthony go and sit, while I worked with Freddie on testing the drainage rates of the Trial 1 milkshake. We run through three trials of drainage. Freddie, excited at watching all this, stayed at the sink the whole time and

counted off the time. He wanted to calculate the averages of the drainage rate. I called Anthony over to see if he wanted to join us. He looked tired and said that he wanted to read and rest. Eventually, Anthony wanted to remake another set of milkshakes. Freddie, however, wanted to stay at the sink and try something new.

Freddie spends 26 minutes at the sink

During this day, a lot of commotion was going on. Being slightly tired myself, I chose to work with Anthony and let Freddie stay at the sink. I observed him quietly, while Anthony and I prepared the Trial 2 milkshake. For the next 26 minutes on video, Freddie stayed at the sink and ran his own water investigation (Figure 19).

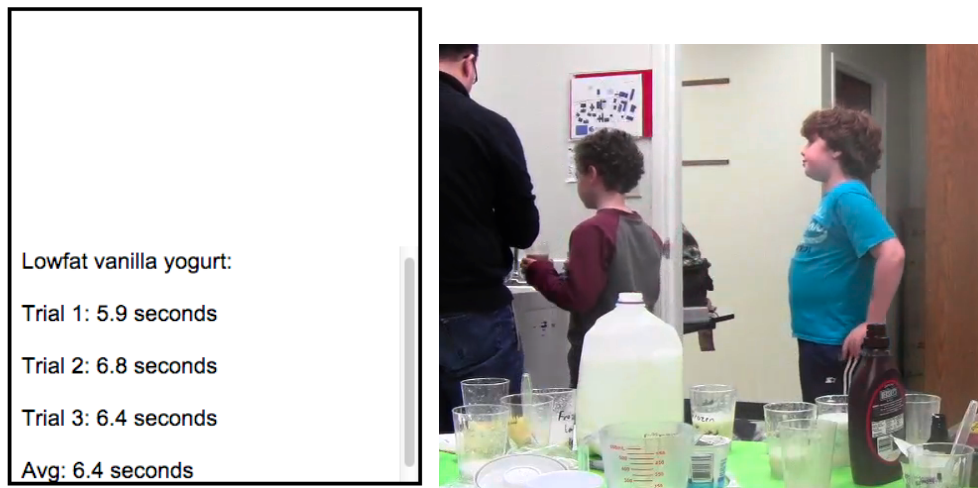


Figure 18: Time trials for draining the Trial 1 milkshakes through a hole in a cup (the viscometer). The second panel shows the position of the children during this time. Anthony stands behind, while Freddie is by the sink.

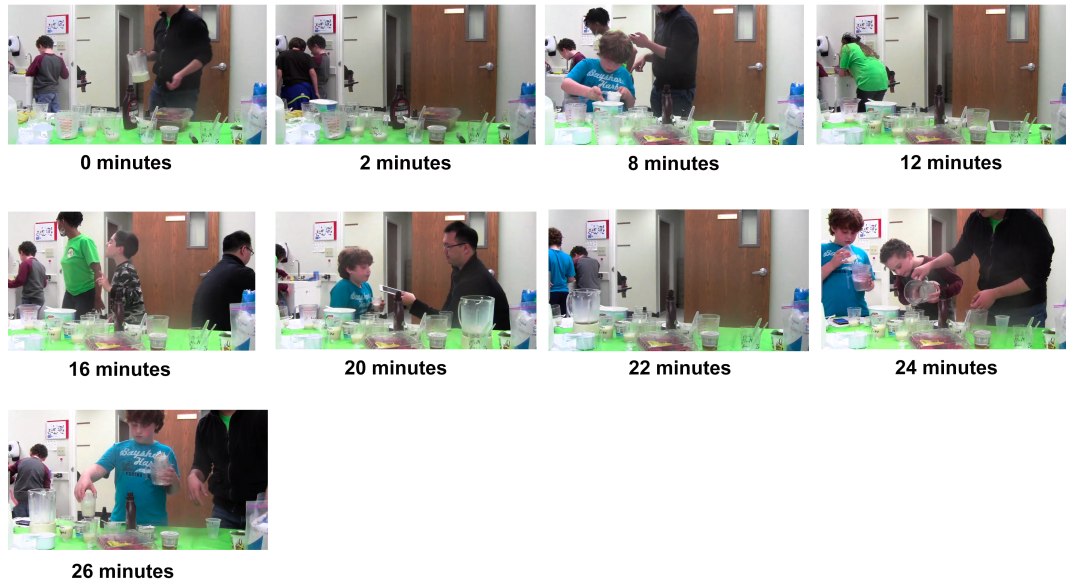


Figure 19: Freddie stays consistently at the sink for 26 minutes.

Starting at 0 minutes in Figure 19, I started to work with Anthony on his next version. Staying at the sink, Freddie again yelled out to Anthony, “Anthony, Anthony, Anthony, this is so cool!” Freddie tapped on Anthony’s hand, “Look, look, look, look, look, look, water is slowly leaking in.” Based on what I believe happened, a pot of water was in the sink and Freddie was either pushing down on a cup with a hole or letting the water leak in. Meanwhile, Anthony, not really interested, walked back to work on his Trial 2 of the milkshake investigation. Around 2 minutes, Freddie called out to Anthony again, “Anthony, Anthony, cool, I got the water trapped.” At this point, Anthony and Ben come over to look at Freddie’s water investigation. Freddie shared, “Water can come in, but not out.” Curious, I walked over and saw this phenomenon. He had submerged a cup into a pot of water. Freddie pulled the cup upside down, forcing the water to stay in the cup (Figure 20). Anthony returned to the

table with me, but Ben stayed behind to look at Freddie's observation of the trapped water.

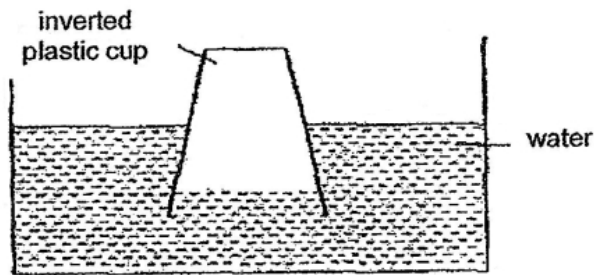


Figure 20: A rendition of what Freddie was doing at the sink.

At this time, I was still working with Anthony on setting up a Trial 2 for his milkshakes. He wanted to make a different milkshake and we would figure out if Trial 2 was more or less thick than Trial 1. We worked together, but Anthony was distracted by Donna's singing and constantly yelled back at her (see Donna – Chapter 8). In the back, Ben was still with Freddie, watching what he was doing at the sink. Eventually Ben left to tend to the caramel investigation. I walked over to check on Freddie. Still focused at the sink, Freddie stated, "I'm seeing how long it takes for the water to fully fill this (cup)."

At 6 minutes in, Freddie returned from the sink to the working area. At this point, I thought he would stay with us and that his time at the sink was over. I asked Freddie if he would help out Anthony by cleaning up. Freddie once again moved back to the sink area and told me that he really just wanted to work at the sink. He even invited me over, "Do you want to help me with this experiment too?" Unfortunately, with Anthony distracted, I replied that I could not help him at this time. Dr. Clegg walked over at 8 minutes to see what Freddie was up to. He commented to her that he

was really alternating back and forth between his own personal investigation and Anthony's milkshake.

Working with Charley and Dr. Clegg

Charley came over around 12 minutes to Freddie to see his water investigation. I was helping out Anthony's milkshake, while making sure he was not getting too mad at a distracted Donna. The room suddenly became more chaotic as Donna ran around, which made Anthony mad. During this time, Freddie stayed quietly at the sink with Charley and started to time the flow of the water from a viscometer. Charley commented that when Freddie submerged the cup into the water, he was observing how long it took for it to fill up from the hole in the bottom. When Freddie filled the cup and measured how long it took to drain he, he found that it longer to drain out than to fill up.

I was somewhat distracted myself with the social behavior that was going on to pay close attention to Charley and Freddie's observation. Charley found Dr. Clegg and explained to her what Freddie was doing, "So we measured how long it took the water to sink up and how long it would take to drain out" (Figure 21).

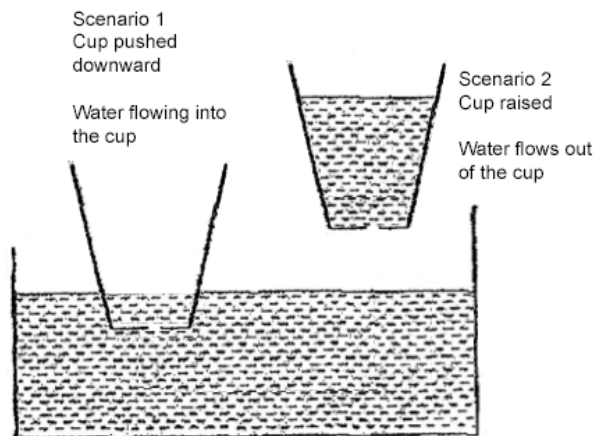


Figure 21: A rendition of Freddie's water investigation setup with Charley.

Around 16 minutes in, Freddie started to talk with Dr. Clegg about his water investigation, "I think I'm doing pretty good." Even with all the noise, movement, and loud sounds, Freddie remained very quiet at the sink. In the video, Freddie raised his cup and watched the flow of water come out. He yelled out, "Oh, this is so cool!" In the background, at 18 minutes, Freddie repeated how he pulled up and down the water and watched the water drain out.

Pouring milkshakes down the drain

I called Freddie over and asked if he would like to run another drain rate trial of the Trial 2 milkshake. At 20 minutes in, I started to bring the Trial 2 milkshakes in for a drain rate test with the viscometer. I asked Anthony if he would like to time the flow. We were both at the sink now in Freddie's space. We started to release the milkshake from the viscometer, when Freddie made another observation, "Look, it's (milkshake) mixing with the water!" He stated to observe how the thinner water started to mix together with the heavier and thicker milkshake. In this observation, Freddie again yelled out how "cool" it was to see this and that "Anthony has GOT to see that!"

At 24 minutes, Freddie came back over to the work area and asked, "This is so cool! Can I have more of the milkshake?" I told him we ran out, but that a little remained. Freddie tapped Anthony's shoulder, and called out, "This is so cool! Anthony, Anthony!" Freddie immediately ran back to the sink with the milkshake at 26 minutes. Freddie poured the last remnants down the drain and exclaimed how

“cool” it was to see this. I asked him, “So why’s that cool?” Freddie excitedly stated, “It’s (milkshake) like taking over the water! It’s like absorbing it!”

Eventually Freddie and Anthony had to go home. At the end of the session, I mentioned to Dr. Clegg what a difficult day managing this group was, “He’s (Anthony) not much into the science, although Freddie seems to be much more interested. He’s more interested on his own personal like investigation.”

Analysis of Vignette #3

1. *Freddie exhibited a strong sense of investment into the water investigation, but did not support the milkshake investigation as much.*

Freddie was very invested and focused at the sink, but not at the milkshake project (*SQ1 – target*). During the first parts of the milkshake activity with Anthony, Freddie acted distracted and inattentive. However, as soon as I introduced Freddie and Anthony to the sink with the viscometers, Freddie became more interested in pursuing his curiosity about water and drain rates (*SQ2 – points*). At the first visit to the sink, Freddie immediately wanted to try to see what the drain rate was of yogurt in the cup. Typically in Choice Day investigations, children tended to pursue the investigation to create a food product they can share and eat. However, Freddie, despite the opportunity in making a milkshake, was not interested in this particular product to taste. Instead, Freddie’s excitement directed towards watching the milkshake flow through hole in the cup (*SQ3 – characteristics*).

One explanation could be that Freddie is genuinely interested in close observations of drainage rates of the milkshake. This interest led into Freddie’s investment into the water investigation at the sink that went on for 26 minutes

straight. At this time, the room became chaotic with Anthony making a Trial 2 milkshake, Donna acting inattentive and distracting Anthony, and a dry caramel burning in the background (see Ben – Chapter 6 or Donna – Chapter 8). Many times in KC, these distractions were a temptation for Freddie, and he would begin to act goofy and contribute to the disruptions. However, even with all the external commotions and with Freddie’s own inattentive personality, he stayed on task with his personal investigation at the sink. He stood the entire 26 minutes, raising and dropping the viscometer to make his own personal observations of the water flow. In terms of investment, Freddie put in a lot of energy, personal time, and focus into this task of observing the water. Freddie had many opportunities he could have walked away from this task, but he chose to stay at the sink until he had to go home. Another explanation is that this activity is a design task similar to Greenies. Here, Freddie came up with several different and new ways to change the flow of water and observe the different outcomes in rates.

In contrast, Freddie did walk away from the milkshakes project and did not make as much of an investment here. He claimed to Dr. Clegg that he was “multitasking” and switching between the two investigations. However, I contend that Freddie put more investment towards the water investigation than the milkshake one. One explanation could be that the milkshake project is Anthony’s creation, Freddie does not have vested interest in it. Freddie did explain before he has done smoothies at home before and that he had always wanted to try a water investigation.

2. *Freddie choices and planning style indicated that he wanted autonomy in his science learning, but help from the facilitators.*

Freddie's water investigation was a completely an unstructured activity that he chose to partake in spontaneously (*SQ3 – characteristics*). Freddie chose to be autonomous and made his own independent decisions for the investigation. He stated in a prior interview that one aspect of KC he would have liked to change was how much interaction the facilitators had. He wanted more action and more hands-on interaction with the cooking, but he also wanted to be in fully in charge and take on responsibilities the facilitators already had. In this case, he chose to be completely in charge of the water investigation. No facilitator was there to guide him (although we did give him the idea for a viscometer); he was completely on his own to make the observations he wanted to. Similar to his Week 06 Greenies investigation, he enacted a bricoleur style of learning (Clegg & Kolodner, 2007). Instead of carefully planning the steps out, Freddie chose to just go to the sink and watch how water interacts with a hole in a cup.

In contrast, I facilitated the milkshake activity with planning. Similar to Emily in Week 06, I also wanted the children to slow down, reflect, and think about what makes milkshakes thick and how we could compare different styles of milkshakes through an investigation. Freddie chose an opposite approach, one that allowed him to start with a simple observation and branch off into more complex interactions and observations. In his water investigation, only the first procedural setup was one that was pre-planned out from the milkshake investigation. The other observations are spontaneously generated open-inquiry tasks that Freddie chose to make on his own.

The facilitators that come and watch him take a follower role. Charley timed his investigation, while Dr. Clegg came and just observed. In these choices, Freddie

took on a leader role and made choices independent of the adults (*SQ3 – characteristics*). In contrast, in the milkshake activity, Freddie was a follower. Since Anthony did not really take charge and just wanted a milkshake, I had the children try to plan out specific steps. Although Freddie did not outwardly say that he did not want to do this, his actions indicated that he much preferred to do his own investigation with the facilitators in the follower role.

3. *Freddie exhibited much pride in his discoveries and called on others to join him in his investigations.*

In contrast to Arman's more quiet personality (Chapter 5), Freddie was much more vocally expressive. On numerous occasions in the water investigation he yelled out, "That's so cool!", "Did you see the vortex?!", and "Look, look, look!". Not only does he yell out to others about the discoveries, on numerous occasions he invited everyone to join in and discover with him (*SQ3 – characteristics*). In his joy, pride, and invitation, I believe Freddie exhibited both an ownership of the space (the sink) and the discoveries (*SQ1 – target*). The sink became his laboratory and he was the one that allowed others to come in. He exhibited selfless ownership in terms of knowledge sharing (Liu & Lin, 2012); instead of keeping the discoveries a secret, he yelled out for others to come and share in his joy. In organizational theory, Lin and Lee (2006) observed that knowledge sharing supported employees' ability to accomplish their goals and those of the larger organization. For Freddie, knowledge sharing increased his pride in his investigation and communicated to the KC group what he had achieved (*SQ3 – characteristics*). This episode is similar to his engineering design of the Greenies; in both he yells for others to come see the

outcome of what he has done. In contrast to the milkshake project, I did not observe him calling people over to taste the milkshakes or to see how thick they were.

7.2 Overall Discussion on Freddie's Ownership of Science Learning

7.2.1 What did Freddie Own?

Design ideas and new discoveries. Freddie's target of ownership started with the design ideas he had. Whether Greenies or water investigations, the ideas he developed were very important to him. One part of the ownership came in from engineering design. Freddie stated that he wanted to make the Greenies "because I want to make brownies that look different." Similar to Ben's case (Chapter 6), Freddie found pride and joy in being able to come up with a design idea no one had before and find a way to enact it out. However, in the water investigation, his observations and discoveries were a target of ownership that he sought after and the processes by which he found them. Two explanations could exist for the water observations and why he was so invested into it. First, the target for the water observations could be based on investigational interests. Prior to the water investigation, Dr. Clegg interviewed Freddie about his interests in science. He stated, "I would like to like look at water up close and stuff like that." and "Well I like water drops when they hit the water. I like looking at that." Unbeknownst to me, Freddie had already an inkling of interest in pursuing a close observation of water and its properties. Another explanation could be that the water observations are similar to an engineering task. Freddie was interested in making new discoveries on his own. He invested much time at the sink to come up with observations on a vortex forming in a cup. Finding creative ways to make the water flow could be a design task for Freddie

similar to the green brownies. Similar to green brownies, he does not provide a causal explanation for his observations, but that he has figured out how to manipulate the conditions for the given flow outcomes.

Personal products and mistakes. While many learners wanted to make food in KC to share with others, Freddie was more interested in making observations and coming up with new ways to create products. Even though the Greenies did not turn out as he had expected, he was proud that he was able to even get the cakes in a green color. Specifically, Freddie even got excited over the mistakes and failures of the Greenies. Similar to Arman and Ben, Freddie expressed that while Greenies were an “epic failure” he stated this was the best accomplishment he made in KC.

Process of implementation. I believe the process of implementing the decisions was a target that Freddie sought through control, investment, and pride. Simply put, Freddie wanted to be in charge of much of decision-making and he wanted the adults mainly as a helper role. In contrast to Arman (Chapter 5), who followed the decision practices of the facilitators, Freddie wanted to be in charge and have the facilitators follow him. In Greenies, Freddie got extremely frustrated when Emily intervened to slow him down and reflect. With his impulsive nature and bricoleur style of acting and reacting, he wanted to quickly go through a process of trial and error, rather than slow down and plan. During the Week 09, Freddie left the milkshake investigation to go on his own to try his own water investigation. When I tried to get Freddie to plan the milkshakes, he seemed disinterested. However, when he was given full autonomy at the sink, he invested most of his time making detailed

observations of water and its interactions. He appeared more upbeat when the facilitators followed his lead (e.g., he directed Charley to time the water flow).

7.2.2 How Does Freddie's Ownership Evolve Over Time?

In this section, I discuss how ownership evolved as Freddie's engagement, alignment, and imagination intersected in KC. Freddie imagined that scientists and investigators are people with autonomous choice and hands-on experiences. This imagination influenced what activities Freddie wanted to engage in and what practices Freddie aligned with. After my analysis on imagination, engagement, and alignment, I examine how Freddie's case study is an example of the tensions and dilemmas that are present in ownership of science learning.

Ownership and Imagination

Freddie's ownership over his investigation was impacted through his imagination of the scientist / investigator, designer / technology expert, and chef roles. The work of imagination allows participants to create connections across boundaries without direct engagement (Wenger, 1998). In Freddie's case, imagination of science influenced how he engaged and aligned his practices and how ownership evolved.

Scientists and investigators. Freddie expressed that he could see himself as a scientist. He stated that, "I like to check things out, look at stuff, study things" and that scientists "look into doing chemistry." As an investigator, Freddie imagined that "they look at things and investigate, um, search around things, and mess with stuff." Investigators tinker and make close observations. From this imagination, to Freddie, working in the kitchen was like working in a lab. Freddie imagined chemists using

chemicals to perform experiments and create new things. Similarly, as a kitchen scientist Freddie also imagined the eggs and flour he was using could be used to make new designs and creations.

Freddie imagined scientists and investigators to 1) mix chemicals together in random ways; 2) serendipitously discover new substances; 3) make close observations; and 4) work in a lab that would be very similar to a kitchen; and 5) trying new things. The fifth point is the most important for Freddie. From his imagination, Freddie took on these imagined practices in KC and home. His mother noted that Freddie often liked “the doing better than the thinking.” If Freddie wanted to be a scientist and investigator, this meant doing a lot of hands-on mixing and making close observations of the final result. In contrast, standing around and planning an investigation was not what he imagined scientists and investigators to do. In this sense, when Emily and I wanted him to slow down and plan, we denied him full control and ownership over his investigation. However, in Week 09 when he had a chance to control and direct his own learning, he appeared more positive and stayed on focus.

Designer and technology expert. Freddie imagined himself as a designer. Although he stated that he was a food designer, he mostly talked about himself as a technology designer. For instance, he imagined working at Apple™ and creating the latest technologies. As a hobby, Freddie drew concept cars and brand new ideas for technologies. He also equated designing the newest computers and technology with designing foods. In this case, instead of wanting to make food that could be perceived as traditional, he wanted to use KC as an outlet for designing of creative food. Similar

to Ben's case (Chapter 7), Freddie wanted to accomplish this task and take on a larger challenge. For Week 06, designing Greenies was the primary goal. He wanted full control into getting this task done and he put in the investment to see it through. Once he was able to see how close he got with the green batter, his pride came out.

Imagination requires opportunities for exploration (Wenger, 1998). When we gave Freddie the chance to enact this imagined role as a designer, he quickly wanted to take ownership of this opportunity and make it his own.

Chef. Freddie stated that while he could imagine himself as a chef, this was not the career direction he wanted to go through. Similar to his view of the scientist, he imagined the chef role as "mixing" concoctions together. Freddie commented that although he wanted to cook at home, his parents would not allow it without supervision. In this role, Freddie imagined the same mixing and autonomy as he had with the scientist. Combining both the imagined view of the scientist and the cook, he had a perception that if you were to embody these roles, you should be able to mix whatever you want without adult supervision. When adults and facilitators attempted to negotiate this role with him, Freddie displayed his frustrations.

Engagement and ownership

Freddie's imagination of the scientist / investigator role and designer role lead him develop certain ways to engage in KC and allow his ownership to evolve and come forth. In his interview, he explained that his role as a designer in KC was to create "yummy" food:

Jason: Do you think of yourself as a designer in Kitchen Chem?
Freddie: Yes.
Jason: Can you talk about that?

Freddie: Hmmm...

Jason: What do you like to design?

Freddie: I like to design computers (says computers in a drawn out fashion). (starts saying "woooooo" to the iPhone).

Jason: Anything else you like to design? Actually, what do you like to design in Kitchen Chem? Maybe that is a better question.

Freddie: Food.

Jason: Food. What kind of food did you like to design?

Freddie: Yummy food.

As a scientist, Freddie thought they this role was meant to do a lot of “chemistry” and “mixing chemicals”.

Jason: Um can you tell me about being a scientist. Like what types of things you did in Kitchen Chem that might have been like a scientist?

Freddie: Look at stuff. Look into doing chemistry. La la la (dismissive).

Jason: What does that mean by doing chemistry? What does that mean to you?

Freddie: Um, like do different chemicals. In this case eggs and flour and stuff.

Jason: Different chemicals. Different eggs and flour.

Freddie: Uh huh.

Jason: What do you mean by chemicals? What are those to you?

Freddie: Um, what I think of is like, how do I describe it? Um, um, yum, um, like, I think of a liquid that has some sort of color and it's dangerous to drink. That has been mixed by a whole bunch of chemicals that have some sort of strange color and is dangerous to drink.

Jason: Do all chemicals have to be dranked [*sic*]?

Freddie: Um, no that's not actually what I think of when I think of chemical.

Jason: Ok, gotcha. You said that, do you think that, flour and eggs are chemicals?

Freddie: Actually, sorta, sorta not.

Jason: Can you talk to me about that?

Freddie: Um, cause you are basically, like how you can mix chemicals to make something that has been made before. Um with flour and eggs, um you can use them to make things that haven't been made before.

As a designer, Freddie saw his role as the creation of food, particularly from scratch.

In the role of a scientist, Freddie acknowledged observation (e.g., “Look at stuff”)

and mixing chemicals. Specifically, Freddie stated that with ordinary objects like “flour and eggs” you can use them “to make things that haven’t been made before.” Both his scientist and designer view are complementary to his target of making green brownies. Here, Freddie would engage in activities that fit within his imagination of scientists, investigators, designers, and cooks. He wanted to make a tasty green brownie that had never been done before.

Ownership and dedication. For Freddie, his level of engagement was a defining aspect of his ownership. Wenger (1998) described engagement and investment as making significant contributions to the pursuit of an enterprise (p. 184). Although he had issues with paying attention and impulsivity, Freddie was highly invested to completing the task of Greenies and his water investigation, but not his partner’s milkshake investigation. Freddie’s investment was reflected in his ability to stay on task and focus in on his own personal activities. For the Greenies project, he took responsibility to watch the time, he stayed with Emily to complete all tasks, and he spent time thinking about why the Greenies did not come the way he had hoped. As for the water investigation, he had deep engagement staying at the sink for 26 minutes with very few interruptions. The sink provided both opportunities either to observe the water or to goof off. Freddie chose to spend his time watching the water carefully and patiently. In his dedication, Freddie enacted his imagination of being a scientist that makes close observations through action and doing. With his increasing engagement and ownership, he imagined himself more as a scientist and investigator.

Ownership and relationships. Freddie was in control of the management of the boundaries of who could come to his discoveries, when they could come, and

what he would show them. Freddie was extremely proud to get the Greenies to come out the color he wanted. As soon as the batter turned green, he called everyone over to come see what he had done. Similarly, Freddie called out whenever a new discovery was made in the water investigation. Here, Freddie controlled whom to invite (e.g., the learners, the facilitators) to build a base of shared experiences with everyone. In this case, his ownership over the green brownies grew as more people could share in this experience with him and complemented him on his achievements.

Alignment and ownership

Wenger (1998) described alignment as “the ability to coordinate perspectives and actions in order to direct energies to a common purpose” (p. 186). As learners align their actions with participants in the community, their participation across communities changes. Alignment allows us to better understand the relationship between engagement and imagination. In Freddie’s case, he had alignment towards the hands-on practices he imagined as a scientist / investigator, but chose not to align with the slower reflective activities that required loss of autonomy.

Coordinating actions between KC and home. Freddie’s ownership of the Greenies project led him to try out new food investigations at home. While I was unable to see if Freddie ever replicated the Greenies project after KC was over, his mother stated that he got more interested in questions about food at home. Eventually, Freddie got into a discussion with her about dipping fruits into chocolate. Based on this conversation, his mother got him several chocolates (e.g., milk, white, and dark) to see how they melted. Similar to Freddie’s melting chocolate in brownies and Greenies, Freddie wanted to isolate and observe just the chocolates alone. Here, his

mother claimed that he took the initiative to ask questions, setup a brief investigation, make observations, and engage in discussion about cocoa content.

- Jason: Can you tell me about Freddie's interest in science and if it's changed in the past couple months?
- Freddie's mom: He's always been interested in science. It hasn't changed in the past few months. Well, I think he's a little more focused on what he wants to do in the kitchen.
- Jason: Can you tell me about that?
- Freddie's mom: He wanted, he got into a discussion about dipping fruit into chocolate. Instead of buying pre-dipped fruit, they decided why not just get a fondue maker. And fruit. He was very focused on how to do the fondue, how to dip the fruit. He did a great job. It didn't turn so well for me. He did it great. He liked the different types of chocolates, what worked best. He was able to, through trial and error, he stayed very focused on task and on hand. I would say he's more focused.
- Jason: Did he ask questions?
- Freddie's mom: Yes.
- Jason: Do you remember what questions he wanted to ask?
- Freddie's mom: Can he use milk chocolate? Can he use white chocolate? Can he use the dark chocolate? Can use up all the dark chocolate? Yes, those questions, but um, it was more, can he use certain materials, certain fruits, certain things, certain food things to dip. Um, and I just said yes. But he had adult supervision. I told him, go ahead.
- Jason: Did he make any predictions or what he thought was going on with the different chocolates?
- Freddie's mom: The white chocolate turned out different than the milk and dark chocolate (Freddie: It tasted different.). Yeah, and I think he made a conclusion that the heat level had to be different for the white chocolate than the others based on how it came out. So, he observed a difference because different type chocolate, he was able to observe and note the difference. So that's an observation he made. (Freddie: We need more chocolate for dipping).
- Jason: Did he ever think about what's behind those differences?
- Freddie's mom: Yes, actually he did, we had a whole discussion of, in which he initiated about why the white chocolate was different than the other chocolates and why it turned out a little different. And um, I think the conclusion of that was something about the heat setting. That white

chocolate doesn't actually have chocolate in it. It's a different chemical makeup.

In this case, engagement and ownership over his Greenies may have extended over towards other investigations beyond KC. He was able to control and make investments into other questions that he had at home. His mother claimed they had discussions about the differences in the chocolate. Interestingly, Freddie made the same observation of the gritty white chocolate in his green brownies as he did in this home investigation. Here, alignment took place as Freddie chose to enact new food investigations in his home kitchen that appeared slightly more structured than his random mixing of liquids in the sink.

Ownership and non-compliance. However, there were times in KC that Freddie did not want to comply with the community practices. Alignment requires specific forms of participation and coordination of perspectives (Wenger, 1998). Freddie wanted complete autonomy and full control over his investigations. On Week 06 Freddie did not want to slow down and reflect with Emily. He wanted to go quickly and try out the green food coloring with little thought or planning. When Emily tried to slow him down to think, he grew quite frustrated. On Week 09, Freddie was not interested in helping Anthony's milkshake investigation. He chose to distance himself away at the sink to enact his own water investigation.

When others negotiated with him, he expressed irritation and annoyance. Wenger (1998) describes alignment as an aspect of power, that is, the power to inspire or demand alignment. In KC, Freddie wanted full ownership and control over his investigations and did not want to align with the slow and reflective practices. He did not want to reconcile the diverging perspectives. Freddie's perspective of science

was based on his home interactions and his imagination of scientists and designers. At home, Freddie commented that his kitchen was his lab and that he would randomly combine ingredients together in his sink to make observations. His view of science was based on a “let’s see what happens when I try new things” approach. Freddie expressed that home science rarely had limitations, “At home you can choose, I can choose whatever I want” and “I like doing my own thing”.

In this case, designing in KC and home came into conflict with Freddie’s ownership, control, and imagination of roles. Freddie wanted to keep his home science perspective of full autonomy and trying new things quickly. He did not willingly want to slow down and plan an investigation. He also did not indicate that scientists plan out their investigation, only that did hands-on and exciting tasks. Freddie commented that KC was “different” than home science. In terms of ownership, Freddie did not like when the facilitators set limits for what he wanted to do. His perception of home science was of freedom of choice and supported his impulsive personality and bricoleur style of learning and engagement. Even in Choice Day, KC had structured guidance through facilitation, which caused tensions and frustrations for Freddie.

School science also conflicted with Freddie’s notion of science. Specifically, Freddie did not think they did science at school.

Freddie: Honestly, we don't do much science at all (in school).
Jason: Can you talk about that?
Freddie: We don't do much science at all.
Jason: What does that mean to you to do science?
Freddie: Um, well, trying new things and stuff.
Jason: Trying new things and stuff.

Freddie: And look up research things that you can choose to do. So we are doing a research project, except like we have to do like a species of bird or you know.

Jason: And how do you, what do you think about those projects?

Freddie: I like doing it, but I wish I could choose whatever I wanted. If you had to do a bird, why can't we do something like T-rex with all the information that's already known about it. And since there's not much information known about it.

From this excerpt, Freddie equated doing science with “trying new things and stuff.”

Trying new things was based on the ability for him to choose whatever he wanted, such as trying to make a green brownie or trying to make water flow in different ways. However, like KC, school provided him choice, but not complete and full freedom. Freddie did agree that in KC, “we get to try new things”, so he may have perceived that he was doing science in KC. Freddie may have initially thought that KC was similar to home in that he got to choose what he wanted to do (e.g., Greenies), but found out that the guidance of the facilitators was more like school science.

7.2.3 Dilemmas in Ownership in Science Learning

Overall, Freddie’s case study reveals that ownership issues in participants can be a source of dilemmas and tensions in science learning. Freddie’s imagination of scientists and impulsive nature came into conflict with aspects of engagement and alignment.

First, Freddie’s ownership over his water investigation clashed with the milkshake project. Multitasking is a very difficult cognitive process for people (e.g., Minear, Brasher, McCurdy, Lewis, & Younggren, 2013). Even though Freddie claimed to be able to multitask and switch between the water investigation and the

milkshake investigation, he was unable to keep full focus on the milkshake project. As a result, when I interviewed Freddie, he was unable to recall many details about the milkshake investigation. Unsurprisingly, Freddie could remember more details about the water investigation.

- Freddie: Um, so basically I took one of the glass like plastic cups, which aren't really glass like you see. I made a crack in the bottom, then filled it with water and saw how long it took for it to leak out.
- Jason: Ok.
- Freddie: Or like I also put in a pan, a pot filled with water and see how long it took to fill up.
- Jason: Ok, so can I ask you why ...
- Freddie: It took a LOOOOONNNNGGGG THHIMMME (drawn out speech).
-
- Jason: What did you find out when you were, when you did that little water experiment?
- Freddie: That glass like plastic cups are very hard to crack.
- Jason: (laughs) That's true.
- Freddie: And that the crack takes 10 minutes for all the water to leak out.

Freddie could recall more about the flow of water and made very specific and keen observations on his own. On his own, he developed a spontaneous set of very creative means to observe water interaction, drainage rates, force, hydrostatic pressure, and solubility of milk in water.

Freddie had very strong ownership over his observations and discoveries about water, as evidenced through his autonomous control, long investment, pride, and invitations to discovery. However, Freddie was also supposed to have stayed with Anthony on his milkshake investigation as his partner. He chose to engage in the activities he wanted and not align towards the ones that did not fit his imagined view of science. His ownership evolved towards conducting his own investigations. As a

facilitator, I initially allowed Freddie to go to the sink to work there because I thought he would have come back to the milkshake project with Anthony. I also observed that Anthony himself was not really into building an investigation over milkshakes.

In this dilemma, I chose to have Freddie stay at the sink to conduct his water investigation, but it did come at a cost. Anthony did not have a partner to work with anymore and Freddie did not spend time working and learning how to slow down, plan, and reflect on an investigation development collaboratively. Wenger (1998) described non-participation as an opportunity for learning. Even for learners, such as Freddie, whose engagement remained peripheral, non-participation can later enable learners towards learning since full participation may not be a goal to start with.

I believe a second dilemma exists, that is, determining the role of facilitator intervention into Freddie's ownership of the water investigation. I could have pushed harder for Freddie to come back and help Anthony with his investigation. A possibility exists that Anthony needed social supports and mutual engagement from his peers to become motivated to take on his milkshake investigation. However, direct intervention may also not have positive effects on Freddie, as seen with his interactions with Emily in Week 06. If I pushed Freddie to come support Anthony's milkshake investigation, it did not mean that Freddie would have come willingly and taken the same ownership he had on his water investigation. Wenger (1998) argues that alignment is unclear when it manifests through authority and submission. Preventing Freddie from developing ownership over his water investigation early on could have created a further negative affect situation between him, adults, and science inquiry learning.

7.3 Summary of Freddie's Ownership of Science Learning

In my examination of these vignettes in Freddie's case study, I contend that Freddie's ownership was affected by his imagination, engagement, and alignment. In imagination, Freddie envisioned that the expert roles of scientist, investigator, chef, and designer all had autonomous choice and hands on experiences. Specifically, Freddie perceived that science was all about trying new things and it was not science if you could not try out new approaches or ideas. Even though he completed engineering design tasks (e.g., Greenies, water manipulation), he perceived this as being science because it was about trying new things. Many of his home experiences in open-inquiry science may have influenced his imagination of science. Freddie was also engaged; this engagement manifested in his dedication to accomplishing his investigations, exuberance of pride, and sharing his discoveries with others. This engagement, however, was limited since he chose not to focus on Anthony's investigation. As his engagement and imagination came together, Freddie wanted full control over his investigations without guidance from the facilitators. He did not want to completely align himself with the investigation practices of KC, such as slowing down to plan an experimental design setup. Freddie had ownership over the design aspects of the activities, but it was his perception and imagination of what science was, rather than the KC community practice of science.

Chapter 8: Donna's Case Study

At the time of this study, Donna was a fifth grade (age 10) female at The Green School. She was the only girl participating in KC for the afterschool implementation. This year was also her first year at The Green School. Donna calls herself a dreamer that identifies with arts, fiction writing, baking, and toy design. A key part of this case study is noting that Donna's mother was a research scientist that had her own lab. I chose these four vignettes (8.1) for this case study on Donna because each section highlights different targets that Donna owns and what was important for her, how she participated in science learning, and how she chose not to participate. In the first vignette (Week 06) I highlight what Donna chooses to focus and ignore (8.1.1). The second and third vignettes are of the same day on Week 07 (8.1.2). The second vignette is an examination of an exchange between Anthony and Donna and how ideas can be stolen. The third vignette focuses on Donna's attention issues in Week 07 (8.1.3). Lastly, the fourth vignette (Week 09) examines Donna's ownership over ideas and end products, but not process and implementation of completing an investigation (8.1.4). From the analysis of these vignettes (8.2), I make the argument that Donna's ownership of science learning stems from her imagination, engagement, and alignment towards science practices she deems "fun" and "exciting".

8.1 Vignettes from Choice Day and Analysis

8.1.1 Vignette 1: Choice Day #1 – Week 06

Coming up with the puffy cakes idea

On Week 05, Donna had decided to try out an idea for “puffy cakes”. In SINQ, she inputted a question, “How do you make things puffy?” In particular, “things” referred to a cake she was thinking about baking. As she started to wonder about puffy cakes, she typed into SINQ the hypothesis, “I think eggs will make it puffy.” She began to ponder more about this idea and developed a brief investigation comparing the amount of eggs in a variation of white cakes. She inputted the following text into SINQ:

- Get enough ingredients for 3 white cakes and a dozen eggs
- Make 1 cake with a lot of eggs in it
- Make another cake with only 1 egg in it
- When their done taste them and see which is the most fluffy and puffy
- Make the last cake with the middle number of eggs

Based on this idea, on Week 06 we had Donna work together with Anthony and Dr. Clegg on coming up with a puffy cakes investigation for Choice Day #1. Dr. Clegg had Anthony and Donna focus on, “What science question will we be able to answer with this (investigation)?” Both children chimed in. Anthony thought, “How many eggs to make it extremely puffy?” while Donna asked, “How many eggs do we need to make it super puffy?” I walked by this group and asked the children, “How do you know what puffy is; what’s your determination of puffy? What does puffy mean?” Donna, tried to convey her thoughts on puffy, answered that puffy meant soft. Dr. Clegg, wanting the children to reflect on the investigation, asked them to think more about what puffy could mean.

Filling out the goals sheet and declaring ownership over ideas

Dr. Clegg had the children read and fill out the KC goals sheet with a series of questions, such as what did they want for taste, texture, and mouthfeel and what did they think would get them to their desired outcomes. She wanted the children to come up with more physical descriptions for their observations. For example, Dr. Clegg asked what did they want the cake to taste like. Donna replied, “White.” Dr. Clegg replied, “But white isn’t a taste, it’s a color. What does white taste like?” Donna explained, “White, I’ve had it before, it tastes not like vanilla, something I can’t really place.” As the children and Dr. Clegg went through the goals sheet, Dr. Clegg came back to this idea of eggs and puffiness. Dr. Clegg asked, “So how do you think the eggs will affect the taste?” Donna believed that the eggs would make the cakes taste “more eggy”. I came by to watch Donna, Anthony, and Dr. Clegg and asked them, “What’s your question?” Dr. Clegg and the group had the following response.

Dr. Clegg:	Our question is, how many eggs does it take to make our cake puffy?
Donna:	Yeah, I put it in.
Anthony	No Donna, I thought up the idea, but then you...
Donna:	<i>I put it on there remember?</i> (pointing to the poster paper of ideas on the board)
Anthony	Yeah.
Dr. Clegg	It’s a team effort. So you want these puffy and soft?

In this excerpt, Donna already started to make claims about the source of the idea to the other participants, while Dr. Clegg wanted them to work as a collaborative team. As the group worked together, they worked on the rest of the goals sheet, exploring mouthfeel, handfeel, smell, and texture. Anthony acted as the recorder for the group and wrote the ideas down on the goals sheet. He would ask Donna questions about what leaveners she wanted to use, what smell should the cakes have,

and what should the cakes look like. Donna engaged, stayed on track, and answered his questions. Specifically, Donna wanted a “tall” cake.

Towards the end of the planning of the cake investigation, Dr. Clegg asked Donna to plan out the steps to create a tall and puffy cake. Donna was still unsure at this point. Dr. Clegg suggested that they start with a cake mix and figure out how different amounts of eggs affect the outcome of puffiness. Dr. Clegg showed some recipe variations the group could try: three whole eggs or four egg whites. Anthony immediately chimed into the conversation, “Let’s do the four egg whites first. Donna, we need the leavener.” Dr. Clegg did not want Anthony to haphazardly start and asked him why he made this decision. Anthony answered, “Because that might be a lot better than the three egg whites.” Donna agreed with Anthony, however, did not provide any further evidence. Dr. Clegg pressed the group more and suggested that they do the egg, oil, and water experiment from Week 03 (Chapter 4) to see how eggs with yolk and egg whites differ in how emulsification would occur in the mixture.

Donna transitioned from engaged to distracted

At this point, the collaboration of the group started to change. Donna, not interested in the experiment, wanted to start baking immediately. However, similar to Freddie’s case study, Dr. Clegg wanted them to slow down and have them try the egg, oil, and water experiment to see if egg whites would produce the same emulsification results as eggs with yolk. Anthony, generally following the direction of the group, went to the pantry to gather materials for the experiment.

While Dr. Clegg and Anthony started putting together the oil, water, and egg (white) experiment, Donna took the iPad™ and started using the drawing tool in

StoryKit to create a picture (Figure 22). While Donna was drawing, Anthony began to help Dr. Clegg setup the egg, oil, and water experiment. Dr. Clegg and Anthony started to talk about the egg whites and what they might do with it. Dr. Clegg noticed that Donna was not participating in the conversation and asked her, “Do you think the egg white is going to do the same thing as the egg yolk?” Donna looked up and briefly mentioned, “Maybe.” Unsatisfied with her response, Dr. Clegg asked Donna if she thought the egg whites would produce the same emulsifying effect as eggs with yolk. Again, briefly looking up from her interaction with StoryKit, Donna tersely stated, “A little.” Dr. Clegg asked Donna if that thought should be put into StoryKit. However, Donna did not hear her and continued to work on the Figure 22 drawing.

Anthony brought over a pot of water and Dr. Clegg had him measure the water out for their brief experiment. Not noticing Donna’s distraction with StoryKit, Dr. Clegg asked if the group wanted to do another variation to compare the results with the original egg. Anthony just liked the egg whites for comparison. Pressing for more details, Dr. Clegg asked, “Well how many eggs do you guys want to use?” Donna completely ignored the question, while Anthony asked, “How many eggs do I want to use?” Not knowing what amount of eggs they should add, Anthony questioned Donna, “Donna, how many eggs?” Donna was still too focused on her drawing in StoryKit. Dr. Clegg pointed to the recipe for the cake mix, “It calls for four egg whites in the recipe.” Anthony replied, “Why don’t we do that?” However, Dr. Clegg still wanted them to do a comparison of different variations for the cake, “So if we use one amount, are we going to be able to tell how many eggs we are going to need to use?”

Meanwhile, Donna continued to not participate in this discussion; she was still fixated on drawing her picture in StoryKit. Anthony noticed her distraction, “Donna, did you hear anything she just said? Well?” Donna simply replied to Anthony, “I don’t know, I’m really focused on this.” At this time Dr. Clegg did not notice Donna’s distraction. She asked Anthony, “So what if we tried different amount of eggs. One we’ll do four (eggs), what’s another we could try?” Anthony, still not sure of the procedures, answered, “Ummm, three? Donna, if we want really really puffy, what could we try?” Donna ignored the question. Anthony, slightly frustrated, asked, “DONNA! Should we do more eggs or less eggs?” Still working on her picture, Donna replied that she was not sure, “Maybe more?” Dr. Clegg, knowing that six eggs were going to provide too much liquid, asked, “Is that too many?” Anthony, who did not want to answer the question, asked Donna, “Donna, is that too many? Six eggs?” Donna did not care for the direction the group moving in, “That sounds like too many, let’s just do four.” Dr. Clegg was not satisfied with her response, “But four is what it (the cake mix recipe) asks for.” Donna quickly changed her answer and then just said, “Five.”



Figure 22: A picture Donna drew in StoryKit in Week 06. Donna was mainly focused drawing this photo for approximately 30 minutes, while Dr. Clegg and Anthony were trying out the egg, oil, and water experiment.

Switching from drawing pictures to separating egg whites

At some point, Dr. Clegg started to show Anthony the arrangement for the oil, eggs, and water experiment. Dr. Clegg suggested to Donna that she help with the investigation, but Donna still wanted to finish what she was doing on the iPad™. While Donna worked on her picture, Anthony started to conduct the eggs, oil, and water experiment. Dr. Clegg, noticing the distraction, asked Donna, “We really need your help with this, Donna.” Dr. Clegg handed one of the first bottles with just the oil and water. Still wanting to finish her picture, Donna shook the bottle with her left hand, while drawing with the iPad™ with her right hand. She did the same with a second bottle of just oil and water. Needing to start the comparison version of the experiment, Dr. Clegg wanted to add in the egg whites. Since Donna was distracted with the iPad™, Dr. Clegg demonstrated to Anthony how to crack the egg and separate the yolks to obtain the egg whites. Dr. Clegg asked Donna if she would switch to another page in StoryKit and take a photo with the iPad™. Donna switched to a new page in StoryKit and took a photo of the demo. Finding new interest in the egg white separation, Donna put the iPad™ down and wanted to learn how to separate the egg whites from the yolks.

The children physically struggled with their hands a bit to learn how to separate the egg whites from the yolk. However, Donna and Anthony both finally appeared focused and excited at this activity. Once the egg whites were separated, Dr.

Clegg wanted them to put them into the bottle of oil and water. They both shook up the oil, egg white, and water mixtures. Donna noted that the egg whites in the bottle become “foamy.” Dr. Clegg asked them to look at the results, “We should look at how much foam it produced.” She asked if the egg whites have just as much foam as the prior experiments with no egg white separation (Chapter 4 - Week 03 of KC).

Frustration within the group dynamics

However, the interest in the egg foam in the mixture began to break down at this point. Both Anthony and Donna wanted to make a cake. Dr. Clegg stated that time was running out and that it would be difficult to start their full investigation this week. Donna observed that other groups had already started making food for their investigation. Dr. Clegg tried to appease them, by asking them to wait to start the full investigation till next week. Donna became frustrated and upset that they would not be making a cake. At this point, the group dynamics started to fall apart as Donna and Anthony found themselves in an argument. Dr. Clegg stated to them “This is why we can’t make cake guys, we’re not focusing.” If they wanted to make a cake, Dr. Clegg wanted them to make a decision about how many eggs they would put in and what kind of variation they would do.” She wanted Anthony and Donna to look at the egg white foam and make a decision based on their observations. However, Anthony retorted, “We just want to make the cake now.”

Noticing the commotion, I walked by to Dr. Clegg’s group and asked Anthony what happened with the bottles of egg whites, oil, and water. Anthony said, “I don’t know, what did happen?” Since there were two bottles, I asked, “Which is which?” Dr. Clegg chided Anthony, “You know what happened; tell him what happened.”

Anthony claimed that all the data was in the pictures and to look at StoryKit. Dr. Clegg stated to the group that if Anthony did not know what was going on, that perhaps they should not make the cake. Donna immediately tried to explain what happened and which bottle had which egg mixture. At this point, I could not determine what the egg white foam was without a control comparison. I inquired, “You don’t have another four egg like comparison to say if it’s foaming up better or not.”

Anthony just wanted to make a cake with three eggs, while Donna wanted “regular”, which meant the four white eggs found in an original cake recipe on the table. Anthony disagreed, “But I don’t want to do that.” Donna and Anthony began to argue over three eggs versus four egg whites. The argument got intense enough that Donna cried out, “*I don’t want to work with him anymore. It was MY idea in the first place.*” Dr. Clegg tried to calm the conflict down, “So look, when we work, we need to work as a team. Ok, that means that every time that, I don’t always get my way, Anthony doesn’t always get his way. And Donna doesn’t always get her way. But we have to work as a team way.” Donna sternly stated to Anthony, “Fine. You can read the first one (line of the recipe), I’ll read the second one.” The children eventually calmed down enough that they took turns reading the recipe and eventually decide to do a four egg white recipe.

Analysis of Vignette #1

1. *Donna’s ownership over the idea and goal of making a cake does not translate to ownership of science learning.*

On Week 06, Donna came into the session with her puffy cakes idea, specifically an investigation to look at how the amount and type of egg (yolk, no yolk) could affect the rise and leavening of the cake. Here, her target of ownership was the idea itself (*SQI – target*). Donna wanted to let others know this idea was under her possession. First, when Anthony stated, “No Donna, I thought of the idea”, Donna immediately reminded Anthony that the origin of the idea came from her. Second, when Donna and Anthony began to argue, she yelled out, “It was my idea in the first place!” and declared how unfair it was that Anthony would even be given a chance to make a decision she did not want. Donna used possession of the idea to remind others about her control over the investigation and that others should not forget this.

However, ownership of the initial design idea did not mean that she had ownership over all parts of the investigation. Although the idea could have been developed into an investigation, this was not Donna’s goal or intention. Donna wanted a “puffy” cake, but she does not show interest in trying to understand how egg whites might affect the puffiness of the cake and does not want to partake in the experimentation process. For instance, as soon as Dr. Clegg wanted her to try the egg, oil, and water experiment to determine the number and type of egg mixture they should use, she went into StoryKit and began to draw her picture (Figure 22). As she drew, she generally ignored the group and did not pay attention. When Anthony asked her for choices into how many eggs to add into the experiment, she gave short and brief answers with little evidence to back up her choices. Here, Donna does not indicate that she has ownership over the inquiry process. She was not interested in

controlling the experiment and making an investment into understanding how the egg whites might contribute to the puffiness of the cake. She might perceive the experiment activity as not related towards the larger goal of making a cake.

In contrast, making the cake product itself was a main target for Donna (*SQ1 – target*). Although Donna’s puffy cake idea could be used as an investigation, this was not Donna’s intention. Donna became upset when Dr. Clegg informed her that they might not have enough time to bake that day (*SQ3 – characteristics*). She wanted to have control over making the cakes and share them with family and friends to show off. As soon as Dr. Clegg started teaching Anthony how to separate the eggs, she put down the iPad™ and joined them in this process (*SQ2 – process*). Taking control of learning how to separate egg whites was another target (*SQ1 – target*), which lends itself towards cooking processes, as opposed to science inquiry. The only time Donna was able to talk about the experiment was when Dr. Clegg asked why they should make a cake if they did not understand the process of the investigation. Donna’s most fierce argument with Anthony was not about the direction of the inquiry, but about control over what egg choice (three eggs vs. four egg whites) to add into the cake.

2. *Dr. Clegg wanted Donna to slow down, while Donna wanted to just make a cake. To resist, Donna switches her ownership towards another activity as a form of non-participation.*

Like other facilitators, Dr. Clegg did not want the children to haphazardly make decisions without evidence-based reasoning. She wanted the children to slow down and plan their cooking investigations through evidence-based reasoning from experiments and comparisons. However, similar to Freddie (Chapter 7), I argue that

Donna was a bricoleur learner (Clegg & Kolodner, 2007) that wanted to quickly go through the cooking process, rather than plan an investigation out. Donna did initially start out engaged and aligned with the practices of KC. Dr. Clegg had her group go through the planning process through the goals sheet. Donna went through all the parts, including taste, mouthfeel, and texture, and what she thought might affect those outcomes. However, as soon as Dr. Clegg introduced the eggs, oil, and water experiment, Donna switched tasks and created her StoryKit picture (*SQ2 – points*).

In contrast to Freddie, who grew very impatient with the facilitator's control over the project, Donna took a more passive route. When she did not want to participate in the experiment, instead of arguing for control, she switched to another activity that took her attention away. In this case, her ownership over the process shifted from coming up with the design idea and thinking about the idea, towards an activity in KC she could better identify with (*SQ3 – characteristics*). When she saw that the activity switched to separating egg whites, I believe she perceived this would fulfill her goal of making a cake better than the experimental setup Dr. Clegg was setting up. As a result, Donna changed her activity and put the StoryKit picture away (*SQ2 – points*).

8.1.2 Vignette 2: Choice Day #1 – Week 07 part I

Coming up with an idea: Puffles

For this second SINQ session (Clegg et al., 2013), Donna worked together with me as her facilitator. Sitting next to Donna and me were Anthony and Dr. Clegg. In this exchange, the physical positions of the interlocutors are important to note.

From left to right, the group was seated next to each other as follows: Donna (child), Jason (adult), Anthony (child), and Tammy (adult) (Figure 23).



Figure 23: The position of the interlocutors in the Week 07 Vignette Part I exchange.

As we began planning for Choice Day, Anthony did not appear to know what to do to start developing a food investigation idea in SINQ. Dr. Clegg prompted him to refer to other questions previously entered into SINQ for ideas. Meanwhile, I was collaborating with Donna who immediately had an idea of what to make for Choice Day, exclaiming “PUFFLES!” I started to inquire Donna about Puffles to refine her idea to create a question to share into SINQ. Donna replied, “Ok, so they are these little balls of, ah, that are like cupcakes and they, you cover them with like some kind of hard sugar.”

As Donna excitedly detailed her “Puffles” to me, the video recording showed that Anthony was glancing over Donna’s direction. When Dr. Clegg asked Anthony if any of the prior food questions inspired him, Anthony replied, “Let’s see, what do I want to make to *compare to Donna’s*?” Instead of referring to the prior SINQ entries for a Choice Day idea, Anthony chose to refer to Donna’s idea. Meanwhile, Donna stopped typing her question into SINQ to discuss more with me. As she talked about the hard sugar coating, Anthony responded to Tammy, “I like candy.” Tammy

prompted him to transform his thoughts about candy into a testable question. At this same moment, Donna repeated to Jason that her question was about “a hard sugar.” Hearing this, Anthony quickly came up with the question, “Why are most candies hard?” At this point, Donna’s hard sugar inquiry and Anthony’s hard candies question were distinct enough that the children did not notice. The SINQ analytics data indicated that Anthony’s question, “Why are candies hard?” was recorded before Donna’s “How do you make a hard sugar?”

Stealing ideas and accusations

Further into our conversation, Donna and I discussed how the Puffles coating would be like “jawbreakers,” with Anthony again listening into our conversation. Tammy, who did not hear our conversation, asked Anthony, “Now what kind of project do we need to do to answer that question?” Anthony replied, “Well we could, we could make kind of like a *jawbreaker* thing and like put...” The moment Anthony said “jawbreaker”, Donna immediately and angrily yelled to Anthony, “*You just take it from me!*” Almost instantly, Anthony retorted, “No, I’m not!” and continued to tell Tammy how he would make a candy in the same type of hard sugar coating. Donna, in complete frustration, told me, “I never should have said it out loud!” I tried to assuage her, but she irritably folded her arms inward and stated, “Puffles was my idea! Then why is he stealing it?” At this moment, I helped her move away from the situation, leading her outside the classroom to devise a new question.

When we arrived to our new location in the classroom, Donna was still upset, “He just stole my great idea.” I tried to explain to her that her idea and his idea were not exactly the same. I tried to compromise with her; I asked her if she would be

willing to create the opposite scenario, a hard middle with a soft inside. Frustrated, she exclaimed, “I can’t do it (the Puffles idea) now!” Because she expressed such anger, I had to walk her away to an even more quiet location in the hallway where Anthony could not hear her ideas and frustrations.

Analysis of Vignette #2

1. Public vs. Private ideas

Donna and Anthony, while close friends in school, often could not work together in close physical proximity. In the interviews, Donna called herself a “designer” and often had many ideas she wanted to develop. However, Anthony was at a different stage of question development than Donna. Because he was absent on Week 05, he had never used SINQ before and had not developed an investigation question on his own. Because Anthony and Donna were coming at the SINQ activity from two different levels of understanding, their physical proximity may have conflicted with what each of them needed (*SQ4 – factors*). In this vignette, an interesting difference between the face-to-face and virtual environment is highlighted. Having an idea up-voted requires others to see and like your idea; this can be a form of social currency.

But, for Donna, being face-to-face with another learner meant giving access to her idea verbally before it was attributed to her (*SQ2 – points*). This situation was problematic and led to conflict over authorship and ownership over the idea (*SQ1 – target*). However, this does not suggest that Donna did not want to interact with others’ ideas. In the beginning of this session, Donna was browsing prior questions that had been written in the first SINQ session (Week 06). Because both learners were

at different points of ideation, in addition to learning new norms for participation, physically separating them may have allowed Donna to have authorship over her own idea first and then refine her idea while considering others' SINQ contributions. Conversely, Anthony may have been less tempted to overhear Donna's idea so he could instead focus on existing questions in SINQ to help inspire his own questions.

2. *Stealing ideas as a form of stealing identity*

Weeks after the incident happened, I conducted an interview with Donna and she reflected on the "stealing" episode. During the interview, Donna spontaneously brought up something she was "really mad about" in KC. She expressed such sensitivity about the topic that she wanted me to close the door of the interview room for privacy. Donna started to explain why she expressed such anger at the stealing of the idea. Her ownership came out about the idea (*SQ1 – target*); she expressed that she was really proud of the Puffles idea and spent great investment in coming up with the idea (*SQ3 – characteristics*), but she still had lingering negative affect over the incident:

Made me feel really mistreated, like, they didn't think that it, it was mine. And when I heard him talking about it, just after I said it, I said why did you steal my idea and he said, I didn't steal your idea. Oh I just came up with this.

I wanted to know more about what Donna meant by "stealing your idea" and how people steal ideas. She explained, "It's like they tell it to somebody else and they like they make it theirs." After the idea was overheard, the idea theft became worse credit was not appropriately attributed to the author.

In this case, Donna perceived that stealing the idea was in some way, a form of identity theft. For instance, after the angry exchange, Donna began to sign all of

her SINQ entries under an alias (“the DESTROYER”), so that Anthony and others would not recognize her contributions (*SQ4 – factors*). In this case, Donna had to assume an alias and could no longer be open about her ideas. In contrast with Freddie (Chapter 7), he was extremely open about his design ideas on Greenies. For Donna, her ideas stem from her view of herself as a designer. In an interview, she imagined herself creating new toys and candies for other children. When the design idea was stolen and credit was not given to Donna, it was as though the person stealing the idea took a part of her identity as a designer. These design ideas that Donna had were deeply rooted as part of who she was and she had a difficulties sharing them with others.

8.1.3 Vignette 3: Choice Day #1 – Week 07 part II

Dense cakes instead of puffy cakes

Originally, we had expected Donna would work with Anthony on the puffy cakes investigation from Week 06. However, between Weeks 06 and 07, we found out that Donna’s parents wanted to restrict her intake of gluten. Because of this request, we had to make sure all products Donna could eat had to be gluten-free. We initially wanted Donna to use a gluten-free cake mix and for Anthony to use another cake mix and have them compare the puffiness of the cakes. However, after their argument over the Puffles idea, we decided to have Donna work with me on the gluten-free mix and have Anthony work separately with Dr. Clegg using the other cake mix.

After we returned from working with SINQ, I ask Donna if we would still be investigating a cake that was puffy. To my surprise, she now wanted a “dense” cake. I

asked her how she was going to make the cake dense. She asked me what I thought. I suggested that her original plan was fine and that examining how different egg preparations changed the outcome of the recipe would still work for a dense cake investigation. Donna simply answered, “ok”. Since she agreed with this suggestion, I had her choose the ingredients and materials that we needed for this investigation.

While we prepared for this investigation, Donna already had ideas she wanted to try, such as adding honey, vanilla, and white chocolate to her cake. I told her we could add those elements in later. My main concern was having her setup an investigation that she could make comparisons with. Based on her prior SINQ entries, I suggested to Donna that we could do three egg preparations: eggs normal (yolk + egg white), egg white alone, and the yolk alone. A fourth cake with just the batter alone (no eggs) would serve as the control since this was what the original recipe had indicated. I checked with Donna to see if this investigation setup would work with her. She nodded and agreed with this procedure. I recommended to Donna to record our investigation with StoryKit. Donna stated she did not think she was very good at typing; we decided to just interview her throughout this process. Meanwhile, Donna showed me that she could now crack an egg and separate the egg whites, a cooking technique that she was very proud of.

Engaged in making the cakes

Donna was excited to make the cakes and started recording into StoryKit a picture of the two of us together. She immediately wanted to make the gluten-free batter. For the investigation, we would pour the gluten-free batter into four ramekins that contained a premeasured amount of the normal egg, the isolated egg white, the

isolated egg yolk, and a ramekin with no eggs. From this, we determined the physical differences in the cakes. As we made the batter, using StoryKit, I interviewed Donna to ask her, “What’s our question today for this experiment?” Donna answered, “How do you make the cake dense?” Curiously I asked her, “What does dense mean?” Donna thought about dense, not in terms of mass or volume measurements, but on taste, “Dense means it’s thin, but it’s got a, you can taste all the good flavors.” I wanted to know if she had a prediction for this investigation. Donna thought that the yolk version would create the densest cake, “Because when I made the puffy cake (Week 06), we used a whole (egg) and it was so puffy. Actually, it may have been the egg white that made it puffy. So I think the egg yolk will make it enough and good.”

As we continued to work together, Donna actively participated by preparing the batter. We needed to decide on how much of the eggs we should use in the ramekins (one tablespoon) and how much of the mixture should be poured in (one-third cup). As we poured in the mixture into the ramekins, Donna noticed that the egg white mixture was the easiest to mix, while the isolated yolk was the hardest to mix. I asked, based on her current observation, if her prediction about the isolated yolk being the densest would still hold true. Donna indicated that her original prediction would hold true. I asked her what she thought about the normal egg as the control. She explained that we used a control to “test” the rest and perhaps the control was already, “dense by itself.”

Disengaged and distracted in measuring

Once the batter was mixed with the three different types of eggs in the ramekins, we placed the mixtures and the control into the oven. After the four cakes

were baked, I brought them over to Donna. However, Donna's attention issues became apparent towards the end. She started to become distracted from her friends. For instance, I tried to remind her about the investigation by asking her to help me make measurements of the cakes. I asked Donna to prop up a ruler and I took photos with StoryKit. We measured out the egg normal (5 cm), egg white (4.75 cm height), the yolk (3.5 cm height), and the control no eggs (4 cm). We also noticed that each of the cakes had different yellow hues based on the eggs added in. During this time, Anthony would come by with the iPad™ and tried to show Donna a video he was watching. Donna noted that she was distracted by the noise and said she was tired of the measuring activity. I had to ask Anthony to turn off the video to keep Donna on task.

In order to support her attention and interest, I had her begin to taste some of the cakes. I had Donna try the control cake and she expressed enjoyment tasting it. She tried the yolk version and the egg white version and again, she made sounds of enjoyment. However, she indicated that she did not enjoy the normal egg version. Donna said her favorites were the "yolk" and the "egg white" since "they just have more taste, but the yolk seems denser." Donna commented that the yolk version seemed denser because, "like the full taste comes out, it comes gushing at me." Similarly, she stated the egg white version was also denser because, "it was dense and the flavor just came at me." Again, Donna uses taste as a way to indicate density, as opposed to a mass to volume ratio. Donna also used descriptive terms, such as "that one (control) was too grainy" and "this one (control) is a little like... scratchiest."

She also started pressing down on the cakes with her fingers to see which how it springs back up.

However, as we continued with the measurements and observations of the cakes, I observed that Donna appeared even more distracted. She looked tired and wanted to go play with an iPad™. Although other children and facilitators started to come and ask Donna questions about her cakes, Donna did not seem interested that people were paying attention to her investigation. Instead, she got found an app on the iPad™ and started ignoring everyone. I asked one final question to get her to wrap up her investigation. I inquired Donna, “so which one is the most dense?” Again, she thought the egg white was the densest, but had difficulties articulating why. She thought the control and egg yolk version was “too grainey” and that the egg white helped to get the flavor out. After all these observations were complete, I asked her, “So what do you think the egg is doing to all of these things right not that’s different than the control?” Donna licked her fingers and shrugged her shoulders, indicating she did not have anything to say.

Analysis of Vignette #3

1. One aspect of Donna’s ownership of learning was her attention issue.

Similar to other KC learners, attention and distraction was a significant personal factor that influenced Donna’s ownership of learning (*SQ4 – factors*). In my interviews with Donna’s mother and her teacher (Terrie), both adults brought up Donna’s attention issues. Her teacher, Terrie, expressed that Donna had difficulties sustaining long periods of attention with a lot of external distractions around (e.g., loud noises, friends). Donna’s mother called her “a dreamer” that “could dream and

drift away if she's not put back.” Donna’s ownership over the cooking task waxed and waned as her attention shifted back and forth. Early in the investigation, Donna wanted to make investments into the cooking (*SQ2 – points*). Here, she wanted to own the cooking process of the investigation (*SQ1 – target*) through making investments. She participated fully in getting materials for the batter, preparing the batter, and coming up with predictions of what she thought would happen. However, her attention diminished towards the end of the activity. For Donna, she got excited in the beginning developing ideas for investigations (e.g., how to eggs make cakes puffy / dense), but had difficulties pursuing the answers to her questions.

Towards the end, as her attention lost focus, she did not want to make measurements and wanted to interact with the iPad™. Based on her mother’s advice, I attempted to remind Donna about her responsibilities. Donna got excited once she could taste her cakes (*SQ2 – points*), but she was not interested in attempting to think about how the eggs might have caused the differences she observed in taste. In this case, Donna was not invested in pursuing a deeper understanding of how eggs could act as leaveners for the cakes (*SQ3 – characteristics*).

2. *Another aspect of ownership in learning is how Donna imagined herself and the roles that she could take on.*

Donna’s issues with attention can explain when her ownership waxes and wans (strong start, more difficulty in finishing), but attention alone does not provide the full story of what she chooses to pursue in the activity. In my interviews with Donna, she had much to say about the imagined roles of a scientist, chef, and

designer. I believe that Donna's imagination of roles allows a fuller picture of how her ownership develops (or not develops) in the investigation.

Donna had a very close connection to scientists at home. As mentioned before, Donna's mother worked as a research scientist in allergies. When Donna had to come to her mother's lab, her mother would often give Donna small experiment kits and let her interact with the equipment. Her mother also led a research lab group that often interacted with Donna through social event or lab interactions. Due to these many factors, Donna had much to say about her imagination of scientists (*SQ4 – factors*). Donna imagined that scientists had a lot of hands-on experience mixing chemicals together. For instance, Donna recalled a time in her mother's lab, "We filled a little tube with a bunch of little um, like with some microbes and stuff. And we put it in this thing that shook them around and when I looked back at it, it completely changed color." She talked excitedly about how she imagined scientists conducting these experiments. She imagined that as scientists would "mix stuff" they would inevitably "find cures and discover new things, stuff like that."

More important to Donna was her view on being a chef and a designer. She wanted to be a "candy maker", "pastry chef", and a "toy designer". Donna identified herself a dreamer, someone that could develop new ideas that could come to fruition and completion. In her imagination, Donna prioritized designing and cooking above science inquiry. For example, when I inquired Donna about her career choices, cooking and designing careers were always high on her list of preferences, but scientists always ended up on the bottom of her list. Donna indicated that designing and cooking were activities that made her happy; she also thought that her products

could also make others happy as well. At home, cooking and designing always gave her a sense of joy with her family (*SQ4 – factors*). In the home and her mother's lab, there was no careful measuring or planning. Instead like the bricoleur style of learning (Clegg & Kolodner, 2007), cooking and designing was meant to be free of restrictions and guidelines.

In examining this vignette, the first half of the activity was focused on the cooking and the designing of the cakes. Although there is an investigation design component to it, Donna appeared fine having me set up the investigation. Here, Donna lets me take the lead, instead of her taking it. At this time, everything was hands-on, such as mixing the batter, cracking the eggs, and setting up the ramekins. Here, both her more focused attention and imagination of roles came together. Her ownership over the cooking aspects of the activity appeared more robust (*SQ3 – characteristics*). However, by the second half of the investigation, her attention waned and the activities in the shifted away from her imagined role. At this point, her ownership over the activity started to decrease towards the end (*SQ2 – points*). Instead of the hands-on mixing of science and the cooking, I asked her to make careful measurements and think more critically about why the eggs might have leavened the cakes. Since her attention was already decreasing and the activities did not fit into what she imagined scientists, cooks, and designers do, Donna became distracted towards the end. Her inattentive nature and her imagined views of cooks, designers, and scientists gave way to a situation in which she chose not to participate and invest into her investigation anymore (*SQ3 – characteristics*).

8.1.4 Vignette 4: Choice Day #2 – Week 09

As I wrote in Ben's case study (Chapter 7), Donna created the idea for caramel. Since I have written this vignette for Ben's interaction, for this section I will emphasize the highlights of Donna's interaction. I will mainly examine Donna's participation and investments, choices, and expressions of pride and possession.

Coming up with the caramel idea

Donna came up with the caramel idea on Week 07 after her argument with Anthony. She posted into SING, "How do I make caramel! -THE DESTROYER". Her pseudonym, THE DESTROYER, was Donna's way of making sure Anthony (and possibly other learners) would not steal this idea from her. Donna and Ben worked together with the facilitators Emily and Elizabeth. The facilitators wanted the children to watch a video on the iPad™ on the production and science of making caramels. After the children watched the YouTube™ video, each of them became responsible for two separate trials. As mentioned before, Version 1 was a dry caramel made with sugar and butter. Ben took responsibility for this version. Version 2 was a wet caramel with corn syrup, cream, butter, and sugar. Donna was the one that was in charge of this one. The goal of the investigation was to compare the two versions and come to explore how a "dry" caramel mixture compared to a "wet" caramel.

In preparation for Versions 1 and 2, Donna was invested into preparing her version of the caramel. As Elizabeth read off the recipe, Donna took responsibility in measuring and pouring in the corn syrup and the heavy cream. Emily also helped to add the butter in. At this time, all members acted collaboratively to get the versions prepared. Once the participants created the mixtures, both Versions 1 and 2 went to

the stove to cook. At this point, Donna became very excited about the caramel, but also got very irritated at the process. As mentioned before in Chapter 6, the caramel took a long time to stir and congeal. Elizabeth described Donna as “getting a little antsy” and impatient with the stirring. Donna was also not as interested as Ben was in conversing about the caramels or making observations.

Burning the dry caramel

When the Version 1 dry caramel burned, Donna became upset at the result. For instance, Elizabeth noted, “She really got upset that it stunk and that it was black.” In contrast to Ben, who was curious and excited over the burned caramel, Donna was unhappy and annoyed at the final product. Elizabeth commented, “Donna’s all about the end product.” While she did get excited over tapping the burned caramel with her hands and seeing how brittle it was, she immediately wanted it thrown away (e.g., “Put it in the trashcan!”) and attributed the ownership of the burned caramel towards Ben (e.g., “It’s yours, you are the one who started it!”). After the caramel burned, Donna started leaving the stove area and walking around distracted.

Growing bored and moving away from the stove

When Version 2 was on the stove, Donna again grew bored and tired of stirring. Even though Version 2 was the mixture she made to compare to Version 1, she did not want to invest into the process of making it. Instead, Donna would stir for a little bit and then leave the stirring to the rest of the group. Elizabeth noted that working with Donna was like a “rollercoaster” going up and down in her attention

and investment. In contrast to Freddie's case study (Chapter 7), in which he stood at the sink for 26 minutes straight running his water investigation, Donna was constantly moving back and forth across the room while her Version 2 caramel was being made. After only about three minutes of stirring, she would leave, start to sing, and interrupt her friend, Anthony. Meanwhile during this time, Ben was having conversations with Emily and Elizabeth about how the wet caramels developed their brown color at certain temperature due to the proteins in the cream and why the dry caramel may have burned due to the rapid increase in temperature.

Elizabeth noted that even though Version 2 was Donna's responsibility, she did not get a sense that Donna wanted to do the tedious work. Donna wanted to have the idea of creating caramels, but was not willing to be invested enough to do the work required to see it through completion. Elizabeth commented:

Stirring is boring work, but it is still what you need to do before you get to the nice caramel. It's tedious and she just didn't want to, she just didn't want to do that. Um, so she lost out on some of our (scientific) conversations.

I asked Elizabeth why the facilitators did not encourage her to stay and take responsibility for her part of the investigation. Elizabeth replied that the group wanted to finish this part of their investigation on their own. Ben had already started taking over her part of the stirring and was engaged in the process and the conversations with the facilitators. They simply assumed that Donna just needed a short break. However, Elizabeth did not anticipate that Donna would not be willing to take on the tedious tasks.

Donna took ownership of the end product

When Version 2 was completed, Donna switched over to take on control and possession of the end product. She began to tell others in the room, “*Try this, it’s my caramel. What do you think?*” As the Version 2 caramel hardened, Donna started staying around the cooking area and helping to cut the candy into smaller pieces. She even started to tell others to not eat too much of it. Donna became excited about the product, even though she did not make full investments into stirring and the conversations. Version 3 of the caramel was also a mixture that Donna wanted to try. As mentioned before, Version 3 was a caramel mixture of corn syrup, cream, jaggary sugar, honey, vanilla, and chocolate. This version was an unstructured mixture that Donna had wanted to create. Like a bricoleur cook, Donna wanted to just mix everything together and see what would happen. Versions 1 and 2 were more structured to understand the difference how the liquid solutions of cream and corn syrup made a difference to the butter and sugar in caramel.

No one understands the dreamer

Similar to Version 2, Donna went back into a distracted state when Version 3 was placed on the stove to cook. Even though this was a mixture she prepared, Donna was unwilling to invest into the slow cooking process. Again, Ben took over this version of the caramel because he was interested in seeing this through. Version 3 was a much softer caramel. Ben started to develop his own hypotheses about the possibility that the added chocolate and honey may have made Version 3 softer. In contrast, Donna again went around the room singing and at this point irritating Anthony greatly. Dr. Clegg eventually had to tell Donna, “If you are going to sing, go

outside. Don't sing." Donna became frustrated that she went outside to cool down. She complained later to me that she was a dreamer that no one understood.

Analysis of Vignette #4

1. For Donna, she had stronger ownership over design ideas and end product

Within this vignette, I argue that Donna's ownership over the investigation was fragmented; she does not fully own all aspects of the investigation (*SQ3 – characteristics*). Instead, Donna chose to make investments into certain targets, while ignoring other aspects. I will categorize Donna's fragmentation as stronger ownership and weak ownership.

Donna's stronger ownership focused on the initial design idea for the activity and the end product (*SQ1 – target*). In contrast to Arman (Chapter 5), who was very quiet and hard to interpret, Donna was very vocal and made clear to others what targets she owned (*SQ3 – characteristics*). She wanted to let others to know the initial design idea was hers. Although she tried to keep the caramel idea private in SINQ (e.g., THE DESTROYER), when it came time to run the investigation, she let others know it was her product idea. She appeared extremely happy that the facilitators let her attempt to make caramel as an investigation, "I liked that you guys were open to new ideas" and that, "You guys let me do what I wanted to do." She commented in the interview that having someone listen to her ideas and take them seriously was important to her (*SQ4 – factors*). Many times people in Donna's personal circle would tell her she could not implement her design ideas, but Donna appreciated that in KC learners could transform their ideas into real products.

Donna also let others (e.g., friends, family) know the end product was her possession (*SQ1 – target*). Her goal in this investigation was to make the candy product, not to understand the cooking and scientific process. Instead, she attributed the end product to herself as a way to show others who she was and what she accomplished (*SQ3 – characteristics*). For instance, she told her family about the caramel, “And I’m like, (loud voice) I MADE CARMEL! AND IT’S THE BEST CARMEL EVER! TRY IT!” Donna later told me that she was extremely proud of the end product and she saw this creation as a contribution to KC, “Yeah, it was the best caramel I’ve ever had” (*SQ3 – characteristics*).

2. *Donna’s ownership over the process of the investigation is weaker*

However, despite the strong attraction towards her design ideas and the end product, Donna also exhibited weaker ownership on the other aspects of the activity. In contrast to the wet caramels, she did not take ownership of the burned dry caramel. While Ben was interested in how hard, brittle, and burned the dry caramel became, she wanted to throw it away. Ben also emphasized learning from the mistakes of the burned caramel, while Donna made no mention of learning from failure. Instead, Elizabeth noted that Donna became upset when the dry caramel burned. Instead of wondering why the dry caramel burned, she saw this as a failure to produce a good product (*SQ3 – characteristics*). She told Ben the burned caramel was his and she would have rather seen it in the garbage can.

Donna also did not want to take full ownership of the cooking process. In this vignette, Donna’s issues with attention manifested again. Following a similar pattern in Week 07, Donna had more focused attention during the beginning of the investigation, but towards the middle and end, her attention diminished. Once the stirring began, Donna lost focus and wandered away (*SQ2 – points*). I asked her about

her behavior in the interview. She commented that she tended to drift off towards the end of the day and that she just needed to sing. Donna noted that the stirring of the caramel mixtures took a long time. While Donna's lack of attention was a contributing factor to her establishment of ownership, Donna also stated that she really was not as interested in the science learning, "I just like cooking." She stated that the experiments and the recording of the data should be optional processes. In contrast to Ben and Freddie, who wanted to make careful and close observations and measurements of their food products, Donna was not as keen to this task. Ben was at the stove stirring and talking with the facilitators about the observations he was making and how the fats from cream prevent the sugars from crystalizing. Donna, however, would have rather cooked the food than engage in dialogue with the facilitators about the process and mechanism of developing caramels.

8.2 Overall Discussion on Donna's Ownership of Science Learning

8.2.1 What Did Donna Own?

Initial design ideas. In all four vignettes, Donna was in charge of establishing and controlling the initial ideas for development. In Week 06, she was excited about her design idea about the puffy cake investigation. In Week 07, she became angry and frustrated when Anthony "stole" her idea. And in Week 09, she acknowledged that the caramel product was her idea, both vocally and in SINQ. For Donna, these initial ideas had a lot of worth to her. These product ideas are deeply connected to Donna's identity as a designer and a cook. For instance, Donna expressed that many people often dismissed her design and cooking ideas as wishful thinking. When she had support for her "outrageous ideas", this gave her a sense of empowerment and pride. Donna wanted acknowledgement in her ideas and therefore, she held tightly for the authorship. When others did not attribute her contribution to the ideas, she reacted with negative affect, such as anger, frustration, and accusation. Donna did not take the theft of her ideas lightly; she came up with her own pen name, "THE DESTROYER", as an attempt to prevent plagiarism from other learners. Donna

wanted the technology to allow her to choose when to be private and when to be public about design ideas.

End products. Donna was often very vocal about the end products made in KC. Her goals in KC were to cook and make food from scratch. Similar to design ideas, Donna enjoyed receiving praise from her family and friends about the food she made. She attributed ownership over these products and let others know that she made contributions in their creations.

Hands-on cooking processes. Donna's goals focused on developing an end product for tasting and sharing. In the vignettes, particularly at the beginning of the investigation, Donna would invest heavily into participating into cooking practices. Donna wanted control over the recipes. She would ask the facilitators to mix into the recipe certain ingredients she really wanted. Donna, however, was not as invested or in full control over the science inquiry aspects of the investigation. Even though Donna claimed that science learning was fun and doing experiments were exciting, Donna did not want to take full ownership and responsibility over aspects of the activity that required slow reflection and investigation setup, careful observations and measurements, and scientific discourse and questioning.

8.2.2 How does Donna's ownership evolve over time?

In this portion of the discussion, I elaborate on Donna's ownership through imagination, engagement, and alignment. I make the argument that Donna's imagination is wide and expansive, but solely concentrated on science as a hands-on and fun experience. Donna acknowledged that part of science is about careful reflection and close observation, but she did not want to engage and align with this

aspect. As a result, along with her attention issues, she has difficulty engaging and aligning with the KC community and developing full ownership over her investigation.

Imagination and ownership

Wenger (1998) describes imagination as being very broad and often less focused with very little boundaries. For Donna, with her attention issues, she had a wide imagination about the numerous roles and identities she could see herself enacting. Mainly, Donna constantly identified herself as a “dreamer”, someone who could come up with creative and wild ideas. Donna identified herself as a toy maker, candy maker, veterinarian, actress, astronaut, and lastly, a scientist.

Scientists and investigators. Donna had two perspectives of scientists: 1) the science that “others” do and 2) the science that “Donna” wanted to do. Donna acknowledged that scientists make discoveries through careful examination and close observations.

- Jason: Very cool. And so you mentioned that scientists help people (interruption), you said that scientists help people, how do scientists help people again?
- Donna: They work with like, my mom for instance works with like the human body and microbes and bacteria. And she's working, like if you study closely and stuff. And like find the cures for stuff, they are just hiding inside you.
- Jason: So how do you think they find those things that hide inside you?
- Donna: Um, they like for instance, they use mice for, they use mice as practicing and they like take them apart and look at the bodies and seeing how they work and the microbes inside. And for instance they make them sick and they try to heal them. Using things they make.

For instance, Donna discussed that scientists, like her mother, would dissect mice and look at the bodies to understand how the microbes inside worked. She also knew that scientists went to public lectures, but Donna greatly disliked the slow nature of these talks and considered them boring. Donna also did not enjoy long conversations about science and how the world interacted. When I asked if she thought of herself as an investigator, she did not see herself in this role; she stated, “I just want to be someone who makes people happy.” In contrast to Ben (Chapter 6), Donna does not talk much about herself engaging in science in terms of making careful observations, being patient, or coming up with ideas about how the world works. This is the kind of science that others, like her mother and scientists, engage in, but this is not what Donna imagines herself doing.

Instead, from Donna’s perspective and imagination of the science, she wanted to engage in 1) creating exciting effects (e.g., little explosions, fizz), 2) working hands-on with little planning (e.g., mixing stuff) and 3) making discoveries to help people.

Jason: Oh ok. What about, so we talked about being a scientist in Kitchen Chem, are there things you can think of that we did like scientists in Kitchen Chem?

Donna: We did experiments.

Jason: Can you talk about that, what kind of experiments did we do?

Donna: We did this thing where we put some kind of food inside a bottle. And we put a balloon on it and the balloon puffed up and then the balloon puffed down. And then it puffed up and puffed back down.

Jason: So why do we do the experiments?

Donna: To help us understand.

Jason: So do you see yourself as a scientist in Kitchen Chem?

Donna: Hmm, mmm (yes)

Jason: Can you talk about that?

Donna: It's cause I've always wanted to make something blow up in an experiment.

Jason: Do scientists always make things blow up?
Donna: Um, no. That only happens with mad scientists.
Jason: Ah, so what kind of scientist are you?
Donna: Um, somewhere in between.
Jason: Somewhere between a mad scientist and scientist?
Donna: It's a mad-za-ba-ta-ba.
Jason: What do mad-za-ba-ta-ba's do?
Donna: They can make explosions.
Jason: Did you make anything explode in Kitchen Chem?
Donna: I would have liked to.

Donna imagined herself as “somewhere between a mad scientist and scientist.” She wanted to mix chemicals together to make explosions, “It's cause I've always wanted to make something blow up in an experiment.” Donna had access to a world of scientists through her mother’s lab, but she chose to pay more attention to the hands-on mixing and the playful doing aspects of science. One explanation is that Donna had a limited playful view of science, that is, she imagined and emphasized the fun aspects of science that she wanted to partake in, but not the slow and careful aspects needed for discoveries and inquiry processes. Donna does not discuss the slower aspects of reflections for herself, but she emphasizes it for others. For instance, I asked Donna how scientists solve problems and what she wanted to solve.

Jason: Are there other problems you think scientists can solve?
Donna: Uh yeah. Like they can solve a new kind of microbe species.
Jason: And what kinds of problems do you like to solve?
Donna: I like to make things explode.
Jason: Oh, so how would you figure that out?
Donna: Um, you gotta make something fizz a lot.

Here, Donna saw problem solving for the scientist as figuring out the cures and diseases and finding new microbes. This view is more abstract and disconnected to her everyday life. But for Donna, she wanted the explosions and the fizz; this was

more tangible, accessible, and exciting for her. Donna even saw this distinction in school compared to KC.

- Jason: What's the difference (between KC and school biological science)?
- Donna: Food is good. Deliciousness. You get to taste it. You can't actually go to a zoo and ride one (animal).
- Jason: So you can't actually go grab a lion and taste a lion?
- Donna: No like RIDE a lion.
- Jason: Oh you mean ride a lion?
- Donna: And then you go, you're not allowed to do that. But in Kitchen Chem you can taste our creations.

Cooks and designer. Similar to the hands-on and exciting imagination of science, Donna imagined herself as a cook and designer that made exciting products. She stated that she wanted to be a candy maker and pastry chef and hoped someday that her mother could find the cure to her gluten intolerance. Donna commented that cooking was an important ritual at her home with her father and that, “every time we cook together, we pretend we're on a cooking show.” As a designer, Donna saw herself creating new toys for children that would make them happy. For both these two roles, the end products are an important indicator and validator of who she imagined herself to be. A toy designer needed to create fun toys and a cook must produce tasty creations. This perspective of the designer is strong in Donna; the products of what she makes are very important.

- Jason: So can you talk about what the biggest accomplishment you can think of you made in Kitchen Chem? The thing you are most proud of. Man, I'm really proud of this thing.
- Donna: I made caramel.
- Jason: You made caramel. So you are most proud of the caramel? Can you talk about, how did you share that with other people?
- Donna: I say, I made the best caramel ever.
- Jason: Who did you tell about this?
- Donna: My parents.
- Jason: You told your parents. Did you tell anyone else?

Donna: Um, no.
Jason: How did you share it with your parents?
Donna: I'd be like, so guess what we made, caramel! And then they were like, what? What are you talking about? We're trying to have a conversation. And I'm like, I MADE CARAMEL! AND IT'S THE BEST CARAMEL EVER! TRY IT! And then they were like what the? Hmmmm (taste sound), true.

In this case, Donna is most proud of the product that she claims ownership over.

Donna perceived the product itself as the accomplishment, not the long process or the reflection of ideas about how caramel formed.

Imagination of roles, ideas, and ownership, and roles. Wenger (1998)

explains, “imagination is an important component of our experience of the world and our sense of place in it” (p. 176). Imagination greatly influences people’s experiences of identity and the potential for learning within activities. For Donna, her imagination of her role as a dreamer was encapsulated as the semi-mad scientist that created exciting explosions and the cook / designer that produced end products everyone wanted. Her imagination was not just a fictional envisioning of herself. Instead, imagination concerns the production of images of the self and her relationship with the world (Wenger, 1998). One explanation is that Donna perceived herself as a product idea generator, someone that could come up with the initial start to a larger project. Her imagination of her identity and her ideas are greatly tied together. Design ideas are personal capital for Donna to own; she wanted people to acknowledge her ideas as well developed, thus supporting her imagination of her role as an outrageous product idea generator. Donna does not seem as concerned over cooking processes or inquiry based reflections on why the caramel formed from sugar and proteins.

As Donna mentioned before, design ideas can also be stolen from her and she can lose that recognition she desperately wanted. I believe the theft of her design idea in Week 07 is analogous to losing a “piece” of her identity. Therefore, based on Donna’s imagination of herself and her interaction in the world, she guarded her ideas carefully, but at the same time, she wanted public authorship, recognition, and acknowledgement. Her ownership over the ideas, end products, and the hands-on process is a partial reflection of her imagination and how she created her identity.

Engagement and ownership

In contrast to the open and broad views of imagination, engagement is more narrow and focused (Wenger, 1998). Engagement is bounded in the context and time; participants each shape their own experiences through negotiation and participation (or non-participation) within a specific temporal space. For Donna, her engagement through ownership in KC gives an indication of how her identity was developing or being enacted.

Mutual engagement and disengagement in shared activities. One component of Donna’s engagement through ownership is how and what she invested into the investigations. Donna negotiated her engagement the way she imagined how she enacted the roles of scientist / investigator and chef / designer. She wanted the hands-on mixing and the exciting explosions, not the slower reflection and planning processes and the careful measurements and observations. Donna got excited over the prospects that her ideas could be translated into investigations. When she was given the opportunity to come up with ideas, she took this task seriously. Donna wanted full control over her design ideas, even to the point of allowing other access and

restriction to these ideas. On Weeks 06, 07, and 09 Donna engaged with the KC participants through investments into setting up the cooking investigation, taking on menial tasks (e.g., mixing ingredients), and wanting to actively cook.

However, a combination of Donna's issues with attention and her imagination of roles prevented her from full investment, control, and possession of the investigation. Donna disengaged from the activities when both her attention faded and the activity did not fit her vision of scientist / investigator and chef / designer. Specifically, Donna tended to become disengaged towards the second half of the investigations when her attention started to fade and the investigations shifted towards slower and more reflective science inquiry processes. In these moments, Donna exhibited lower ownership over the activities. She chose not to take responsibility and investment into the project. When the investigation process did not go as planned, she disavowed her ownership (e.g., "It's yours, you are the one who started it!"). The design ideas and the end products were worth more to Donna than the actual process of implementation, especially when the process did not match her expectations (e.g., slow stirring, no explosions).

Ownership expressed through participation and non-participation. Wenger (1998) describes engagement through participation and non-participation in communities through six aspects (p. 167 – 168):

1. How we locate ourselves in a social landscape
2. What we care about and what we neglect
3. What we attempt to know and understand and what we choose to ignore
4. With whom we seek connections and whom we avoid
5. How we engage and direct our energies
6. How we attempt to steer our trajectories.

In these vignettes, Donna did not engage in full participation of the activities. Instead, she chose to focus what she wanted to know, understand, and own (e.g., bricoleur style cooking, idea generation) and what to neglect (e.g., careful planning and measurements). Similar to Freddie, the goal of full participation into the KC investigation was not Donna's main goal. As a newcomer, full participation is a future goal, not something that can be always achieved in the short term (Wenger, 1998). In Donna's case, full ownership through engagement and alignment did not quickly manifest in KC.

Instead, Donna exhibited a complex mix of participation and non-participation in the KC community. Non-participation can be split into two types: marginality and peripherality. Marginality and peripherality can only be understood through context of participation and not the actual behaviors themselves. Wenger defines marginality as participation restricted by non-participation. For example, women seeking equal opportunities in their jobs may find themselves constantly being forced into marginal identities of non-participation. Peripherality is participation enabled by non-participation. Newcomers may choose to stay in the peripheral bounds since full participation may not yet be a goal for them.

In Donna's case, I make the argument that her non-participation in the inquiry aspects of science is a combination of marginality and peripherality and that her ownership over the investigations gives evidence for this. As her facilitators, teacher, and mother pointed out, Donna had issues of attention in all communities she interacted with, particularly towards activities that required deeper inquiry and reflection. Donna's marginal non-participation in KC could be seen as she chose to

neglect investments and give up full control of the slower paced experiments (e.g., egg, oil, and water experiments), argument building (e.g., what do you think eggs do in the cake?), and long conversations and observations about phenomenon (e.g., ignoring the stirring of the caramel). She chose to cope by drawing pictures on StoryKit, tasting the cakes, and going around the room singing. Donna showed frustration when others in the community did not understand her being a “dreamer” and how she had difficulties paying attention. In this case, Donna gave up ownership of the deeper reflection activities because of her struggle to keep focus and her imagination of what roles she wanted play. This form of non-participation prevented full participation.

However, Donna also may have needed peripheral non-participation. Her non-participation could be seen as an enabling factor of participation and ownership. Donna still wanted to participate in the KC investigation, especially the cooking aspects. Although Donna chose to not participate and gave up ownership over the science inquiry, she still expressed that she had ownership through control, investment, possession, and pride in her design ideas, end products, and cooking processes. Donna’s non-participation could be examined as peripherality; she chose the science aspects to not engage in, but needed the other cooking aspects to develop some aspects of ownership over the investigation.

Alignment and ownership

Alignment is more focused than imagination, but broader than engagement (Wenger, 1998). A learner’s alignment connects imagination and engagement together. Alignment entails an investment of personal energy to enact practices and

behaviors that help to coordinate perspectives towards a common purpose. Through alignment, learners become a part of something larger by playing their parts. For Donna, she attempted to align her practices from home into KC, but did not always change her practices at home.

Coordinating actions from home and school to KC. Drawing from her imagination as a cook and designer, Donna would often align her practices of this identity with her family outside of KC. Donna talked about times with her father when she would cook and bake with him. She explained that during these times, she and her father would imagine they were on a television show telling people about cooking. At home, Donna's mother observed that much of the conversation on cooking focused on creating an end product and Donna was very proud of what she created. From her imagination as a partial mad scientist that makes things explode, Donna would go into her mother's lab and playfully interact with the equipment and conduct mini experiments. Her mother explained that Donna was fond of the "physical aspect of science." At school, Terrie explained that Donna was a type of learner that "really likes to get her hands on stuff" and that she enjoyed "anything that has hands on activities that she can do."

Alignment requires participation in the form of aligning actions with participants in other communities (Wenger, 1998). For Donna, aspects of KC aligned with her home life in science. In terms of ownership and alignment, Donna desired to shape the practices of KC to what she envisioned from her home life and the hands on aspects of school science. Donna wanted some of the same home aspects of science in KC, such as the mixing things to produce exciting effects and cooking to produce an

end product. Donna aligned her established practices from home into the KC community. The aspects of KC she chose to make investments into and wanted full possession over were the activities she was already used to being engaged in from her home life. As she aligned herself between home practices and KC practices, her identity as an explosive scientist, outrageous idea generator and designer, and cook solidified.

Non-coordination of actions from KC to home. Certain aspects of KC did not transfer to her home life. For ownership, Donna chose when to enact practices and discourse and when not to in both at home and in KC. Donna's mother noted that conversations with Donna often occurred about observations and questions she had, but that discussions on the "actual basics of science" with Donna were a bit difficult due to Donna's inattentive nature. Donna enjoyed talking with her mother about science, but only briefly and never long enough to reflect on the phenomenon in the cooking process. Donna's coordination of KC's slower science inquiry processes across home and KC was difficult. Her alignment towards the hands-on aspects of sciences (e.g., mixing, experimenting), the idea generation, and the end product development coordinated well between home and KC. For the aspects of science inquiry that required more focus and reflection, Donna chose to engage in these aspects less, both at home and in KC.

8.3 Summary of Donna's Ownership of Science Learning

Donna's ownership over certain aspects of KC is a reflection of her identity through imagination, engagement, and alignment. What this case study reveals is that cultivating general a sense of ownership in science learning can be difficult. Learners

may conceptualize science learning, not as a generalized whole, but rather in fragmented pieces that fit what they choose to imagine, engage, and align in. Under imagination, Donna imagined science as hands-on activities that are constantly filled with “fizz”, “explosions”, and “fun”. Donna had access to science learning more than most people could imagine (e.g., mom’s lab). While she recognized that reflection, critical thinking, and close observations were part of being a scientist, she did not think of herself as engaging in these characteristics. Instead, she envisioned herself primarily as a dreamer, a designer, and a cook that would come up with new ideas and end products for food. Although Donna has issues with attention, her imagination is broad and does include fantasies that enable a creative process beyond just engagement (Wenger, 1998).

Engagement and alignment, however, are much more difficult processes for Donna; both require more directed focus, energy, and personal investment than imagination. Donna chose to have ownership over aspects of the investigation that fit into her imagination. I suggest that opportunities to cultivate ownership do not necessarily mean that learners will take full control, investment, and possession over all parts of science. We attempted to give opportunities for ownership to Donna, but we could not control how her ownership would manifest. Donna’s ownership of the design idea and the end product could be considered “low hanging fruit”, that is, it is easier for her to claim ownership of an idea and product than to invest energy into the process.

Developing full ownership of science learning can be difficult because science inquiry (and even cooking) requires focused attention (e.g., careful observations,

measurements), investment into both the exciting aspects and the menial tasks (e.g., long stirring, investigation setup), and delayed gratification. For Donna, who already had attention issues and imagined herself as a candy maker dreamer, she had difficulties latching onto the slower paced conversations about proteins, temperature, and crystallization, watching a mixture gradually heat up, and making careful and close observations.

Specifically Donna's identity was shaped through her ownership in engagement as she sought control over design ideas, expressed tremendous pride in end products, and put investment and decision-making practices into cooking processes. However, her choice to disown the reflection process, slow menial tasks, and conversations over observations indicated non-participation. In Donna's case, our conception of science learning cannot ignore how learners imagine what science means to them and what aspects fit into their imagination. Donna imagined, engaged, and aligned with science based on her choice in how she defined science. Some aspects of the ownership in science learning were natural, while others parts might take much longer time to develop.

Chapter 9: Cross Case Analysis

In the following section, I analyze and discuss each of the four cases across three categories: 1) the characteristics of ownership I observed in the focal learners (9.1); 2) the cultivation of ownership within KC (9.2); and 3) tensions and dilemmas I encountered between ownership and science learning (9.3). Characteristics of ownership refer to the traits I observed in science learning. Cultivation of ownership indicates the factors that promoted or denied ownership in the focal learners. Tensions and dilemmas focus on the role of conflict in ownership of science learning. Each of these three categories consists of a series of grounded themes on ownership I believe were pervasive in the cases. Although O'Neill and Barton (2005) have previously developed grounded themes for ownership, this analysis is a finer grained examination of the ownership I encountered for the focal learners. At the end of this chapter, I provide a brief analysis and a summary of the grounded themes to lead into the discussion and implications of this dissertation (9.4).

As mentioned before in the methods section (Chapter 3), I conducted the cross-case analysis through a comparison of cases. I examined the vignettes through a direct interpretation method (Stake, 1995). For each part of the vignette, I started placing themes of ownership I observed in the learners. As I went through multiple rounds of placing and categorizing the vignettes into themes of ownership, I began to notice three major categories emerging: characteristics of ownership, cultivation of ownership, and tensions in ownership. The presentation of this cross case analysis is based on these three categories:

Characteristics of ownership

- *Theme 1:* Ownership of science learning can be weaker or stronger and positive and negative.
- *Theme 2:* Learners can exhibit ownership of science learning that can be selfish and selfless.
- *Theme 3:* Ownership of science learning can be vocal and expressive or quiet and subtle. Making ownership known to others can be risky or rewarding.
- *Theme 4:* Ownership is influenced from learners' imagination of genuine science learning.

Cultivation of ownership in communities

- *Theme 5:* Ownership of science learning transitions into different microsystems through mesosystem inter-relations.
- *Theme 6:* Learners needed reminders about the ownership of science learning.
- *Theme 7:* Idea development is an important aspect in ownership of science learning.
- *Theme 8:* Ownership of science learning may develop in science further when children feel safe to make mistakes and learn from them.
- *Theme 9:* Shared space and materials allows learners to develop ownership.
- *Theme 10:* Learners needed time to collaborate together, but sometimes they needed separation for personal ownership to develop.
- *Theme 11:* One person's idea can become someone else's target of ownership.
- *Theme 12:* Technology can act as a mediator for ownership in science learning.

Tensions and dilemmas in ownership of science learning

- *Theme 13:* Ownership can be complementary or conflicting with inquiry-based science learning.
- *Theme 14:* Structure and freedom is a delicate balance in cultivating ownership of science learning.

9.1 Characteristics of Ownership

Theme 1: Ownership of science learning can be weaker or stronger and positive and negative.

These four cases demonstrate what is “owned” and what is “disowned” in science learning can be highly variable or unwavering in nature. In organizational theory, Ceja and Tàpies (2011) classify psychological ownership into a 2 x 2 matrix of profiles between 1) weak and strong ownership and 2) positive and negative ownership (Table 11). Weak ownership refers to feelings of low attachment of a target, whereas strong ownership indicated high attachment. Positive ownership denotes feelings of joyful attachment, while negative ownership emphasizes oppressive attachment. Each of the focal learners indicated one or more of the profiles of ownership of science learning.

Table 11

Profiles of strong / weak and positive / negative ownership from Ceja and Tàpies (2011)

	<i>Strong ownership</i>	<i>Weak ownership</i>
<i>Positive ownership</i>	Strong and joyful feelings of attachment to science learning	Weak positive attachment to science learning
<i>Negative ownership</i>	Oppressive attachment to science learning, feelings of pressure and obligation	Weak negative attachment to science learning

Stronger and positive ownership of science learning. In Freddie’s case, despite issues with attention, focused heavily on getting his Greenies product done with little distraction. Even though his task focused more on engineering design, aspects of ownership over science learning were present, as he held strongly to his

explanatory ideas about the heat flow comparison between the metal and rubber pans (Week 06). For the water investigation (Week 09), even though a loud commotion was present throughout the day, Freddie rarely fell into the temptation of inattention; he concentrated nearly 26 minutes at a sink observing the flow of water. Even though he wanted to find ways to manipulate the water flow, Freddie does closely observe to find the different ways to change the flow. Freddie also spent a great deal of time and energy into the design and implementation and exhibited attachment to the investigation weeks after it was over. Specifically, Freddie could remember and recall more details about the Greenies and the water investigation and developed his own simple mechanistic arguments (Russ, Scherr, Hammer, & Mikeska, 2008) for why the Greenies turned out the way they did.

While fostering strong and positive ownership in science learning is a worthy goal, one disadvantage for learners could be supporting collaboration efforts. In Donna's case, she exhibited both strong and joyful feelings over her Puffles design idea (Week 07 part I). However, she refused to collaborate with anyone and did not want to share her idea with Anthony. After her idea was stolen, she conveyed feelings of frustration and anger, along with later expressions of mistreatment. Balancing strong and positive ownership in science, along with the need to collaborate together is an important aspect that needs consideration.

Weak and positive ownership of science learning. One example of weak and positive ownership in science learning is Arman and his cookie investigation. In this case, Arman enjoyed developing the cookie investigation, but was quite hesitant to make decisions. Instead, he often relied on the expertise of Elizabeth (facilitator),

even though she wanted Arman to make his own decisions. In Arman's instance, weak and positive ownership can be interpreted through peripheral participation. Instead of developing a full commitment to the activity, Arman wanted to stay on the borders and take a weaker ownership over the process and let the adults lead. Even though Arman stated the experience was positive, he found it difficult to tell others of his experiences, due to fear of social rejections. While Ben, Freddie, and Donna immediately latched on to their activities or design ideas, Arman's ownership over his project may have taken longer to develop and build up. I argue that some factors that need to be considered are confidence and self-efficacy, collaboration styles, and time and experience in the investigations. However, in contrast to Donna's negative feelings on collaboration, Arman's weak and positive ownership allowed him to want to collaborate with others. He was willing to give up control over his activities to work well with others.

Strong and negative ownership of science learning. In contrast to positive ownership, negative ownership can be indicated by feelings of oppression. For Freddie's case, he recognized the need to work with Emily (facilitator) on his Greenies investigation. On one hand, the facilitators helped Freddie with his investigation. On the other hand, the facilitators' goals in KC on slowing down and reflecting were in conflict with his impulsive nature and imagination of scientists. Whenever the facilitators wanted him to slow down and plan, Freddie showed signs of frustration and being upset, such as breathing heavily and raising his voice. Even though Freddie had a target of developing Greenies, he expressed that working with the facilitators was an obligation he did not want.

Weak and negative ownership of science learning. Similar to Freddie's case, Donna also exhibited impulsivity and inattention. Donna has strong and positive ownership over the ideas she generated for the food investigation. However, she does not care towards making alignment in the implementation, specifically towards processes that have her slow down (e.g., careful observations, measurements) and reflect (e.g., develop arguments). She expressed that she would much rather have experiments and recordings as optional activities, as opposed to required tasks in KC. Instead of becoming angry or upset at the facilitators, Donna passively disengaged during parts of the investigation. For Donna, even though she had strong ownership over her ideas, she displays weaker and negative ownership towards the science activities that are slower paced. O'Neill (2010) comments that, "A student's expression of ownership in one moment does not equal the expression of ownership in all moments" (p. 17). Donna's case demonstrates that learners may have strong and positive ownership towards a design idea, but later have weaker ownership in terms of the investment and cost of implementation. Ownership and interests are separate; interest does not always lead to ownership of learning.

Theme 2: Learners can exhibit ownership of science learning that can be selfish and selfless.

In social dilemmas, people often have to "decide between maximizing selfish interests or maximizing collective interests" (Komorita & Parks, 1995, p. 190). Similarly, ownership can take on two types: selfish and selfless. Using Hernandez's (2012) work on stewardship in organizations, I define "selfish ownership" as ownership that maximizes self interests and minimizes collaboration and collective

interests. In contrast, “selfless ownership” is ownership that promotes stewardship behaviors such as collaboration, service, communal trust, and self sacrifice. Selfish decisions can harm collective interests. Stewardship places “the long-term best interests of a group ahead of personal goals that serve an individual’s self-interests” (Hernandez, 2008, p. 122). These four cases demonstrate that ownership of science learning can take on selfish or selfless forms or a complex mixture of the two.

Selfish ownership. Donna’s ownership over her Puffles idea (Week 07 part I) is an example of selfish ownership. Although Anthony took on her idea for the investigation as his own, she refused allow him any ownership of the design idea. Rather than work together and collaborate to see the investigation through, Donna quickly abandoned the Puffles idea because she wanted acknowledge and attribution for the idea. For Donna, it was more important that she got authorship over the idea, than seeing the project through. Selfish ownership can tear down community building practices.

Selfless ownership. Two examples of selfless ownership could be seen in Ben’s pizza balls and the negotiation of the design (Week 07). In this vignette, Ben asked Arman and Charley (facilitator) if they wanted pepperoni in their pizza balls. Since both could not have pepperoni due to dietary restrictions, Ben ended up not adding this ingredient into his investigation. Here, even though Ben had full control over this activities, he still wanted to negotiate the design of the investigation with the participants around him. For Arman, he allowed the facilitators to help him out with the investigations, even to the point the facilitators commented he wanted them to make the final decisions. In both cases, the children allowed other participants to

shape the investigation experience. Even though both children had the final say in the investigation process, they valued the contributions of others. Selfless ownership can help to build communities. However, I argue that we need to be careful with making selfless ownership a priority. In Arman's case, he was unwilling to take a strong stance on his ownership over his activities. In Week 06, he did not argue against Ben's two-egg flour suggestion. In Week 10, Elizabeth (facilitator) did not get a sense that Arman wanted to make decisions, but instead deferred to adult authority.

Selfish and selfless ownership. Selfish and selfless ownership are not mutually exclusive. Instead, selfish and selfless forms of ownership can co-exist together, creating a complex mix of collaboration and personal self interests. Freddie's water investigation (Week 09) is an example of this. His selfish ownership manifested since he wanted full control of the investigation and relegated the duties of the facilitators to timing the flow of water. He also chose not to participate in the milkshake investigation and abandoned working with Anthony. However, during his own water investigation, he wanted others to come and join in his discoveries. Numerous times he yelled out, "This is cool!" and "Look! Look!". He physically tapped on the shoulders of other children and adults to invite them to come see what he observed. As selfless ownership of the water investigation, he wanted others to share in his observations and build a social experience around this investigation. However, he did not want others to change the experience for him; he wanted to be in charge of how to direct the water investigation.

Theme 3: Ownership of science learning can be vocal and expressive or quiet and subtle. Making ownership known to others can be risky or rewarding.

While O'Neill and Barton (2005) indicated that ownership of science learning could be exhibited through investments, control and decision-making, expressions of pride, views of self-identity, and perspectives of contributions of science, what this dissertation reveals is that learners have different ways that they express ownership.

For some of the focal learners, they were very vocal and public about their ownership. Some learners would yell out their idea, while others would draw their idea into StoryKit. Expression could also be seen as the learners invited others to participate in their investigation. Freddie yelled for others to come see his Greenies and water investigation. Ben asked Charley (facilitator) and Arman for their opinions on the direction of his investigation. Learners would also directly make bold statements about who the owner was of their investigation. Donna made it very clear to Anthony she was the possessor of the Puffles idea (Week 07 part I) and that he stole her idea. When the caramels were done (Week 09), she cried out to everyone that her candies were made. Freddie became frustrated when the facilitators wanted him to slow down and reflect, thereby taking control away from his investigation. Lastly, the focal learners would tell their family and friends about their investigations. The parents of Donna, Ben, and Freddie all expressed that their children spoke about KC to them, specifically what they made and if they could replicate the investigations at home. Children indicated to their families the importance of staying in KC and were proud to show of their work.

However, making ownership known to others is not always vocal; it can be quiet and subtle. Donna and Arman, while very different in how they expressed ownership, both commented that making ownership known is socially precarious. For

Arman, the facilitators all expressed he was the hardest to read and interpret. They wanted him to make decisions, but he often took a passive approach. The facilitators often had to advocate for him and make sure he was making decisions. Charley (facilitator) noticed that Arman was happy to know that he could do the cinnamon rolls investigation, but he was hesitant to push forward with this investigation. Several reasons exist as to why Arman did not want to make his ownership known. First, making ownership known to others is socially risky. While the other focal learners declared their ownership explicitly, Arman was anxious about letting others know because he did not think they would be interested in what he would have to say. He did not have the confidence to prove that he had mastered any tasks as a chef, scientist, investigator, or designer. Second, perspectives of adult authority made him shy away from sharing. He described adults as possessing more knowledge and that if he shared with them what he owned, he did not know what their response would be.

Making ownership publically known was also risky for Donna, but in terms of idea plagiarism. Her argument with Anthony over the stolen idea made her feel mistreated and left a deep impression on her. Whenever ideas were posted online into SINQ, she posted the idea under the guise of “THE DESTROYER.” Donna wanted anonymity for her idea so that others, particularly Anthony, would not be tempted to steal the idea for themselves.

Theme 4: Ownership is influenced from learners’ imagination of genuine science learning.

I make the argument in this dissertation that ownership of science learning is difficult to separate from a learner’s imagination of what it means to “do science.”

Each of these four learners had their own imagination of what genuine science meant to them. Imagination is a dynamic feedback loop with engagement and alignment. Imagination changes as learners engage and align, and vice versa. As these shifts occur, identity changes. I believe ownership is a reflection of that identity and changes to identity.

In Ben's case, he imagined scientists as finding discoveries that did not already exist. He imagined scientists as explorers in ideas that needed to be patient and be able to multitask. When structured experiments already had "the answer", he was skeptical as to why he was engaging in these activities. Genuine science for Ben meant exploring the unknown. As he engaged in the KC activities, he developed ownership towards the practices that allowed him to enact his imagined view of scientists as exploring the unknown. He wanted to design food creations no one had answers to (e.g., pizza balls) and he wanted to act out the multitasking and the patience he pictured. Even though much of what he was doing in KC was a design task, his perspective of science as venturing into the unknown is complementary to designing unknown and unorthodox foods. When he saw that mistakes were part of his activities, he negotiated the meaning of mistakes towards a positive spin. As a result, he owned the mistakes and showed them off to others. Later, he stated scientists learn from their mistakes.

For Arman, he imagined scientists through the lens of "legal scientists", that is professional scientists who had a job. Arman did not imagine himself in this employed role and was hesitant to make any claims to identity as a scientist and investigator. Arman imagined genuine science as what professional and established

scientists do. From his imagination, Arman was cautious in decision-making for Choice Day. Both facilitators stated he appeared more willing to please the adults than stand his ground on decisions. Here, Arman's imagined view of the scientist and far he thought he was from it impacted how much ownership he wanted to take on in the investigations. He had difficulty even after KC on identifying himself as a scientist.

Freddie's imagined view of genuine science was based on autonomy and full control. To Freddie, real scientists have total control over their investigations and activities and do not plan ahead. Instead, his imagined view of scientists included many hands-on activities, mixing, and surprising and serendipitous discoveries. When the adults asked Freddie to slow down and plan, he grew frustrated and angry because this prevented him from enacting his imagined genuine science. Freddie saw himself as a stifled scientist. He expressed that ownership was being taken away from him and that he would have rather done the same unstructured experiments he had at home.

Finally, Donna's imagined view was similar to Freddie's. She had the same imagined view of scientists, that is, they create explosions, fizz, and everything is hands on. Donna imagination is not limited, since her own mother was a professional research scientist. Donna recognized and imagined her mother making discoveries from microbes to solve the problem of Donna's gluten intolerance. However, Donna chose not to imagine herself in this reflective and slow thinking manner. Those practices belong to the professional scientist. Instead, she imagined genuine science to be full of design ideas and exciting effects. Even though Donna had similar

attention issues as Freddie, she chose very different aspects of the investigation to focus on. Her identity focused more on the design aspects that science (or engineering). Based on her imagined view, Donna only wanted to own the activities that allowed her hands-on engagement, end product creation, and idea generation.

In all four cases, learners' imagination of genuine science had striking similarities and contrasts. As a result, each of them enacted their ownership of science learning very differently. Learners' imagination of genuine science also began to expand as a result of KC. For instance, both Ben and Freddie recognized how independent decision-making and ownership of failures as important to science. Both children noted that science in KC was different than science in school.

9.2 Cultivation of Ownership

Theme 5: Ownership of science learning transitions into different microsystems through mesosystem inter-relations.

In these four case studies, I make the argument that ownership of science learning is not isolated within one specific microsystem, but traverses through the different microsystems in a learner's mesosystem. Bronfenbrenner (1994) describes the microsystem as "the pattern of activities, social roles, and interpersonal relations experienced by the developing person in a given face-to-face setting with particular physical, social, and symbolic features that invite, permit, or inhibit engagement in sustained, progressively more complex interaction with, and activity in, the immediate environment" (p. 39). Examples of microsystems include home, school, friends, and religious organizations. The mesosystem is the system of microsystems and comprises of the linkages and processes that connect the different

microsystems (e.g., the relationships between home and school or school and sports team).

In this study, I compare the microsystems of the focal learners home, school, and afterschool (KC) environments as a single mesosystem. I contend that learner's ownership of science learning is not isolated only in the classroom or school, but can be impacted through the different microsystems.

From home and school to KC. All of the case studies show that ownership of science learning can dynamically be influenced by home, school, and afterschool settings. First, learners' perspectives of science from their home and school impacted ownership of science learning in KC. Each of these four learners discussed science learning from divergent perspectives and indicated different priorities. Although Arman and Donna's ownership of science learning was impacted from their experiences at school and home, I mainly compare and contrast Ben and Freddie's ownership in the following analysis.

For Ben, science learning at home and school was about idea generation and patience. Ben discussed how he enjoyed home and school science that allowed him to come up with large ideas about how the universe worked. For instance, he enjoyed conversations with his friends about black holes and The Big Bang. Ben also had numerous conversations with his father about the unstructured experiments they would try in the kitchen. From his imagination, Ben indicated that professional scientists are patient, can multitask, and learn from their mistakes. At home and school, Ben had many chances to explore the unknown science on his own terms, such as looking around the local forest or trying out new activities in the kitchen. For

Ben, doing science meant the problem needed to be genuine and unexplored. The answer to the problem should not already be known. All of these factors in the microsystem of home and school influenced how Ben took ownership of science learning in KC. First, Ben wanted the activities in KC to be genuine and have unknown answers. If he perceived the structured experiments to already have a known result, he did not appear interested in pursuing these activities strongly.

In Freddie's case, he wanted autonomy and full control of the KC investigation. At home, Freddie stated he could take over the sink and combine many solutions together to satiate his curiosity on how different liquid solutions mixed. He stated that at home, he engaged in these personal investigations without structure or guidance. For Freddie, his view of science consisted of mixing chemicals, making close observations of what they mix, and engaging surprising discoveries. When it came time to work with Freddie on his tasks in KC, his ownership of science learning impacted how he took ownership in KC. Freddie wanted full control of his investigation and an unstructured process in the investigation. When Emily (facilitator) wanted him to slow down and reflect on the process, he became irate and frustrated. In this case, ownership of science learning from Freddie's home microsystem influenced his reactions and affect in KC. He wanted the same direct control and possession of the investigation as he had in his home.

From KC to home and school. Vice versa, the KC microsystem also impacted how ownership of science took place at home and school. In Ben's case, he started to talk more with his father about the processes and questions of cooking. Based on what Ben's father claimed, Ben started conversations about how to cook during the

time they prepared family meals. In this case, Ben was more aware that similar conversations from KC could take place at home. He chose to engage in these conversations without prodding from the facilitators. In Freddie's case, he wanted to do more investigations at home with food. Working with his mother, they both came up with an investigation on their own to examine the differences in melting milk, white, and dark chocolate. In both Freddie and Ben's case, their perception of ownership of science learning in school changed after KC. Both stated it was difficult to "do science" in the classroom. Ben highlighted how he wanted more investigative type projects in school like KC, with unknown answers. Freddie emphasized that choices in science in school did not appear as genuine as it was in KC; he wanted to be able to choose any idea he wanted and develop an investigation around it. In these two cases, ownership of science learning can connect the different microsystems together and show how the microsystems dynamically influence learners. Therefore, researchers studying and examining ownership must consider how learners imagine, engage, and align with practices both in a community of practice and outside that community (see Chapter 10).

Theme 6: Learners needed reminders about the ownership of science learning.

This study recognizes that ownership in science learning does not instantly take root in learners and drive them to motivation. Instead, I suggest that facilitation and cultivation of ownership requires reminders of ownership to learners. I observed that facilitators needed to remind learners who owned the investigation and where the

source of the idea came from. Two cases are an example for why ownership needs reminders.

Distraction. In Ben's Week 06 case for pizza balls, he was very distracted at the start. On the videos, he would make goofy noises and start drumming with the spatulas. At this time, Charley saw his distraction and had to remind him whose idea this was in the first place: "Wait, wait, wait this isn't my idea to make the pizza balls, right? *So how come I'm reminding you guys what to do?*" For many learners, open style problem based learning can be difficult because of the lack of guides and structures. For Ben, he needed a reminder from Charley on how this was his investigation and how he needed to take responsibility for its implementation and decisions.

Reservation and shyness. For Arman's cookie investigation (Week 10), Elizabeth noted that she had to remind Arman about how he needed to make decisions in the investigation. Arman tended to be shy and hesitant about taking control of the investigation. Elizabeth noted:

So, um, but he's so hard to read in that regard because he, because like I said earlier, I think he really does respect um, I don't know whether it's his family background, but he really does respect this sort of adult, um, personal authority. Um, you know that power dynamic. And I don't know whether his teacher said something about that either, but he seems to be, "Yeah, I'll defer to you because you are the adult." Like, "*Hey dude, it's your experiment.*" And so, um, so, so, I don't know whether, I don't know how much that, that deference to that power dynamic played into any of his ownership. But I do know that he, that he seemed content that his choice had been gotten a voice.

In Arman's case, he needed reminders of ownership from the facilitator to assure him that he had control over the investigation. Learners who are new participants in a community may not perceive they are up to the challenge of taking on responsibility

of decision-making. Elizabeth noted that Arman greatly respected the adults and did not want to upset the power dynamic. When power is transferred to the learners, some learners will opt to quickly make decisions and want to take full control and possession over choices. However, others like Arman, may seem unsure. Therefore, for learners like Arman, he needed ownership reminders because children are often not used to this shift in power dynamic.

Theme 7: Idea development and design is an important aspect in ownership of science learning.

For all four learners, ideas appeared to be very important targets of ownership. The children talked greatly about their ideas and how important it was for others to listen and engage with their ideas. I observed that in these four learners, ownership of ideas in KC took three forms.

Ownership over creative ideas. Learners wanted to see their ideas become a reality as a way to validate their identity. The focal learners talked more about their Choice Day investigations more than anything else in the interviews. Specifically, the children had goals to make food investigations through creative means. Ben wanted activities with “trashcan brownies” and “pizza balls” and Freddie wanted “Greenies.” Donna, who was told by her friends that caramels were made only through machines, wanted to prove that it could be done by hand. Arman wanted to examine cinnamon taste either baked into the dough or sprinkled throughout the dough. In these cases, the children expressed ownership over their creative ideas. Many of them wanted the challenge to prove to others they could make what they set out to try. For example,

Freddie wanted to see what would happen if green dye was added to the mixture or if it was even possible to make the brownies green.

Ownership over discoveries. In Freddie's water investigation, he set forth in sharing his ideas about how to find ways to observe the flow of the water through a cup. Through invitations, Freddie set forth boundaries that he controlled who could come share in his ideas and who could not. However, these boundaries were open; Freddie called out to everyone in KC to come see the observations he was making about the water and examine the "vortex", the comparison of the two rates of flow, and the mixing of the milkshake with water. Freddie also came up with his own explanation (e.g., muffin pan vs. baking tin and heat flow) for why the Greenies were an epic failure. These ideas are part of Freddie's curious nature and his identity as an investigator.

Ownership over ideas on process. As part of Ben's investigation into pizza balls, he came up with his own techniques for measurement and organization. He had ideas about how to calibrate an old straight ruler to make more careful measurements of round objects. Ben also developed an organized way of systematizing all the variations of the pizza balls. Ownership over the ideas on process could be seen as Ben worked meticulously on his measurements and organization. He invested a great deal of time to align with this practice in his cooking. Ben also came up with these techniques and wanted to implement them.

Opportunities for creativity in science learning can lead to more ownership. For these four learners, ownership of the ideas is a reflection and validation of their identity as scientists, investigators, cooks, and designers. Design ideas represent

imaginative possibilities and open up new realms that reach beyond their experiences. Each of these learners wanted positive validation of their ideas. For example, Donna stated in her interview that many people outside of KC often denigrated her design ideas. She appreciated that KC facilitators appeared friendly towards her “outrageous” ideas on design. Arman, though very quiet, double-checked with the facilitators to make sure that his Choice Day ideas would be supported later on in the program. These cases demonstrate that fostering ownership of science learning means taking serious the ideas and imagination of children and finding entry points that allow these ideas to grow.

Theme 8: Ownership of science learning may develop in science further when children feel safe to make mistakes and learn from them.

Similar to Theme 7, ownership over ideas is a rather risky endeavor, given the premise that ideas may not work out as planned. For learners, social risk and peer pressure can often hinder idea generation and implementation. Ownership of science learning can be facilitated when learners are able to own the mistakes they made. For three of the learners, ownership over the failures were a comforting aspect of KC. Ben liked the idea of “learning from mistakes.” He went into great detail about how scientists make mistakes all the time and that they should be proud when they are able to learn something. Freddie called the “epic failure” of the Greenies as his most proud accomplishment because he was allowed to take a risk in making them. After going through how the Greenies were a disaster, he proceeded to spend time providing an explanation and critique of his experimental design and setup. Arman just enjoyed the friendly, low-pressure atmosphere and expressed how this allowed him to take more

risks. Cultivating ownership in science learning means that learners have to develop a sense of comfort for risk-taking. Ownership of science learning can be difficult for learners when penalization for mistakes happens. Learners need STEM learning spaces in which they can try out new ideas and experiment with new processes.

Ownership of failure is an idea that researchers are currently exploring. Kapur (2008) developed a concept called “Productive Failure” (PF). Under PF, learners are exposed to a delay of structure from direct instruction. Instead, learners are given opportunities to activate and differentiate prior knowledge that allow them to generate, explore, critique, and refine problem solving methods for complex problem. Since no direct instruction and structure takes place, ill-structured learners inevitably fail at well-structured tasks. However, Kapur found ill-structured group discussions were significantly more complex than the well-structured counterparts. Over time, after exposure to structure, learners from ill-structured problems outperformed the well-structured learners on both well- and ill-structured problem. Kapur argues that delaying structure helped learners to activate and differentiate prior knowledge structures and become more flexible and adaptive to new situations.

One key finding from Kapur and Bielaczyc's (2012) study on designing learning environments for PF is an affective dimension of ownership. The researchers suggest from their observations of classrooms, that PF learners exhibited strong ownership of the representations and solutions methods they created. Although my work does not go into PF, I believe that my case study on ownership does support Kapur and Bielaczyc's notions of failure. Learners in my study took ownership of failure since they invested a great deal of time coming up with their investigations; 2)

saw exciting and unintended outcomes of their failures; and 3) the learners re-negotiated the meaning of failure in the community into a positive outcome.

Theme 9: Shared space and materials allows learners to develop ownership

We allowed the children in KC access to the materials, space, iPads™, and ingredients. While each of them staked out specific areas in different parts of the room, the learners also went around to each other's spaces to observe. They also developed comfort in getting materials and ingredients, many times without asking adults. Some learners like Freddie, stayed at a very specific spot and took over that territory. In Freddie's water investigation, Freddie stood over the sink and conducted his investigation there. He even started inviting people to that space at opportune times. Allowing learners to gather materials from the pantry and take control of the stove and oven gave them more initiative and shared responsibility for the community.

In Gardner's (2011) dissertation on *Kitchen Science Investigators* (the original life-relevant learning program that KC was derived from) she argues that shared access to materials, resources, and tools are critical components of the setup of the learning environment. Having shared materials, such as a pantry for materials and ingredients, are beneficial to help participants make decisions at key points in the investigation. Shared resources allow learners to collaborate together at critical points in the investigation and allow learners to meet up at a central location. For example, similar to my study, when learners would leave their stations to go retrieve materials, they would go and look at other learner's work and have brief discussions and times to share their work. For example, Ben went to Freddie's water investigation (Week

09) and spent time at the sink observing what he was doing. In this way, ownership can be promoted as learners already begin to start expressing what they are doing in the investigation.

However, ownership over space and responsibility was often a negotiation with the learners and the adults. The facilitators often had to restrict usage for various reasons. For example, Freddie was a case in which he wanted full access to the oven, without adult supervision. As responsible facilitators, we could not allow him to pull and put baking goods into an active hot oven. Full ownership of the space and materials without responsibility can be dangerous. Emily also had to prevent Freddie from impulsively grabbing ingredients without careful planning. The negotiation for space and materials created some tension between the adults and the children. While we wanted children to take on the ownership of the space, giving full access to the learners would have been unwise. As a result, we had to take control when necessary, but Freddie noted in his interview that adult limitations and control was a factor in KC he did not appreciate. He expressed that at home he could do whatever he wanted in the kitchen, even though his mother wholeheartedly disagreed with that statement.

Theme 10: Learners needed time to collaborate together, but sometimes they needed separation for personal ownership to develop.

These cases demonstrate the need to balance times for collaboration and times for independence in order to foster ownership of science learning. Ownership is a personal attribute that is influenced by social interactions. Allowing times in which learners work together and independently helped to support ownership.

A time for collaboration. For instance, in Ben and Arman's case, on Week 06, both of them needed to work together in mutual engagement in order to create the doughs they needed for the investigations. Activities do not exist in isolation; mutual engagement allows learners to develop meanings through negotiation with one another (Wenger, 1998). Ownership of learning depends on mutual engagement. When Ben and Arman did not have the initial shared practices in the investigation (e.g., investigation standards, questions, goals), the learners appeared lost and confused in the early parts of their investigation. Wegner explains that through mutual engagement communities are built through every day talk, interactions, information exchanges, and direct relations. Learners need time to work together and develop communal scientific and inquiry-based practices before they can develop ownership. After getting used to the setting, norms, and standards, Ben eventually went from distracted towards invested and responsible.

A time for independence and privacy. Cultivating ownership means giving times for independent work. Since ownership is such a personal trait, learners ought to have opportunities of which they can work independently and privately. In Arman and Ben's case, after mutual engagement together, both had separate time away to work independently on their own projects (Arman's cinnamon rolls and Ben's pizza balls). Charley (facilitator) noted in Week 07 that once Ben and Arman knew the goals of the investigation and the direction they wanted to go, each of them immediately stopped playing around and went straight into the investigations. While mutual engagement allowed these two learners to come together and become familiar with the investigation, both learners needed time on their own for investment.

Although Arman could have followed Ben's lead in the pizza ball investigation, he expressed to Charley that he did want to try to work on the cinnamon rolls investigation on his own. In this way, ownership becomes more established since the learners can have their own time to have full control and test out different methods and ideas they wanted to implement. For instance, during separation time, each Ben and Arman developed his own way to measure and organize the investigation. Similarly, Freddie needed time on his own at the water investigation (Week 09) to give him a chance to make decisions, whether planned or spontaneous.

Time alone to establish ownership was also needed for Donna and her ideas. During the Anthony argument (Week 07 part I), she needed time away from other learners so that they would not "steal" her idea. Privacy and ownership are complementary constructs; often people choose privacy to as a way to maintain ownership over information, ideas, and knowledge. For learners like Donna, she may have needed more private time to develop her ideas before they become public knowledge. After the Anthony argument, she often retreated to quiet areas in the room whenever she wanted to talk to a facilitator about her idea on SINQ.

Theme 11: One person's idea can evolve into someone else's target of ownership

For three of the focal learners, the design ideas they pursued did not originally come from them. Instead, learners often developed ownership towards ideas from other learners and sources. Ownership of one aspect can later lead to other stronger forms of ownership (O'Neill, 2010).

First, learners can take ideas from others sources and make it their own. Even if the ideas are not sourced with the learners, they can still engage and take ownership over other aspects of the process. Ben did not come up with the idea of the caramel investigation. Ben, Elizabeth (facilitator), and Emily (facilitator) all attributed that original design idea to Donna. However, over the course of the investigation, Donna gave up participation in the stirring, while Ben decided to take over and invest his time. Here, even though Ben did not come up with the idea or take credit for its inception, he took over the ownership of the process and the inquiry conversations with the facilitators. Lastly, ideas from others can lead to new ideas for investigations. Anthony was the one that came up with the idea for the milkshakes thickness investigation, but Freddie was the one that was most interested in the process of the viscometer and flow rates. In this case, Freddie “remixed” the idea of milkshakes, thickness, and viscosity to examine the flow rate and hydrostatic forces in water.

In these three examples, the ownership process is not an isolated process, but a social endeavor. All three children developed ownership over specific targets based on interactions with other learners and facilitators. While it may be important for learners to have times of independence (Theme 10), opportunities for collaboration allow learners to find inspiration for further ideas and processes.

Theme 12: Technology can act as a mediator for ownership in science learning.

For all four cases, aspects of ownership of science learning can be seen in the use of digital media and learning technologies. I assert that technologies are mediums in which learners’ ownership can be examined and what are priorities for them.

First, the learners used the digital stories as expressions of ownership and priority in the investigation. Prain and Hand (1999) argue that writing tasks in science learning can allow researchers to understand students' learning, ownership, purpose, and vision of science. Specifically, learners' sense of ownership could be seen through development of ideas and control over learning. StoryKit (Bonsignore et al., 2013) allowed the learners in KC to not only write, but draw, record audio, and take photos of the aspects of KC they thought may have been important. In terms of ownership in stories, learners would often use the drawing and audio recording tool to express what they had ownership over. For instance, early in Week 03 of KC, Freddie drew in large letters, "GREENIES" in his story. Later in Week 06, Freddie sang about Greenies and how proud he was to accomplish the task of turning the batter green. However, the end of his story has a recording of disappointment; he stated the Greenies were "terrible, absolutely terrible." His ownership over the Greenies investigation was not only seen through his actions, but what he chose to take photos and recordings of. Here he chose the priority of the idea and the accomplishment and disappointment of the task. For Donna, she prioritized design and cooking over scientific inquiry. In her puffy cake story (Week 06), she spent 30 minutes drawing a picture of her and Anthony making a cake. The photos she wanted to be recorded were of her separating the egg whites.

Second, social media allowed learners to post ideas and announce authorship over ideas. As in Theme 7, ideas were often a target of ownership the focal learners fixated on. The social media app, SINQ, gave learners a chance to post ideas and to vote up which ones they thought were important. Each learner used SINQ in a variety

of ways to declare their ownership over ideas or gain ownership. The focal learners invited many people to come see their ideas. For instance, both Ben (pizza balls) and Freddie (Greenies) asked their fathers to come over and look at their ideas for the investigation. Both fathers in the video make comments about the idea. As discussion in the idea occurred between fathers and sons, Ben and Freddie both wanted to engage more in the investigation. Through mutual engagement, focal learners saw the ideas over SINQ and already knew what some of the projects were. Interest developed over time and the learners would come to each other and ask what they were doing. However, as mentioned in Donna's case, close proximity to Anthony before her idea was written into SINQ caused a rift between their collaboration. Because she was unable to declare authorship over the idea quick enough, she refused ownership.

SINQ was also a platform for facilitators to help the children scaffold their ideas into investigations. For some, the ideas for food production were present, but not the ways in which to convert the ideas into an investigation. The guided questions allowed the facilitators to work with the learners to come up with questions, hypotheses, and project ideas. During this time, SINQ gave learners the chance to slow down and reflect on the ideas. At this time, this reflection helped learners to gain ownership over ideas. Specifically for Arman, he had initial difficulties coming up with an idea he really wanted to pursue. Mike and Charley (facilitators), using SINQ, worked with him to come up with the idea for cinnamon rolls. From the initial conversations and SINQ input, Arman was able to bounce ideas off the facilitators, see others contributions, and come up with his own idea. For quieter learners like

Arman, the technology and the learning environment acted as a safe space for him to develop ideas.

However, learners did not always want to use the iPads™ in their investigations. Namely, the iPads™ were often clunky and difficult to use in a kitchen laboratory environment. Many learners would choose not to use the iPads™ because the devices were obstructive to the investigation. Freddie's water investigation at the sink required both hands in the water. Arman and Ben's hands were covered in flour. While the developers of KC wanted learners to develop stories about their investigation to facilitate ownership, I observed that children had difficulties with this task. In my implications (Chapter 12), I will discuss the design features that are needed to support ownership of science learning.

9.3 Tensions and Dilemmas in Ownership of Science Learning

Theme 13: Ownership can be complementary or conflicting with inquiry-based science learning.

In my prior literature search (Chapter 2), I found that the majority of studies consider ownership of science learning as an important motivating factor in supporting STEM engagement. However, what these case studies reveal is that ownership of science learning is both support and hindrance to science learning. Researchers examining ownership of science learning need to consider the complexity of this personal construct in learners.

Ownership as complementary to science learning. These case studies confirm the literature (e.g., O'Neill, 2010; O'Neill & Barton, 2005) and the importance of ownership of science learning in engaging learners. First, ownership allows learners

to take on responsibilities they had never before encountered. For Ben and Arman, both of them came up with new ways of measuring and organizing their projects. Both learners also had to develop ways to micromanage their tasks and plan for how they would compare and contrast the different variations of products. Ben and Arman's investments into their projects took much time and energy. Second, ownership supports learners' long-term investment into science. In Freddie's case, he thought about his Greenies long after the investigation was complete. He critiqued his own investigation setup (e.g., rubber muffin pan vs. metal baking pan) and came up with an explanation as to why the Greenies turned out non-favorably. Freddie spent much time invested into the Greenies and wanted to think more critically about its implementation. Lastly, ownership of science learning supported learners' self-efficacy. As the focal learners saw their ideas being taken seriously into the creation of an end product, each of them reported how important this was in building confidence.

Ownership as conflicting to science learning. Ownership of learning also has a "dark side" (Pierce et al., 2003) that focuses on selfish ownership (Theme 2). As well, how learners imagine science taking place and how willing they are to negotiating the personal meaning of science can promote conflict. First, ownership of science learning can create breakdown of collaboration. In Donna's example, she refused to share her ideas with Anthony (Week 07 part I). Instead of wanting to collaborate to create an investigation, she chose to make accusations and let the idea fall apart. In this case, Donna's strong ownership over the idea and her self-interests in wanting recognition eliminated the idea. Barron (2003) explains in her study on

successful and less successful learner groups that the unwillingness to negotiate a shared space interfered with reasoning and lead to failures in productivity. In Donna case, she was not keen on allowing others any kind of joint ownership of her design idea. While educators may strive for ownership of science learning, I believe it is important to define what is being owned (e.g., an idea, a process, a space) and focus on the right balance between selfish and selfless ownership.

Second, ownership of science learning may exhibit an unreasonable sense of full control. While utopian in nature, we idealistically wanted the children to develop curiosity and questioning on their food investigation. We quickly found that handing over full control of the investigation could lead to haphazard results. For instance, Freddie wanted total control over all parts of the activities, both Greenies (Week 06) and the water investigation (Week 09). Full control does not always lead to slow reflection and planning, especially in impulsive learners. The projects in KC Choice Day needed to take time to plan and prepare; this was different than just “messaging around” in the kitchen. Facilitators wanted to have discussions around the activities and find ways to setup cooking questions in the form of investigations. Even though the ideas are generated from the learners, for some, there are other targets they would rather choose to own. For Freddie, he did not want to align towards science inquiry practices they did not believe was pertinent to the development of the end product. He perceived that making the Greenies itself was doing science because of the mixing of unrelated ingredients (e.g., green food coloring, white chocolate) to create a surprising end product no one had yet discovered.

Theme 14: Structure and freedom is a delicate balance in cultivating ownership of science learning

Researchers interested in the design of STEM learning environments and technologies that consider supporting ownership need to contemplate the role of structure and freedom. I believe these four case studies are examples of why a delicate balance between structured guidance and open freedom need to exist in sustaining strong ownership in learners. On one hand, learners need to have the ability to have open freedom to explore what they are personally interested in. Personal choice, building meaningful connections to STEM and everyday life, and opportunities for self-determinism are important ways to foster ownership (O'Neill, 2010). However, open freedom and unstructured play does not always garner ownership of science learning. Sustained and strong ownership in science learning is difficult because science learning is not always immediate and instant. Instead, science learning requires investment, not just towards the exciting hands-on activities, but the slower paced reflection process and the times that are tough.

In Donna's case study, she had difficulties keeping attention and focusing on inquiry-based tasks that required deeper reflection and meticulous observations. Both Donna and Freddie were also impulsive and wanted to just start cooking and mixing ingredients together with little reflection on the experimental design process. For Ben in Week 06, he had difficulties coming up with a plan because of the open nature of the problem. He became distracted and started to goof off. Charley the facilitator had to remind Ben that the pizza ball was his product idea. Arman expressed he had difficulties with making choices in an inquiry environment and that this process was overwhelming. All of the focal learners needed reminders about their ownership; the

facilitators had to explicitly state to all of the children that the ideas and investigation belonged to them and that the focal learners needed to take responsibility for choices and consequences.

Too much open structure in STEM learning environments can be taxing for learners and cause cognitive overload (Kirschner et al., 2006). For instance, my study suggests that the development of ownership in science learning is partially attributed to learners' ability to keep attention and focus. Without structure, guidance, and interventions the children lost focus on the STEM learning aspect of the KC Choice Day investigations. Many of them just wanted to cook and randomly mix ingredients together. In short, a "tyranny of freedom" effect in ownership can occur. Too much open freedom leads to too many choices and options, which can undermine STEM learning and provide learners little opportunities for ownership towards STEM learning.

On the other hand, providing too many scaffolds and guidance can stifle imagination, creativity, and personal ownership. Too much structure in STEM is currently a problem in many traditional classrooms and learners find science learning to be abstracted and disconnected from their everyday lives (e.g., Atwater, 1996; Basu & Barton, 2007). We provided scaffolds and guidance in the form of goals sheets, facilitator interactions, mobile technology usage, and whole group discussions. This study reveals that even though the learners picked their own investigations and developed personal ideas for science learning, structure and guidance in STEM learning did not always support and cultivate ownership. For example, both Freddie and Donna did not always want facilitator guidance in their

investigations. In these two cases, the facilitators' guidance in the investigation prompted negative affect over ownership. Freddie would show great ire at the notion of slowing down and reflecting on the development of his investigation. Here, facilitator guidance towards planning and experimental design violated Freddie's space and territory in the investigation. When facilitators had to explicitly get him to slow down, he had to give up his full control and possession of the investigation, which made him frustrated and angry. In Donna's case, she would become distracted and attempt to ignore the slower paced STEM activities.

In both Freddie and Donna's case, structured guidance from the facilitators and activities took ownership partially away from the children. Both children owned aspects of science (e.g., hands-on activities, idea design), but did not always want to give up how they wanted to engage in science. Despite the difficulties with open choice and personal freedom, the children expressed this was the aspect of science that was the most genuine. Ben and Freddie both complained about school and the lack of genuine choice and control over their STEM learning. Both children stated KC was the place they could "do science." Donna articulated that she was grateful that Choice Day allowed her to transform her new ideas into actual products.

These cases reveal that providing opportunities to cultivate ownership in science learning can be a challenge. For some children, such as Arman, he welcomed a facilitator to guide him through the investigation, while others, such as Freddie, rejected such a notion. For Arman, he needed the facilitators to advocate for this ownership, but for Freddie, he thought of facilitators as an obligation. Other children, such as Ben, handled freedom more responsibly than others. Although we as

facilitators attempted to provide opportunities for ownership through structure and freedom, we could not control how ownership manifested and evolved in each learner.

9.4 Summary and Conclusions

In this cross-case analysis of the four learners, I focused on several categories and grounded themes on ownership. I highlight the characteristics of the ownership I observed, the ways ownership was supported and cultivated, and the tensions and dilemmas ownership presented. I found that while grounded themes could be developed to explain and describe the ownership of the learners, ownership of science learning is a complex phenomenon that is difficult to encapsulate in simple and general principles. The term “ownership” and “science learning” takes on a multifaceted nature that makes it problematic to define a single generalizable goal for learners. Even though participants in a community of practice work together, mutual engagement often promotes heterogeneity. Learners will react differently to cultivation of ownership. Finally, I argue that ownership is neither a positive or negative factor in science learning and that understanding the tensions and dilemmas ownership presents allows us better insight into the learning process.

In Chapter 10, I will discuss the implications of this dissertation, both the theoretical and the design outcomes.

Chapter 10: Discussion and Framework Proposal

In Chapters 5 – 8, I focused on the case studies on the focal learners to do an analysis of the evolution of ownership of science learning in six weeks of an activity called Choice Day. In these chapters, I examined three to four significant vignettes that represent how ownership evolved in the focal learners. Using Wenger's (1998) framework of modes of engagement (imagination, engagement, and alignment) I examined how home, school, and KC factors influenced how ownership of science learning took place. In Chapter 9, I developed 14 grounded themes from a cross case analysis of the four learners. The themes were categorized into characteristics, cultivation, and tensions and dilemmas of ownership of science learning.

In this chapter, I present a discussion of the significance of the findings. First, I go back to the original four sub questions of this dissertation. I provide a summary of the findings from the questions and discuss the impact and importance of the findings (10.1). I summarize the work I completed in this chapter (10.2).

10.1 Research Questions

Sub-question 1 (SQ1): What aspects of the design activities (e.g., technology, products, ideas) do learners have ownership of when they are given the chance to design in a guided inquiry science environment?

Summary of findings: In this study, I found many targets of ownership in KC that the focal learners primarily sought after. First, all four of the learners wanted ownership over *ideas*. Ideas can take on many forms. Some ideas were about design. All four learners wanted control over their ideas on the design of their investigation. Learners like Freddie and Donna wanted absolute full control over design ideas,

while other learners like Ben and Arman could share and collaborate about the design ideas. Specifically, many of these learners were proud of their creative ideas (e.g., Greenies, trashcan brownies, caramel from scratch).

Second, learners wanted control over the *process of implementation*. Freddie and Donna, both impulsive learners, wanted total control over how to run the investigation and often showed impatience and frustration when the facilitators wanted them to slow down to reflect on the investigation process. Ben and Arman both took responsibility for the measurements and observations in the investigation. Both learners found ways to make their own careful measurements and close observations of the products. Many learners' investment in the process was evident in their choosing to stay longer and sacrifice more personal time to complete their tasks. The process of implementation also included ownership of the space and materials in the investigation.

Third, all the focal learners wanted to share and give away their *end products*. The creation of the end products (e.g., caramels, brownies, pizza balls) was a tangible way of accomplishing their goals and showing off what they did. Arman, who was normally quiet and shy, showed off his spreading cookies to his father. All of the children wanted to take their products home to give away to their families. Some learners got upset when the end product did not meet their expectation. Donna disliked the burned caramel, while Freddie called his Greenies a failure in how they tasted.

Fourth, learners took possession and ownership over their *mistakes*. Arman, Ben, and Freddie had a positive perception of mistakes. Instead of getting upset, each

of these learners found ways to change the meaning of failure into a positive perception. Ben got excited when his dry caramel burned and started to ask more questions on why the dry caramel burned, while the wet caramel stayed smooth and creamy. Freddie called the “epic failure” of his Greenies his best accomplishment in KC. Even though the taste was terrible, the fact that he was able to manipulate the color into green and think more about the reasoning behind why the investigation went poorly contributed to his positive vision.

Discussion of SQI: O’Neill (2010) comments that learners’ ownership is a complex trait due to the multiple dimensions of what are “owned” and the context behind ownership. Although I have summarized learners’ targets of ownership into four categories, what is significant about these findings are both the ways that targets can promote and hinder ownership development in science learning. While identification of targets of ownership in science learning is important, knowing the context behind how learners take possession of these targets is critical. I showed in my literature review (Chapter 2) how science education researchers indicated generic targets in statements about ownership.

This analysis builds on that work and goes on to show that ownership of science learning is intricate and simple identification of targets is not enough to understand the motivation and engagement of learners. For example, I indicated that “ideas” were a target in which learners sought after. However, seeking ownership of the ideas can positively and negatively influence science learning and collaboration. Donna held tightly to her “Puffles” idea (Chapter 09 – Week 07 pt. 1) and refused to collaborate with Anthony on the activity. Ben had ideas about how to design a pizza

ball for an investigation and included Arman and his facilitator in the process of decision making. Both children have ownership of design ideas, however understanding how each learner's possession of the idea impacts collaboration and science learning is just as important as understanding what the targets.

Another significance of these findings is the negotiation of meanings of targets of ownership in the community. Both Ben and Freddie both came to see mistakes and failure as positive for science learning. Wenger (1998) describes negotiations of meaning as the process by which people experience the world and see their engagement as meaningful. The world does not simply impose meaning on people. Instead, negotiation of meaning is a productive process that constantly changes the situation and gives meaning to all participants and allows for new relationships in the world. Both Ben and Freddie did not believe that making mistakes in KC was a negative trait. Instead, through working with the facilitators and the participants, Ben and Freddie negotiated failure into an aspect they could grasp onto. By accepting mistakes and failures as a positive part of science learning, both Ben and Freddie's ownership over their investigations took on new meanings and stronger holds. What this dissertation shows is that the targets themselves do not give meaning in science learning. It is a mutual process by which owner and the social contexts make meaning to the target.

Lastly, what was surprising in this dissertation was how little the children sought after the technology as a target for ownership. We initially predicted that the learners would want to use the apps to write personal stories and collect data using the iPads™. Prain and Hand (1999) suggested that story writing was a way to

encourage the development of ownership in science learning. Although learners could use iPads™ to post questions, hypotheses, investigation idea, and record data and stories, the learners did not take as strong of ownership of the technology as the other targets. Many of them wanted the facilitators to record, while they engaged in the cooking investigations.

One possibility could be that the learners were more interested in conducting the investigations and that the usability of the technology was obstructive. For instance, many learners had their hands messy and could not use the iPads™ in the investigations. The iPads™ also slowed the learners down from engaging in the Choice Day investigations due to the reflective nature. Another reason could have been that the apps were not designed for science investigation usage. As a story telling app, StoryKit was open ended and allowed learners to take photos and record, but it was not easy for learners to access the stories for later editing. We observed that learners wanted quick recordings of the investigations, but did not want to write stories about their investigations during the actual implementation. Lastly, the learners did not have their own personal iPad™ and story. Each week the iPads™ would be rotated around to another learner. Without a consistent iPad™ and story to develop, the learners did not attribute as much ownership over the technology.

Sub-question 2 (SQ2): At what points during the design activities do learners begin to take ownership of what they own?

Summary of findings: The focal learners all took ownership over different aspects of KC at different times. Even with four learners, it is difficult generalizing a pattern of time in which ownership of science learning starts to take place. Some

patterns do take place to determine the points in which learners start to take ownership.

First, some learners took immediate ownership over ideas, while others took longer. Idea generation was always learners' first step developing their KC Choice Day activities. Some of the learners already had ideas in mind coming from their home environments. Donna, for instance, already wanted to make candy and this was something she envisioned doing in KC. She immediately grasped on to making sweets as the ideas she wanted to take ownership of. Like Donna, Ben's interactions at home also gave him ideas for what he wanted to do in KC. He expressed that a trip to Florida and seeing a certain type of ice cream gave him the idea for trashcan brownies (Chapter 07 - Week 10). Others, like Freddie, were inspiration from their interactions in KC. In Week 03, Freddie quickly became attracted to the idea of making green brownies. On Week 09, Freddie's attraction to the viscometer and flow of water motivated him to abandon Anthony's milkshake activity to start his own water investigation at the sink. As part of ownership development, he immediately wanted to take control over his own goals, rather than stay to support his friend. In contrast, other learners like Arman, took a long time before they took ownership over a design idea.

Second, learners needed reminders about ownership to take ownership. Even though the focal learners may have generated the ideas, ownership was not necessarily constant and pervasive. Many learners would often lose sight of the investigation and become distracted. These open inquiry tasks can be cognitively taxing on learners and they can lose focus (Kirschner et al., 2006) or defer ownership

away. Both Ben and Arman needed reminders from the facilitators that these Choice Day investigations were their ideas and they needed to follow through on them.

Third, learners needed a safe space to make mistakes. Similar to owning the mistakes, learners started to take more ownership over aspects of KC when they could fail without penalization. Freddie, Arman, and Ben all wanted a low-pressure environment that allowed them a chance to take risks safely without academic consequence. The ability to take risks in a safe space gave learners a chance to take further steps in owning aspects of their investigation and taking responsibilities.

Lastly, some learners needed collaboration to start owning aspects in KC, while other learners needed privacy. Collaboration allowed the learners to develop mutual engagement. Through talk, interactions, information exchange, and idea sharing, learners could work together and build ownership. For instance, when Ben and Arman did not have mutual engagement prior to the first Choice Day (Week 05), they were lost and distracted. After engagement together, the children knew the rituals and practices needed to accomplish the task. By Week 07, Ben and Arman could work independently and took responsibility over their own task. However, collaboration could be detrimental as well for learners who needed privacy. Privacy allows learners to spend time thinking about their own ideas before it becomes public. For example, when Donna lost privacy in her incident with Anthony, she rejected her ideas and expressed mistreatment (Chapter 08 – Week 07 pt. 1).

Discussion of SQ2: The significance of these findings is that cultivation of ownership is very complex. O’Neill (2010) calls the cultivation of ownership a “complicated balancing act” (p. 18). My findings support O’Neill’s conjecture that

cultivating ownership is not a prescriptive task that would automatically generate ownership. Some learners in KC needed support in ownership of ideas, while for others needed to tone down their ownership to allow for collaboration. One reason for this was that some learners have naturally shy personalities that need support to help them take control. Others had more assertive personalities that were often impulsive. Learners here needed to develop ways to wait and be patient, otherwise conflicts in ownership would occur. Some learners needed privacy to develop ideas, while others needed teamwork. For some learners, their ideas were still forming and they needed that quiet time to develop their thoughts. Other learners have more social personalities and need time with others to get ideas developed. Because the nature of ownership is so personal, the cultivation of ownership needs to acknowledge that supports for some learners may not work for others.

In particular, these findings also suggest that ownership of science learning is not quickly established, but often takes time for learners. Learners in KC needed support to remind them of their ownership of the investigation. They needed the facilitators to generate a safe space to allow for risk and failure. Even if ownership develops fast, it is not constant and may flicker away without support. Ownership in one moment does not mean that it is pervasive in all moments (O'Neill, 2010). Ownership may be more fragile and delicate than what is known (Sharples et al., 2010). These findings support the conjecture that ownership in science learning is contextual. Literature that refers to ownership indicates that learners can own data sets, arguments, ideas, and discoveries in science (see Chapter 2). However, learners

may develop strong ownership over one aspect of science learning or the activity, but we should not assume that this would lead to other aspects.

The findings in this dissertation also contribute to a substantial understanding of the role that other contexts play in supporting and influencing ownership. Many of these learners already had ideas they wanted to engage in through interaction in both KC and outside of KC. Ownership in science learning is not something that is always new, but it may have its roots and foundations in other areas of influence. For instance, Freddie started to develop an ownership over his water investigation through his quick interaction with the flow of water through the viscometer (Chapter 08 – Week 09). However, he indicated in an interview he had already thought about wanting to closely observe water. He also had prior interactions at the sink at home for his own personal investigations. Donna already thought of herself as a candy maker and played around with science kits involving candy at home. While some learners may already gravitate quickly towards specific ideas, it may be that learners have had a “seed” of ownership that needed to be nurtured.

Sub-question 3 (SQ3): What are the initial characteristics and outcomes from ownership and how do these characteristics change over time for learners as they participate in design activities in science learning?

Summary of findings: In this dissertation, I revealed that the term “ownership” needs more explication than what is currently used in science education research. I argue that it is not enough to determine that learners have ownership, but understanding the context and expression of ownership is important. These case studies demonstrate that ownership of science learning is expressed very differently among learners. O’Neill and Barton (2005) indicate that ownership of science

learning is partitioned into five characteristic themes: agency, investment, expressions of pride in science, perception of contributions, and development of self-identity.

What I have shown to complement O'Neill and Barton's work is tying together the literature on psychological ownership and demonstrating that the characteristics of learners' ownership vary based on three aspects. First, learners' ownership can be weaker or stronger and show positive (e.g., feelings of joy, excitement) and negative (e.g., feelings of pressure, frustration) affect. A second characteristic of ownership in science learning is that ownership can be selfish or selfless. Lastly, learners can exhibit ownership through expressive means or quiet tones. In both cases, making ownership known to others carries both risk and reward.

The outcomes of ownership of science learning are not simply all positive. While the majority of literature overwhelmingly portrays ownership as a positive motivator to encourage science learning (see Chapter 2), I have shown in this dissertation that the outcomes of ownership can be complementary or conflicting to inquiry-based science learning. Hay and Barab (2001) indicate that the more learners interact with genuine science, the more likely they may have to give up ownership of science. The culture of science indicates that participants need to follow specific guidelines, such as experimental design, evidence-based reasoning, and following careful procedures and measurements. Learners may have to give up certain autonomy and full control in order to collaborate well with others. The findings in this dissertation show that the outcomes of ownership in science learning depend on the strength of the ownership (no control to full control), the goals of the learners, what is being owned or sought after, and whether collaboration can occur. The

outcomes of ownership of science learning also depend on the balance of structure and freedom learners are allowed and how much of the structure and freedom they want. Too much open freedom may allow for increased ownership over certain aspects of science learning, but cause distractions and the inability to focus. However, too much guidance can stifle ownership and lead to negative affect about science learning.

Lastly, the findings in this dissertation indicate the characteristics of ownership can change over time. For some learners, ownership started strong, but diminished over time. For example, Donna started with strong ownership over her design ideas. However, during the course of KC, when the work became more involved and the facilitators asked her to slow down and reflect on her investigation process, she gave up ownership and wanted to simply ignore parts of the investigation. For others, changes in ownership was a long process. In Arman's case, he had a weaker ownership over his investigations. Arman's change in ownership over time would be a slow process, in which developing competencies over time may help ownership and confidence grow.

For other learners, ownership over aspects of their activities increased as their self-identity developed over time. I have shown in this dissertation that interaction in communities of practices (e.g., homes, schools) can influence how ownership took place in KC. As well, I have shown that shifts and changes in modes of engagement and self-identity (Wenger, 1998) impact how ownership takes place, both in KC and outside of KC. Both Ben and Freddie took on new imaginations of scientists as people who make mistakes. As they imagined mistakes and failures as part of the

science process, each of them took on possession and negotiation of the mistakes as something to be proud of and show off.

Discussion of SQ3: Based on the findings here in this dissertation, I suggest that the initial characteristics and outcomes of ownership in science learning are quite complex. As I mentioned in the literature review (Chapter 2), ownership is often conveyed in science education research as a “sense” or “feeling” that learners have. What my research indicates is that learners expressions of ownership have a wide variety of characteristics, from strong to weaker, negative to positive, expressive to subtle, and selfish to selfless. Therefore, aiming for a single goal for learners to have ownership hides the complexity that exists in how people express the need for control, possession, agency, and responsibility and what the outcomes are of that expression. I argue that much of how we need to interpret ownership of science learning is based on both the personal identity formation in communities and the social relationships and interactions. The findings of these case studies are significant, not only because they reveal how diverse the characteristics and expressions ownership are for learners, but they also raise the question, “what goals of ownership do we want for learners?”

For instance, Freddie exhibited strong and positive characteristics of ownership over his water investigation, but he also abandoned Anthony’s milkshake activity. Freddie also showed strong and negative ownership towards the facilitators’ guidance and structures, but he also needed discipline and focus in his investigation. Arman showed weaker and positive ownership that allowed for good collaboration, but was also too selfless and did not always want to make final decisions. These two

cases demonstrate that ownership is multifaceted and too complex of a personal trait for learning just to simply declare that learners need more opportunities for ownership. My research makes the case that researchers need to be careful when declaring that technology learning innovations and curricular interventions support ownership in learning.

The case studies also reveal the outcomes of ownership over science learning can lead to tensions. As I documented earlier, science education research rarely acknowledges the tensions in science learning as a result of ownership. Tensions include

- how do learners express ownership in groups compared to individuals (e.g., Enghag & Niedderer, 2008)
- the role of power and authority in classrooms (e.g., Cornelius & Herrenkohl, 2004; O'Neill, 2010)
- the role of ownership in enactment of authentic and legitimate science (e.g., Hay & Barab, 2001)
- structures and guidance can diminish learners' ownership (e.g., Kock et al., 2013; Reiser, 2004)
- the overprotection of ideas and unwillingness to accept other perspectives (e.g., Haglund & Jeppsson, 2012)

My findings show that all of these tensions in science learning and ownership were enacted in KC. What is important about these case studies is not that tensions in ownership exist, but the reasons behind ownership development and enactment that causes conflict. While many of these studies show the outcome of conflict in ownership, my findings reveal that conflict in ownership is tied to the development of self-identity in science. Very few studies have examined the role and development of

self-identity as it pertains to ownership, tensions, and how learners see themselves “doing science”.

What is ownership of science learning? This perception of what it means to do science is important for understanding what exactly “ownership of science learning” encompasses. As I noted, each learner came into KC with an imagination of what it meant to “do science” and each perspective was different. Since these views of doing science and learning science were different, each of them expressed ownership in diverse ways.

Ben imagined science as exploring investigation with unknown answers. When Ben focused on creating pizza balls, caramels, and trashcan brownies, he perceived himself to be doing science because these activities had not been explored and he did not know the answer to them. Even though these tasks were mainly engineering and product design focused, Ben perceived he was doing science because he was “being an investigator without the clues.” For Ben, taking control over these creative products and making large investments into the process of developing them is his ownership over science learning.

Arman imagined scientists through the perception of competencies and professions; what he termed as “legal scientists.” For Arman, doing science meant research and “taking in knowledge” from authoritative sources. This meant being quiet, following the lead of the adults, and playing a largely supportive role. For Arman, his framing of doing science meant being a good student. For Arman’s ownership of science learning, he took control of this role and made large investments of time to making sure the adults appeared happy with him.

Freddie imagined science as having full autonomy and control over all the investigation with little planning. Similar to Ben, doing science also meant “trying new things”, but it also meant “choosing whatever” he wanted. When Freddie was told to slow down and reflect, this went against his perspective of doing science. In Freddie’s case, even though much of what he was doing was an engineering task, his ownership of science learning is expressed when he sees himself having full hands-on experiences with questions he has and with full decision making practices. What is interesting about Freddie’s case is that he does have resources for owning inquiry practices in science through engineering failure of his Greenies and asking why that happened.

Donna imagined “fun science” and for her, science meant creating explosions. Although Donna was exposed to scientists (e.g., mother, mothers’ lab) and their context, Donna never characterized doing science as slow and reflective. Similar to her small experiments in her mother’s lab, doing science was meant to be experimental, fast, fun, and show dynamic reactions. For Donna, ownership of science learning meant taking control of activities and tasks that produced exciting outcomes (e.g., tasty food products, explosions) and investing into hands-on activities that were fun for her.

Each of these learners’ different imaginations of science affected how learners engaged and aligned to the practices of science in KC. Since Arman perceived scientists in a professional role, he welcomed more scaffolds and guidance to help him navigate through experimental design. However, the scaffolds and facilitator guidance proved to be difficult for Freddie and Donna, who imagined themselves as

having total control over the entire process. Both Ben and Freddie imagined science as an exploration of unknown design ideas; in their cases, engagement and alignment in science meant being able to develop new questions and ideas about the phenomenon or product at hand. Ben and Freddie wanted to own and control aspects of their activities to pursue new observations and ideas about the phenomenon. For Donna, who imagined herself as a baker and candy designer, the pursuit of arguments and ideas did not appeal as much to her.

These case studies demonstrate that being able to define ownership of science learning is difficult as each learner's conceptions of science learning were often different. One possibility is that KC is not a long established community of practice. Instead, over the course of 12-weeks in KC, the children attempted to engage in science on their own terms, rather than long established practices that were well recognized. As a result, using the framework of imagination, engagement, and alignment to examine the children's internal perspective in KC meant making multiple interpretations of how each focal learner negotiated their perspective of what it meant to do science in KC.

Interestingly, all four learners had generally positive views of science; they all stated they enjoyed learning science in schools, homes, and field trips and expressed that science made contributions to their lives. However, each of these cases show that the perception of science learning can even be different between peers and even what researchers define as inquiry-based science (e.g., Chinn & Malhotra, 2002). Even though as researchers we observed the children mainly in cooking and design tasks (as opposed to reflection and inquiry), the four children here saw themselves in these

cooking tasks as doing science. While O'Neill and Barton (2005) partition ownership of science learning into five themes, this dissertation extends their framework, in that it is also important to understand how each learner imagines, engages, and aligns to their own conception of what science learning means to them. For instance, as adult facilitators, our perceptions of science learning focused on aspects of slower reflection, asking critical questions, designing experimental setups, and determining measurements of multiple variables (e.g., Chinn & Malhotra, 2002). This perspective often came into conflict with the children's view of doing science, which ranged from taking in knowledge from authorities to trying out new ideas with full autonomy.

I contend that understanding how imagination, engagement, and alignment shifts in communities of practice allows us to interpret ownership, not just as a series of actions towards control, agency, and possession, but gives us insight into the evolution of identities within different communities. For example, Hay and Barab (2001) noted that increased authenticity helped to support ownership over science for learners because the learners developed pride over accomplishing tasks that were important in real-world science. What my dissertation argues is that Hay and Barab's assertions on ownership are true, but this also depends on the imagination of science of the learners, what prior engagements learners have had in science, what alignment learners make, and the goals learners bring forth. The change over time of ownership in science learning is a reflection of the changes in self-identity and goals. This dissertation makes the argument that understanding the evolution of ownership of science learning also means examining how learners have engaged in science in

schools and other communities (e.g., homes, afterschool, camps) to get a full picture of ownership.

Sub-question 4 (SQ4): How might the features (e.g., facilitation, technology) of KC, school, home life, and other contexts potentially impact and influence how ownership takes place in learners?

Summary of findings: My dissertation reveals that ownership of science learning is both a personal and social characteristic that is influenced and cultivated over many factors between different communities of practices. Most of the literature only examines ownership of science learning as it pertains to science learning in the classroom. My case studies shows that a better interpretation of ownership of science learning can be made when we examine both the factors in and outside of the classroom and what connections exist between the different microsystems.

I found a number of factors that influence ownership of science learning, both in KC and outside. First, unsurprisingly the facilitators in KC largely influenced how ownership took place. Similar to O'Neill's (2010) action research study, the facilitators created ownership structures that allowed learners to have a sense of control and agency. The facilitators gave learners a shared space and materials. This allowed learners to develop responsibility for their own investigations and gave them a chance to glance and socialize at each other's projects (Gardner, 2011). The facilitators also encourage creative idea development. Creativity in the ideas allowed learners to take risks they had never taken before. When failures occurred, facilitators helped learners negotiate mistakes into opportunities for learning. Facilitators also encouraged learners to come up with their own organizational schemes, measurement procedures, and investigation development. The most surprising finding of the

facilitators was the need to remind learners about ownership. Even though learners developed initial ideas for the investigations, the learners constantly needed reminders about responsibility, possession (e.g., “this is your investigation.”), and choice (e.g., “I can’t make this decision for you.”).

Second, similar to the facilitators, social relationships in and outside of KC impacted ownership. Relationships are an important component to the targets of ownership that learners seek after. Some learners needed time to collaborate and develop mutual engagement and shared practices before they established comfort in taking control and agency of their investigations. Learners also needed ways to share their design ideas to others. For many in KC, families acted as the audience. The learners were quick to share their investigation ideas with their parents and wanted them to help out. They also took other people’s ideas and created their own inspirations for investigation. However, other learners needed privacy and independence before they could engage with anyone else with their ideas.

Third, the technology acted as a mediator for ownership. Although the learners did not take direct ownership over the technology, they used the technology as an expression of ownership in science learning. Some learners used StoryKit to indicate what aspects of the activities were important to them. They took photos of each other, drew pictures, and personalized many of their stories on the investigations. Others used the social media tool SINC to post ideas and make known the authorship of those ideas. Learners also used SINC to browse other learners’ contributions to get inspiration and to riff and remix off the posted ideas. Scaffolding and guidance from SINC also allowed the learners to interact with the facilitators to

better go through the ideation process. Each of these factors helped learners to 1) declare authorship over ideas using digital media; 2) refine ideas so that the learners become more invested in them; and 3) slow down learners so that they could reflect more on their investigations and become more invested into the process.

Lastly, the social interactions and experiences in science learning in home and school communities the learners engaged impacted ownership in KC. As I wrote before, ownership of science learning is not a personal construct that is isolated in the classroom. Feelings and expressions of possession, agency, and choice do not simply stay in a single location. These findings show that as learners interact in science learning in the different microsystems (e.g., home, school, KC), learners' self-identities evolve and change through imagination, engagement, and alignment. As the modes of engagement shift, ownership of science learning will also shift since ownership is a reflection of self-identity (Pierce et al., 2003).

Discussion of SQ4: The findings in this dissertation support the assertion that ownership in learning needs cultivation (e.g., O'Neill, 2010). What this dissertation reveals is how cultivation of ownership needs to take place beyond a single microsystem. Most of the literature that refers to ownership of science learning generally indicates one space and usually it is the classroom. Science education research tends to attribute the cultivation of ownership towards a particular curriculum, technological innovation, or teaching style. Very few studies have been conducted on how learners' everyday lives impact ownership in science learning. Anastopoulou et al. (2012) is one of the few studies that show the impact of home factors on learners' ownership of science in school.

These dissertation findings are significant because they show the dynamic relationship and interconnections among the three communities through ownership. Each of the learners' science experiences among the three microsystems influences their identities in science and how ownership is expressed. For instance, even though the KC facilitators played a large role in supporting ownership in science learning, the experiences in science at home and school played also impacted what support was needed. All of these case studies show learners' experiences at home and school in science greatly influenced how they want to take (or not take) ownership of science learning in KC.

Ownership is tied to perceptions of power and who is able to own and not own learning (e.g., Cornelius & Herrenkohl, 2004). For example, the perception of adult authority in science influenced whether or not learners wanted to take ownership of aspects of their investigation. Even though the facilitators attempted to cultivate a culture in which learners could take on ownership, how the learners imagined the adult power and their role in science influenced how that ownership could be expressed.

Ownership of science learning is not a unidirectional influence from outside forces, but it is bidirectional. Although home and school experiences influenced how learners took ownership in KC, experiences in KC also affected how learners took ownership of science learning at home and in school. All four of the focal learners stated that science in KC was different than science in school and home. They also realized the degree of ownership they had in school and home science was different.

In two of my cases (Freddie and Ben), the perception of what it meant to do science shifted for the learners as their modes of engagements evolved over time. Both of them recognized that “doing science” at home, school, and KC differed between the contexts. Furthermore, they negotiated expectations between home and school and brought those expectations into KC and continued negotiating their perspectives of science and ownership there. The learners began to see what they could own in science depended on the relationships and supports that were present and what it meant to have the ability to make choices and decisions. This study argues that supporting ownership of science learning in learners is not about just empowering learners in one setting, but understanding the connections that occur across different communities and what relationships learners interact with.

10.2 Summary and Conclusions

In this chapter, I summarized the findings of my dissertation in the four sub-questions and I discussed the significance of these findings. In short, the evolution of ownership in science learning is a difficult concept to pin down because it depends on how learners conceptualize what it means to “do science” in their lives. These four focal learners show that even though they all had positive views of science in their lives, each of them had different perspectives of how they thought they enacted science in KC, homes, and schools. As a result, as these learners came to imagine, engage, and align into the practices of KC, they all had different ways they expressed what they owned. Specifically, even though learners may have taken control solely of cooking tasks and making food products, they also expressed this was science to them. In this way, what children own in science learning and how they express

control, possession, and investment is dependent on their perception of what it means to do science.

Chapter 11 is the final conclusion chapter. Here, I will outline the major theoretical and design contributions of this dissertation and discuss the implications of my findings to researchers, educators, and learning environment and technology designers.

Chapter 11: Implications and Conclusions

The goal of this study has been to contribute to both the theory and understanding of how ownership of science learning evolves and to inform the design of learning environments and technologies to best support ownership. In this chapter, I outline the theoretical contributions of my dissertation (11.1). Second, practical implications of this dissertation to three audiences: practitioners and learning environment and technology designers (11.2). Third, I express the limitations of this study (11.3). Finally, I make my final conclusions and suggestions for future research (11.4).

11.1 Theoretical Contributions

Theoretical contribution #1: *Unpacking ownership in science learning involves understand how learners think they are doing science.*

This dissertation highlights the complexity of ownership in science learning. Ownership of science learning is not a single definable and generalized construct. Instead, understanding ownership of science learning may be based more on examining how learners imagine, engage, and align into practices of how they think they are “doing science” in different contexts and what targets they choose to seek after in these spaces.

One of the contributions of this dissertation is highlighting the difficulty in situating the ontology of ownership in learners. While much of the literature focuses on developing ownership in science learning for learners (e.g., O’Neill & Barton, 2005; O’Neill, 2010), this dissertation shows that it important to understand 1) how learners conceptualize their own imagination, engagement, and alignment to science

learning; 2) what targets they go after (or do not go after); and 3) the contexts in which they seek after these targets. All of these cases demonstrate that even though the learners all had overall positive perceptions of science learning, they all had different conceptions of what it meant to “do science.” Despite the complexity, this dissertation shows that we as researchers can recognize ownership as it is developing through an analysis of learners’ imagination, engagement, alignment, targets of ownership, and contextual information.

For instance, a child making green brownies for the first time may think of this task as doing science because of an imagination, engagement, and alignment towards practices that reflect science as trying new things out through hands-on experiences. Even though from an adult research standpoint, designing the green brownies is an engineering design task, the child continuously engages, controls, and invests and depicts this activity as doing science because they define science as innovation and design. The child can have ownership over the product, the process, and the design ideas; this may be how learners conceptualize what it means to do science, even if it does not fall under research definitions of inquiry learning (e.g., Chinn & Malhotra, 2002). As a result, how children indicate what it means to do science can often conflict with how adults (e.g., teachers, researchers, parents) define doing science, and this tension can be expressed through conflicts in ownership and control when one tries to impinge on what science is with the other. This is not to say that adults should not attempt to guide and scaffold what inquiry-based learning is and its utility. Instead, my dissertation attempts to show that understanding ownership

of science learning means exploring why learners pursue certain targets, what contexts they pursue them, and how perceive that pursuit as part of science.

Theoretical contribution #2: *Opportunities for ownership in science learning are important, even though it may take a while before learners develop ownership over inquiry-based practices. However, learners have resources and funds of knowledge that can help to begin to develop ownership in inquiry-based practices.*

These four cases demonstrate some of the difficulty in helping to cultivate ownership of inquiry-based practices. As this dissertation shows, ownership of certain targets and can be fast or slow, strong or weak, and positive and negative. All the learners in KC were given opportunities to design personal investigations around food. As facilitators, we attempted to connect inquiry-based practices of science learning into the design of these food investigations, in order to facilitate learners taking on more control, possession, and investment in their learning. However, it was often not easy and learners did not always want to delve into inquiry-based practices we thought were necessary in science learning. Instead, many of them framed their activities as designing cooking products or getting their hands messy in the kitchen. They wanted to be creative with design tasks, but did not always necessarily want to slowly reflect on the mechanism of how caramel mixtures congeal or think about how eggs act as emulsifiers.

However, this is not to discourage the notion of cultivating ownership in science learning. Many learners described KC as the only place and opportunity they thought they had to “do science.” Instead, it may be more fruitful to consider what epistemological resources children have that can lead to ownership of inquiry-based practices and how learning environments can facilitate this (Hammer & Elby, 2002).

For instance, this study showed that the children do ask questions about food preparation and creation to their families after engagement in KC. As learners develop ownership over their food product, they asked more questions about the ingredients and the preparation with their families. It is during these conversations that inquiry-based learning can take place within families and schools, but this takes time to nurture. Learners also expressed they perceived a difference between science that occurred in schools and home compared to science in the kitchen. Even though much of what the children did appeared to be baking and cooking, the opportunities in KC allowed learners to try new ideas and to find ways to connect personal interests to science learning. It may be that these opportunities to own and control can later lead towards pursuit of inquiry-based practices.

Theoretical contribution #3: *Ownership of science learning is not a construct that resides only in the science classroom. Instead, like learning and identity, ownership is influenced by the interactions of the learner in multiple microsystems in a given mesosystem. We can use communities of practice as a framework to analyze and examine the ownership across different settings.*

My analysis shows that examining the evolution of ownership meant understanding the interactions of the learners between KC, home, and school. For all four of my focal learners, ownership of science learning was not isolated in KC. Arman, Ben, Freddie, and Donna all had experiences in science and in their communities that influenced how they took on ownership of certain targets in KC. All four learners also expressed that they observed differences in ownership between KC, school, and home. As well, two of my focal learners, Ben and Freddie, took on practices of KC at home. The research on the evolution of ownership in science learning needs to further explore other contexts that can connect to formal schooling.

This dissertation highlights the importance of how home and school contexts impacted and influenced ownership practices in KC and vice versa. Understanding the microsystems and mesosystems that learners reside in is critical to exploring human development (Bronfenbrenner, 1977).

Specifically, in this dissertation I used Wenger's (1998) framework of modes of engagements in communities of practices to analyze and make interpretations of ownership. As mentioned earlier, KC is not a widely established community of practice; the discipline and focus itself was still evolving and forming. As a result, the findings I observed of the focal children were that they were still trying to figure out for themselves what it meant to own science and what it even meant to do science in such a new context. Instead of following along a specific trajectory in KC, learners were negotiating and situating their ownership practices from their homes and schools.

11.2 Practical Implications

11.2.1 Implications for STEM Educators

First, ownership over design ideas and the products of design could be key resources for getting learners engaged in STEM inquiry-based practices. We observed that some learners often did not want scaffolding towards inquiry, while others generally were fine with it. For many learners in KC, this was their first opportunity to create, design, and engineer foods in ways they never did before. They needed moments of unstructured play with food just to develop a sense of ownership over the activity.

Second, facilitators and educators should still attempt to scaffold and guide inquiry-based practices, even if some learners reject these practices. Facilitators and practitioners should make attempts to scaffold and build towards inquiry-based practices. However, ownership over reflection and inquiry processing may come later after learners think more deeply about their designs. Initial pushback against reflection and slowing down are not indication that ownership will never take place. In this case, ownership over inquiry-based ideas, explanations, and reflections take time and may not occur in a linear or predictable fashion. Instead, if learners truly care about their designs and the process of creation, they may come to own science learning and have their own resources in ways we would not preconceive of.

Lastly, facilitators and educators need to be aware of learners that just follow along the lead of the adult. Even if learners strongly pursue inquiry-based practices, this is not indicative of ownership over those practices. Arman went through KC spending numerous amounts of time investing into the practices of KC, but my case study demonstrated he did not take ownership of the reflection and reasoning needed in inquiry-based learning. For example, learners like Arman, he may need more time and develop confidence over time to assert their ideas.

11.2.2 Implications for Learning Environment Design

Learners often are not given a chance to make decisions and choices about their learning. Therefore, the design of the learning environments plays a pivotal role in cultivating ownership. First, the environment needs opportunities for ownership that are not directly focused on learning. For instance, Gardner (2012) states in her dissertation that the option to take responsibility for the space and grab materials

when necessary fostered more social interactions. Learners could choose to get materials when they needed from the pantry and start to converse with others on what they were doing. In this way, learners could share what they were doing in their investigations and develop pride and investment in their work. However, space also needs to be negotiated for control and ownership. Learners were not allowed to touch the hot oven. They also needed to respect each other's space and not interfere. Learners also became territorial of space and would invite others in when they wanted to. Learning environment designers should consider finding ways to build science learning into other familiar spaces, such as the gym, parks, and basketball courts.

Second, one of the key implications of this study is the role of engineering integration and science inquiry-based learning into learning environments to cultivate ownership. Specifically, the role of failure and mistakes is a resource that can be built into environment and activities. Learners in KC needed to perceive that creativity in their investigations was allowed and that failures and mistakes were cultural norms. In particular, learning environments can give learners the opportunities to “fix” engineering failures and use ownership of design to support ownership of inquiry-based practices. Within engineering education, Kazerounian and Foley (2007) note that in order to foster creativity in learning, students must learn to fail. Mistakes and failures can lead to deeper understanding; however, students must also not fear discipline, embarrassment, and risk.

Learners may have to learn how to fail, but they need to also own the mistakes and failures they make. Learning environments can be designed to promote “ownership of failure.” Although, this dissertation has only begun to scratch the

surface on research on the connection between ownership and failure, one practical design application for environments is to structure and build in times for learners to share their failures with others, including parents and other adults. In KC, when failures happened many learners spontaneously shared with others about these cooking disasters, but also let others know this was “their” mistake. In moments such as these, the possession of mistakes can become a resource towards further reflection. By sharing with other what mistakes happened and why they thought the mistakes happened, the risk of embarrassment might be minimized. Some learners may develop more ease in possessing the mistake as an opportunity to learn and reflect. Being able to promote and design a culture of ownership over failure may support self-regulated learning (e.g., Duckworth & Britain, 2009), productive failure (e.g., Kapur & Bielaczyc, 2012), and grit and determination (e.g., Duckworth, Kirby, Tsukayama, Berstein, & Ericsson, 2011).

However, I need to make a caution about designing learning environments for ownership of failure. Some results from design may not be failures at all. For example, Arman thought that his spreadable cookies experiment was a mistake because the two cookie types did not show significant spread differences. He showed disappointment that his prediction did not come true. In this case, the result that was generated may not be a mistake per se, but framing it this way can mislead learners into thinking of knowledge in science as correct and incorrect answers. Some design projects are easier to determine if they are failures or successes, while others may be more nuanced. It is important in setting up a learning environment that cultivates ownership of failure to recognize some of these possible complexities.

11.2.3 Implications for Learning Technology Design

From my findings of this dissertation, the role of technology in supporting ownership of science learning may not be explicit. Indeed, the technology is not central to the implementation of KC. Learners can still design, create, and reflect on their Choice Day activities with simply a pen and paper. However, what makes the usage of technology worthwhile in KC and ownership is its ability to help learners slow down, reflect, and personalize their work, while at the same time, allowing learners to collaborate and share ideas with others. These affordances can help in supporting and cultivating aspects of ownership.

First, learners should have consistent accounts and an ecosystem to store data and recordings. One limitation of this study was the use of three different apps (StoryKit, Zydeco, and SING) in KC. Each of these apps was standalone and the data could not connect between each other. We also did not give learners consistent iPads™ each week. As a result, the collection of the data and the recordings of the iPads™ were too fragmented for learners to start developing investment into storytelling, recording data, and sharing. One moment the learners would use Zydeco to collect data; another moment they would write a story; and the next they would use SING to develop the ideas. However, none of the data and recordings in these three standalone apps could be used with each other and stored in a portfolio system. I make the recommendation in order to cultivate and develop science ownership across settings, we will need to develop a socio-technical ecosystem that 1) allows learners to switch roles easily (e.g., storyteller, recorder, idea generator, collaborator), 2) can be taken into different communities (e.g., home, school, after school), and 3) gives

learners a chance to reflect back onto the data and recordings they have made. Similar to a portfolio, learners should be given an account in this ecosystem that gives them a chance to see their progression of science learning within home, school, afterschool, and other settings.

Second, ownership over ideas, knowledge, and information can be very strong in learners. Learners need the choice to either post ideas or knowledge privately or publically. This study shows that ownership of ideas and knowledge is a sensitive issue for learners. Ideas and knowledge are value laden and the perception of who controls information and ideas (e.g., teachers, other learners) gives that person power (e.g., Cornelius & Herrenkohl, 2004; Goodnow, 1990). Learners' ownership over ideas are a reflection of their developing identities and internal cognitive structures (e.g., Papert, 1980). As such, publically showing their ideas without attribution, consent, or reflection may cause conflict. In this study, Donna's anger over her ideas being stolen from Anthony shows the sensitivity over authorship and ownership. She needed a chance to work privately and independently on her ideas with a facilitator before someone else could hear it. Learners also valued ideas greatly and wanted to openly share them with other participants, as long as credit was given properly.

Based on the results of this study and the literature, I recommend that designs in sharing in technology can support ownership of learners in science. First, learners need to be given options for public and private posts of ideas, knowledge, and information in science learning. Learners may initialize and think about their ideas, but may want feedback from certain members of the community (e.g., teachers, facilitators, friends, parents). They may not want to post ideas and knowledge onto

any social media or online forum just yet. Learners may need options to either choose full open access, limited access, or temporary no-access. Similar to remixing in the Scratch community (Monroy-Hernández, Hill, Gonzalez-Rivero, & boyd, 2011), learners need to also recognize that others may remix their ideas and knowledge. As such, community guidelines need to be put in place to protect both the poster and the remixer. Notes need to be place to add credits to the ideas.

11.3 Limitations of the Study

Although I have outlined numerous recommendations and implications for researchers, educator practitioners, and learning environment and technology designers, I must address several limitations to this study.

First, this study is a small sample of four focal learners in an independent Montessori elementary school. As such, the findings are not meant to promote statistical generalization over a large population, but theoretical propositions (Yin, 2003). As mentioned before in Chapter 3, I consider this case an ideal case because of the settings and support we received to conduct this study. The ideal case shows that if problems occur in ownership, it is likely other less ideal contexts could show more difficulties in ownership development. Indeed, the development of ownership of science learning was diverse and not the same in all learners. Some learners evolution of ownership developed in a way that helped them identify further with scientists, while others did not shift and experienced difficulties in developing ownership. Although this study was conducted in such a small ideal setting, I speculate that since ownership of science learning was difficult to maintain, the possibility exists that ownership development will be a challenge in a number of contexts.

Second, this small study was conducted as a 12-week after school program. The evolution of ownership may need longer time to develop in learners. Specifically, since ownership is tied to self-identity development how learners see their competencies in science may influence their self-efficacy. It may take a long time for ownership to develop and 12-weeks may not be enough time to see large shifts.

Third, home and school access was limited in this study. Science in The Green School was not conducted in specific lessons or classes. As a Montessori school, learners had choices on when to engage in science learning given the plans of their day. It was difficult to fully observe how learners engaged themselves in science with others in the classrooms. Home interactions in science were also spontaneous events. It was impossible to come and make direct observations on how learners engaged in science at home. For both school and home, much of the data was anecdotal from the learners, teachers, and parents. As much as I could, I attempted to triangulate the stories I recorded from the participants of this study to make sure these anecdotes could be verified.

11.4 Final Conclusions and Future Studies

This study builds on the work of ownership of science learning. I set out to explore how ownership of science learning evolves and what factors from home, school, and KC influence how ownership develops. Ownership is more than a feeling or need for possession and control. I show that ownership is a complex construct and its evolution is based on a combination of personal and social factors. I discuss how identity development through imagination, engagement, and alignment, targets of ownership, social interactions, and different communities of practice impact the

development and expression of ownership. I believe this model of ownership has many applications for researchers, education practitioners, and learning environment and technology designers.

I suggest that future studies on ownership will need to be conducted to examine the connection between learning and the evolution of ownership. Specifically, I recommend more studies that examine the impact of learners' ownership on specific targets affects the outcomes and development of learning. I also recommend future studies to examine the viability of the conceptual model I developed in other cases and contexts. I believe to better understand ownership of science learning we need to look beyond just examining a single context (e.g., classroom). Instead, future studies may look into the role of bridging learning between home, school, and afterschool to understand how ownership plays a role in connected learning. Future studies can also address ownership over specific targets, such as ownership of failure and how this relates to learning. Finally, studies on technology integration to support ownership will be a necessary key in bridging. Mobile and wearable technologies can be used to connect members across different communities of practice and help learners further develop science dispositions and ownership in multiple settings.

In conclusion, ownership is a key characteristic found in all humans. Our ability and need to control, possess, invest, and manipulate non-material and material objects is such a basic part of who we are and our social interactions, but is still not fully understood in its role in learning. Ownership and our expressions of what we own are a reflection of the internal and dynamic shifts in our self-identity. It is my

hope that we can develop environments, technologies, and pedagogical strategies that allow learners to see themselves as scientists and be able to take on ownership of their own learning.

Appendices

Appendix A: Literature Review on “Ownership” (2008 – 2013)

Author	Title	Purpose	Citations to ownership (Y / N)	Positive / Negative / Mixed / NA	Context of learning	Target of ownership	Unit of analysis
Anastopoulou et al. (2012)	Creating personal meaning through technology-supported science inquiry learning across formal and informal settings	A study that reports an approach to engaging students in personal inquiry learning	N	Mixed	High school science classroom and home	Inquiry process, personal inquiry, technology.	28 high school students
Bang and Medin (2010)	Cultural processes in science education: Supporting the navigation of multiple epistemologies	A study using a conceptual framework that focuses on culturally-based epistemological orientations of Native Americans with science instruction.	N	P	Science learning in tribal schools	Science	Communities of Native Americans
L. K. Berland & McNeill (2010)	A learning progression for scientific argumentation: Understanding student work and designing supportive instructional contexts	In this study, the authors compare four examples from elementary, middle, and high school science classrooms to see how students' argumentation varies	N	P	Elementary, middle, and high school science classroom	Scientific practice	Students' argumentation
Chen, Hand, and McDowell (2013)	The effects of writing-to-learn on elementary students' conceptual understanding: Learning about force and motion through writing to older peers	A study examining how fourth graders conceptual understanding of force and motion changes as they write to 11th graders	N	P	Elementary and high school science classrooms	Writing	835 elementary school and 416 high school students
Clark and Sampson (2008)	Assessing dialogic argumentation in online environments to relate structure, grounds, and conceptual quality	The article is an analytic framework for assessing argumentation in online science learning environments that relates levels of opposition with discourse moves, use of grounds, and conceptual quality.	N	P	Four classes of eighth grade students	Ideas	Student arguments
Cronje, Murray, Rohlinger, and Wellnitz (2011)	Using the science writing heuristic to improve undergraduate writing in biology	A study that investigates the impact of the Science Writing Heuristic (SWH) on undergraduates' ability to express logical conclusions and include appropriate evidence in formal writing assignments	Y	P	Undergraduate laboratory sections	Inquiry	Students in three laboratory sections
Dianovsky and Wink (2012)	Student learning through journal writing in a general education chemistry course for pre-elementary education majors	This paper describes research on the use of journals in a general education chemistry course for elementary education majors.	Y	P	Elementary education course	Learning	Elementary education students
Dorion (2009)	Science through drama: A multiple case exploration of the characteristics of drama activities used in secondary science lessons	The study focused on teachers' own drama activities in five lessons taught across England.	Y	P	High school science classroom	Learning	Pre-post interviews with teachers and students
Evagorou and Osborne (2013)	Exploring young students' collaborative argumentation within a socioscientific issue	This study follows a case study design, examining two different pairs from a class of 12- to 13-year-old students that participated in a specially designed instructional approach within a socioscientific issue.	N	P	Middle school science classroom	Argumentation	Student arguments
Fields (2009)	What do students gain from a week at science camp? Youth perceptions and the design of an immersive, research-oriented astronomy camp	This study explored an American high school students' perceptions of the benefits of a summer astronomy camp.	Y	Mixed	Summer astronomy camp	Research project and creative and critical work, design and implementation of research projects, mastery of a tool and piece of technology	Staff and campers
Ha and Song (2009)	Patterns of linguistic communication in teaching and learning science: A case study of Korean middle school science classes	The purpose of this study is to investigate patterns of linguistic communication in learning and teaching science and to find out how the formation of each pattern was related with the classroom, particularly in Korean middle school context.	Y	P	Korean middle school science classroom	Open-ended science inquiry	Science classes in three middle schools

Author	Title	Purpose	Citations to ownership (Y / N)	Positive / Negative / Mixed / NA	Context of learning	Target of ownership	Unit of analysis
Haglund and Jeppsson (2012)	Using self-generated analogies in teaching of thermodynamics	A case study examining the role of analogies and ownership in teaching thermodynamics	Y	Mixed	Preservice teacher university course	Learning, analogies, creative aspects of self-generated analogies, ideas	8 preservice teachers
Haglund et al. (2012)	Young children's analogical reasoning in science domains	An exploratory study in a classroom setting that investigates first graders' (age 7-8 years, N = 25) ability to perform analogical reasoning and create their own analogies for two irreversible natural phenomena: mixing and heat transfer.	Y	P	Elementary school science	Learning focused on analogies	Children's analogies
Hay, Williams, Stahl, and Wingate (2013)	Using drawings of the brain cell to exhibit expertise in neuroscience: Exploring the boundaries of experimental culture	This paper explores the research perspective of neuroscience by documenting the brain cell (neuron) drawings of undergraduates, trainee scientists, and leading neuroscience researchers in a single research-intensive university.	N	P	University science setting	Science concepts	Undergraduates, trainee scientists, and neuroscience researchers
Holmegaard, Madsen, and Ulriksen (2012)	To choose or not to choose science: Constructions of desirable identities among young people considering a STEM higher education programme	This paper presents results from a Danish longitudinal study which examines students' choice of whether or not to continue studying STEM after upper-secondary school.	Y	P	Upper secondary school	Education	38 students
Hsu, van Eijck, and Roth (2010)	Students' representations of scientific practice during a science internship: reflections from an activity-theoretic perspective	The purpose of the study is to further address the debate in terms of the ethnographic data collected during an internship programme for high school students right through to their public presentations at the end.	Y	P	Internship program for high school	Investigating science issues in authentic science contexts	Students in science internship program
Hsu and Roth (2009)	Lab technicians and high school student interns—Who is scaffolding whom?: On forms of emergent expertise	The purpose of this paper is to report the results of an ethnographic study of high school students' internships in a scientific laboratory.	N	P	Science internships in a lab	Open-ended science inquiry	50 participants (13 high school students, 1 high school teacher, 2 scientists, 5 technicians, 25 laboratory members, and 5 educational researchers)
Hug and McNeill (2008)	Use of first-hand and second-hand data in science: Does data type influence classroom conversations?	In this study, the researchers examine how students discuss and interpret data and whether these actions vary depending on the type of data they analyse. More specifically, they are interested in whether students perform differently when analysing first-hand data, which they collect themselves, compared with second-hand data provided to them.	Y	P	Middle school science classroom	Data (first-hand and second-hand)	Students in middle school class
Hume and Coll (2008)	Student experiences of carrying out a practical science investigation under direction	This paper reports on the reality of classroom-based inquiry learning in science, from the perspectives of high school students and their teachers, under a national curriculum attempting to encourage authentic scientific inquiry (as practiced by scientists).	Y	P	Secondary schools	Clear learning goals	Students from two large schools
Kim and Tan (2013)	A collaborative problem-solving process through environmental field studies	This study explored and documented students' responses to opportunities for collective knowledge building and collaboration in a problem-solving process within complex environmental challenges and pressing issues with various dimensions of knowledge and skills.	N	P	Middle school and high school science classrooms from two Singaporean public institutions	Knowing and learning in group work	32 students from two Singaporean public schools
Kind et al. (2011)	Peer argumentation in the school science laboratory—Exploring effects of task features	This study explored the impact on the quality of argumentation among 12- to 13-year-old students undertaking three different designs of laboratory-based task.	N	P	Middle school science classroom	Data	12-13 year old students in a laboratory based tasks

Author	Title	Purpose	Citations to ownership (Y / N)	Positive / Negative / Mixed / NA	Context of learning	Target of ownership	Unit of analysis
Lee et al. (2012)	Socioscientific issues as a vehicle for promoting character and values for global citizens	The main objective of the study was to observe how and to what extent socioscientific instruction might contribute to cultivating character and values as global citizens.	N	P	High school science classroom	Actions, issues	132 ninth-grade students over 3–4 weeks
Lehesvuori, Viiri, Rasku-Pattonen, Moate, and Helaakoski (2013)	Visualizing communication structures in science classrooms: Tracing cumulativeness in teacher-led whole class discussions	This study addresses how classroom talk develops by presenting how different communicative approaches constitute a specific, cumulative communication structure.	N	P	High school science classroom	Ideas	Science classrooms
Luehmann (2009)	Students' perspectives of a science enrichment programme: Out-of-school inquiry as access	The study is an analysis of the students' own perspectives on a specific out-of-school program—a one-year partnership with a university-based science outreach program, which culminated in a half-day laboratory experience for a total of 292 secondary students (ages 11–18 years).	N	P	Half-day laboratory experience	Perspectives, enacted curricula	292 secondary students (ages 11–18 years)
Maskiewicz and Winters (2012)	Understanding the co-construction of inquiry practices: A case study of a responsive teaching environment	The study examines how different instantiations of inquiry emerged in two different years of one elementary teacher's classroom.	Y	P	Elementary school science	Learning	Longitudinal observations of a 5th grade class
Padalkar and Ramadas (2011)	Designed and spontaneous gestures in elementary astronomy education	This study examines how gestures and actions can convey spatial and dynamic properties of systems. Problems in learning elementary astronomy are analysed in the context of demands of spatial thinking, in a system which is not amenable to direct perception, namely, the sun–earth–moon (SEM) system.	N	P	Astronomy lessons in Grade 4 and Grade 7	Gestures	80 students from three different schools in India
C. Price & Lee (2013)	Changes in participants' scientific attitudes and epistemological beliefs during an astronomical citizen science project	This study (1) how volunteers' attitudes towards science and epistemological beliefs about the nature of science changed after six months of participation in an astronomy-themed citizen science project and (2) how the level of project participation related to these changes.	N	P	Citizen science astronomy project	Process and product of projects	Pre-post tests of 333 participants
Prins et al. (2008)	Selection of authentic modelling practices as contexts for chemistry education	The aim of this study was to explore, analyse, and select authentic chemical modelling practices for use in chemistry education.	N	P	High school chemistry classroom	Modeling, topic, modeling knowledge	Student interests and expert opinions
Rivera Maulucci (2013)	Emotions and positional identity in becoming a social justice science teacher: Nicole's story	A case study of the historical development of an African-American, Caribbean preservice teacher's social justice stance.	Y	P	Pre-service science teacher education	Science	A single teacher
Rule et al. (2011)	Impact of adaptive materials on teachers and their students with visual impairments in secondary science and mathematics classes	This study focused on attitude and instructional changes across the year of the programme in 15 science and mathematics teachers educating students with visual impairments.	Y	P	School science	New information	Students with visual impairments and their teachers.
Sloman and Thompson (2010)	An example of large-group drama and cross-year peer assessment for teaching science in higher education	Undergraduate students pursuing a three-year marine biology degree programme (n = 86) experienced a large-group drama aimed at allowing them to explore how scientific research is funded and the associated links between science and society.	N	P	Undergraduate marine biology	Role	86 undergraduate marine biology majors

Author	Title	Purpose	Citations to ownership (Y / N)	Positive / Negative / Mixed / NA	Context of learning	Target of ownership	Unit of analysis
Smith et al. (2012)	Developing scientific literacy in a primary school	The study examines the expertise of primary teachers by analyzing the insights and thinking that emerged as they attempted to unravel some of the pedagogical complexities associated with constructing an understanding of scientific literacy in their own classrooms	N	P	A Catholic primary school in Australia	Learning	Teachers
Tran (2011)	The relationship between students' connections to out-of-school experiences and factors associated with science learning	This study examined the relationship between students' out-of-school experiences and various factors associated with science learning.	Y	P	Survey of science learning experiences across contexts and science understanding of learners from two urban high schools	Learning process	1,014 students from two urban high schools
van der Valk and de Jong (2009)	Scaffolding science teachers in open-inquiry teaching	The present study deals with a school-based professional development trajectory for secondary science teachers, aiming at scaffolding teachers in open-inquiry teaching for the topic of water quality	N	P	High school science classroom	Investigations	Teachers
van Rens, van Muijlwijk, Beishuizen, and van der Schree (2011)	Upper secondary chemistry students in a Pharmacochemistry research community	This study deals with the participation of 10 upper secondary chemistry students, aged 16–17, and their chemistry teacher in a pharmacochemistry research community on anti-allergy medicines at VU University, Amsterdam, The Netherlands.	N	Mixed	High school science and university partnership	Research	Students and teacher
Vos, Taconis, Jochems, and Pilot (2011)	Classroom implementation of context-based chemistry Education by teachers: The relation between experiences of teachers and the design of materials	The study identifies characteristics of the interaction between innovative context-based materials and teachers that hinder or facilitate classroom implementation as intended by the designers.	Y	P	Science classrooms in the Netherlands	Actions	Artifacts and observations of the classrooms

Appendix B: Connecting Data Sources With the Sub-questions

Sub-questions	How to answer the question	Data sources
SQ1: What aspects of the design activities (e.g., technology, products, ideas) do learners have ownership of when they are given the chance to design in a guided inquiry science environment?	<p>Identify the “targets of ownership”</p> <ul style="list-style-type: none"> • Actions, views, and language relating to the possession, control, pride, and investment into ideas, space, artifacts, products, roles, process, etc. 	<p>Interviews with participants</p> <ul style="list-style-type: none"> • Usage of language that indicates possession of some target (e.g., mine, my, ours) <p>Video recordings and field notes</p> <ul style="list-style-type: none"> • Language, actions, and behaviors that might indicate learners have control over some aspect of the design activities. <p>Software artifacts</p> <ul style="list-style-type: none"> • Expressions of how learners might feel about their investigations.
SQ2: At what points during the design activities do learners begin to take ownership of what they own?	<p>Identify the choices and decisions learners make and when they make them:</p> <ul style="list-style-type: none"> • Independent choices that learners make throughout KC • Consequences and impact of choices made <p>Identify the investments learners make and when they make them:</p> <ul style="list-style-type: none"> • Time spent on the design of investigations during and outside the KC context • Other resources used to accomplish goals <p>Identify learners’ personal goals</p> <ul style="list-style-type: none"> • What do participants want to accomplish in KC • What do participants want to accomplish in schools and science • What do participants want to do in the future or their later careers 	<p>Video recordings, field notes, and software artifacts</p> <ul style="list-style-type: none"> • Decision points made in the design • Time and other resources (e.g., social capital) used <p>Interviews with learners</p> <ul style="list-style-type: none"> • Determine “why” they make certain decisions and investment • Determine if learners’ personal goals match with KC
SQ3: What are the initial characteristics and outcomes of ownership and how do these characteristics change over time for learners as they participate in design activities in science learning?	<p>Identify engagement: Identify practices learners took to be active or non-active in KC.</p> <ul style="list-style-type: none"> • Choices • Investments • Relationships • Social interactions <p>Identify alignment: Learners coordination of themselves to the activities and culture of KC</p> <ul style="list-style-type: none"> • Discourses • Negotiations • New practices • Roles <p>Identify imagination: How do learners</p>	<p>Software artifacts - Photographs, text, drawings, and audio in narrative fashion</p> <ul style="list-style-type: none"> • Self-identity – Tell us about yourself • Contributions of science – What do you like about science? What do you not like about it? • Expressions of pride - What do learners express in their stories about their investigations? <p>Interviews with learners</p> <ul style="list-style-type: none"> • Personal views of self-identity, perspective of science contributions, and learners’ expressions of pride using interview data from the beginning, middle, and end of KC. <p>Video recordings, field notes, interviews</p>

	<p>see themselves and see others.</p> <ul style="list-style-type: none"> • Learners' self identity in relation to science over time, views of science, cooking, and school, aspects of belonging in a community (e.g., home, school), views of self outside of school • Learners' pride, self-efficacy, and expression their ideas and designs to others • Learners' perspective of science contributions, how learners utilize science knowledge in designs, how learners see science knowledge in their lives 	<p>with teachers, parents, and facilitators</p> <ul style="list-style-type: none"> • Triangulate the software artifacts and interviews with learners
<p>SQ4: How might the features of KC and the learner's own environment potentially impact and influence how ownership takes place in learners?</p>	<p>Features to examine</p> <ul style="list-style-type: none"> • Facilitation, semi-structure activities, whole group discussions, Choice Day, and technology usage <p>Home</p> <ul style="list-style-type: none"> • Science experiences at home <p>School</p> <ul style="list-style-type: none"> • Science experiences at school 	<p>Interviews with learners</p> <ul style="list-style-type: none"> • Ask open ended questions on the aspects of KC. • Have learners compare KC and other science context in their lives. • Ask learners to change anything or redesign aspects about KC <p>Interviews with parents and teachers</p> <ul style="list-style-type: none"> • Ask open-ended questions on science experiences of the learners at home and school. <p>Video recordings and field notes</p> <ul style="list-style-type: none"> • Use field notes to highlight times when I observe learners taking ownership within the design activities. • View and analyze how the different aspects of KC might be influencing ownership.

To answer SQ1, I needed to identify the actions, views, and language of the learners that relate to the possession, control, pride, and investment over “targets of ownership.” These targets included material and non-material possessions. The data I used to answer this question were 1) interviews with learners, facilitators, parents, and teachers; 2) video recordings and field notes of the behaviors of the children in the activities; and 3) software artifacts that indicated what the learners thought about their investigations and designs.

For SQ2, I started by examining the choice and decision-making practices of the learners and when they made them. I looked at what independent choices they made throughout KC and the consequences of their actions. I also identified the investments learners made into their activities. Examples of investment include time spent on activity and the actions learners took to ensure their goals were met. Lastly, I examined what goals learners had and what they wanted to accomplish in KC, school, and home. To answer this question, I used video recordings, field notes, and software artifacts to investigate where and when important decisions occurred. I also

conducted interviews with learners to understand why they made certain choices and investments.

To answer SQ3, I used Wenger’s (1998) framework of engagement, alignment, and imagination to understand what characteristics of ownership existed in the KC community and how did those characteristics change over time. For engagement, I looked what practices learners took on to be actively (or not actively) involved in KC. These practices included the investments they made, the choices they wanted to take on, the social interactions they had, and the relationships they made. For alignment, I examined how the learners coordinated their energies and activities to fit (or not fit) into KC. I examined what discourses took place, what new KC practices they took on, what negotiations took place, and what roles existed (e.g., follower, leader). Finally, for imagination, I examined what images of the world the learners had about themselves and about others. Specifically, I looked at four identities of scientists, cooks, investigators, and designers. Here, I investigated what did learners think of these four identities, what pride they exhibited, and what contributions they felt they made. The data for this question came from multiple interviews with the learners and their teachers, parents, and facilitators to understand their personal views, video recordings to examine their actions and behaviors from the beginning, middle, and end of KC, and the personal software artifacts they generated.

Finally for SQ4, I examined three main contexts to understand what factor influence and impact ownership of science learning. For the KC context, I examined how the facilitation, activity structure, discussions, and technology supported or hindered ownership. In the home context, I examined what science learning and cooking occurred, what the children enjoyed doing at home, and what the general personality of the children were like at home. For the school context, I investigated what the general personality of the children were like in school, what the children liked or disliked in school, and how did the children interact in social groups. To find answers for this question, I interviewed the learners about what they enjoyed most and least about and asked them to compare their home and school with KC. I also interviewed facilitators to triangulate this data. Next, I interviewed the parents and teachers about the children’s science experiences in these two contexts and what the children were like. Finally, I used video recordings and field notes to observe when learners took ownership and triangulated the interview data I gathered about KC, home, and school.

Appendix C: Interview Schedule, Format, and Time

Learner	Facilitator	Parent	Teacher
Arman March – after KC with parent, video May – after KC with parent, video Total: 57 minutes	Elizabeth March – Skype, audio June #1 – Skype, audio June #2 – Skype, audio Total: 136 minutes	Arman’s Dad March – after KC with Arman, video May – after KC with Arman, video Total: 29 minutes	Arman’s teacher April – in class, video Total: 23 minutes Ben, Freddie, and Donna’s teacher April #1 – in class, audio April #2 – afterschool,
Ben March – after school,	Charley March #1 – in person, audio	Ben’s Dad March – after school,	

video May – after school, video Total: 85 minutes Freddie March – at home with parent, video May – after school with parent, video Total: 59 minutes Donna March – after school, video May – after school, video Total: 81 minutes	March #2 – Skype, audio June – in person, audio Total: 202 minutes Emily March #1 – in person, video March #2 – in person, audio May – in person, video Total: 102 minutes	video June – at home, video Total: 52 minutes Freddie’s Mom March – at home with Freddie, video May – after school with Freddie, video Total: 54 minutes Donna’s Mom March – at work, video June – at work with Donna, video Total: 89 minutes	audio Total: 159 minutes
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Appendix D: Interview Guides and Instrumentation

KC Participant Interview Guide

This is an interview protocol I adapted from Clegg’s (2010) dissertation. This is a beginning interview guide for KC participants. Follow-up interviews will ask some of the same questions, and will also include specific questions that come up from our observation and analysis.

Scientists

1. Describe a scientist or what a scientist does?
2. What are some important things that scientists do?
3. What does it take to be a good scientist?
4. Who (what individuals that you know or know of) are ideal scientists to you and why?
5. Do you see yourself as a scientist? Why or why not?
6. Is there a difference in the way scientists communicate and the way people communicate at home? What’s the difference? Tell me about it. How is it similar?
7. How does the way that you solve everyday problems compare with the way that scientists solve problems

Designers and investigators

1. Describe an investigator or what an investigator does?
2. Do you see yourself as an investigator? Why or why not?
3. Describe a designer or what a designer does?
4. Do you see yourself as a designer? What are some things you design?

KC Participation

1. Why did you choose to participate in KC?
 - a. Can you tell me why you are still participating in KC?
2. What do you hope to learn in KC? What do you hope to get out of participating in KSI in general?
3. Are the things we talk about in KC useful? Why or why not?
4. Tell me about your cooking experiences in KC
 - a. Explain the kinds of experiences you had and jobs you did

- b. Explain how you work in teams
 - c. How did you use the technology?
5. Tell me about your experience during the whole-group discussions.
6. How has KC matched or not matched your expectations so far?
7. What do you like most about KC? Least?
8. What contributions do you make to the KC group?
9. What have you learned in KC so far?
 - a. Are those things useful to you? How so or why not?
10. Tell me about Choice Day.
 - a. Tell me about your investigation and what you are hoping to find out.
 - b. What kinds of decisions are you making?
 - c. What kinds of collaborations are you experiencing?
 - d. What kind of science knowledge are you using in your designs?
 - e. What are some of the difficult aspects of Choice Day?
 - f. Tell me about your use of technology in Choice Day?
11. Tell me about what you think about the technology in KC?
 - a. How would you redesign the technology?
12. What are some things you'd like to change about KC?

School/science class and prior experience of science

1. Tell me about your science classes.
 - a. How do you participate or contribute?
 - b. What do you like the most and what do you like the least?
 - c. What is your favorite subject in school and why?

Interests

1. What do you want to be when you grow up?
2. Do you have any hobbies or interests? Tell me about them?
3. Do you cook at home? If so, how is cooking at home similar or different from cooking in KC

KC Facilitator Interview Guide

1. Tell me about _____'s participation in KC?
 - a. Has that changed in the past five months? How so?
2. What are _____'s strengths and weaknesses?
 - a. How have they changed over time?
 - b. What has caused the changes?
3. How does _____ work in groups?
 - a. What roles does he or she tend to take on?
4. How is _____'s participation similar or different from other learners in KC?
5. What types of accomplishments and contributions has _____ made in the community?
6. What kind of help do you usually provide to _____ and why?
 - a. What have you found most effective?
7. How would you describe _____'s confidence in KC?
8. What would you say are _____'s interests and goals in KC?
 - a. When is _____ most engaged?
 - b. Most motivated?
9. What do you think were _____'s goals in KC?
10. What things were important to _____ in KC?
11. What kinds of decisions and choices did you see _____ make in KC? What were some of the consequences?
12. What were some of the things you thought _____ liked about KC? What were some of the things you thought _____ did not like about KC?
13. What has been your experience like in KC with _____?
14. How has _____ used the technology in KC?

15. Tell me about your experience with _____ in Choice Day?

KC Teacher Interview Guide

1. Tell me about _____'s participation in science class? Has that changed in the past 5 months? How so?
2. Tell me about science learning at this school.
3. What are _____'s strengths and weaknesses? How have they changed over time?
4. How does _____ work in groups? What roles does he or she tend to take on?
5. How is _____'s participation similar or different from other learners in your class?
6. What types of accomplishments and contributions has _____ made in the class?
7. What kind of help do you usually provide to _____ and why? What have you found most effective?
8. How would you describe _____'s confidence in your class?
9. What would you say are _____'s interests and goals in your class? When is she most engaged? Most motivated?

KSI Facilitator Interview Guide

1. Tell me about _____'s participation in KC. Has that changed in the past 5 months? How so?
2. What are _____'s strengths and weaknesses? How have they changed over time? What has caused the changes?
3. How does _____ work in groups? What roles does he or she tend to take on?
4. How is _____'s participation similar or different from other learners in KC?
5. What types of accomplishments and contributions has _____ made in the community?
6. What kind of help do you usually provide to _____ and why? What have you found most effective?
7. How would you describe _____'s confidence in KC?
8. What would you say are _____'s interests and goals in KC? When is she most engaged? Most motivated?
9. What were _____'s goals in KC?
10. What things were important to _____ in KC?
11. Tell me about _____'s involvement in Choice Day.
 - a. What kinds of choices were the kids making for Choice Day?
 - b. What kinds of investment do you see the kids making (or not making) in Choice Day?
 - c. What kinds of knowledge (science or otherwise) are they using for Choice Day?
 - d. What do you think are their goals for Choice Day investigation?
 - e. What kinds of roles are the kids taking on for Choice Day?
 - f. What kinds of things do you see the kids trying to take control of (e.g., ideas, space, roles, tech) during this time?

Appendix E: Classroom Field Notes

Adapted from Creswell, 2007 and the National Center for Improving Science Education teacher observation protocol

BACKGROUND INFORMATION

Teacher Name _____
Date of Observation _____
Start Time _____ End Time _____
Observer (s) _____
Grade Level _____
Place _____

No. of students _____
 Focal learners present _____
 Placement of class or lesson within the unit of study: _____
 Teaching aids/materials (per activity/task if appropriate): _____

Descriptive Notes	Reflective Notes
<p>Classroom layout - Describe how the seating is arranged, number and kind of windows and lights, describe / list any special equipment or materials. Note especially if there are separate areas for different activities (e.g., a “library” with a place for students to sit).</p> <p>Describe what is on the walls, especially bulletin board displays. Give an overall general description of the size of the room, e.g., ‘large’ is sufficient.</p>	
<p>Introduction to Lesson: Describe how the teacher starts the lesson (e.g., gives a content overview, relates the content to previous work or to science). While it is assumed the student grouping will be whole class, there may be an occasion where it is not.</p> <p>Student Grouping _____ Duration _____</p>	
<p>Describe the content and the nature of the lesson or classroom activities including the method of teaching, how/if students are grouped/interacting.</p> <p>Describe what the students are doing e.g., listening and taking notes, writing answers to questions.</p> <p>Describe how the teacher is interacting with the students, and how the students are interacting with one another.</p> <p>Student Grouping _____ Duration _____</p>	
<p>Assessment strategies used (per activity/task if appropriate): If during the observation the teacher uses some form of assessment strategies, record them. For example, a teacher may circulate among students doing work in small groups and make notations on a check sheet.</p>	
<p>Time not devoted to teaching and nature of non-academic or procedural activity (e.g., management, announcements, discipline); description of non instructional event:</p>	

Characterize students and their attitudes toward the subject matter and the teacher:	
Notable non-verbal behavior:	
Surprises/concerns:	
Overall thoughts on classroom:	
Overall thoughts on focal learners:	

Appendix F: Development of Initial Analytic Open Coding Scheme

These codes are based on the five themes of ownership laid out by O’Neil and Barton (2005). I have also adapted Pierce et al. (2003)’s notion of “targets of ownership” as part of the coding scheme. Lastly, these codes are also based on observations from a prior exploratory study.

SQ1: What aspects of the design activities (e.g., technology, products, ideas) do learners have ownership of when they are given the chance to design in a guided inquiry science environment?

Evidence for targets of ownership

- An individual may display emotions commonly associated with “me”, “mine”, or “ours”
- There is a sense of possession and control of an object for an individual
- Close relationships and connections between an individual and a target (material or non-material) can be seen
- The more information possessed about a target, the more intimate connection between an individual and target
- Preventing access to a target of ownership for an individual may cause stress, anxiety, and negative affect
- An individual may be unwilling to share the target of ownership and want to retain exclusive control over it
- There is an immersion of self into a target of ownership
- Positive feelings associated with targets of ownership include (but are not limited to) an assumption of responsibility, caring, protection, nurturance, stewardship, and a willingness to make personal sacrifices and assume risk for the target.
- Negative feelings associated with targets of ownership include (but are not limited to) jealousy, alienation, frustration, stress, unwillingness to share control, and anger.
 - Radical change or destruction of objects for which there are strong feelings of ownership can result in a diminution of one's self concept, adverse health effects, and feelings of normlessness and powerlessness.

SQ2: At what points during the design activities do learners begin to take ownership of what they own?

Evidence for agency

- Learners make independent choices on the design of their investigations
- Learners integrate everyday knowledge into their designs
- Learners make decisions that attempt to satisfy their personal and social goals
- Learners take initiatives to make certain decisions

- Learners are the primary decision makers
- Learners need to consider what decisions have to be made to make sure they adhere to specific goals and design constraints
- Learners ask facilitators for advice on how to make a decision

Evidence for lack of agency

- Learners are not the primary decision makers. Instead, an authority figure may be making many of the decisions.
- Learners defer to someone else to make the decisions
- Learners do not take initiative to make decisions; they often follow someone else's lead.
- Learners' goals are not being met through the decision they are making
- Although learners may make a decision, either the decision is done begrudgingly or unwillingly.
- Learners' may be presented with choices, but these are not the choices they want.

Evidence for investment

- Learners devote time to their designs and are focused on developing their investigations
 - Learners devote personal time outside of the context to learn and / or investigate about science
 - Learners ask for more time to keep working on their designs
- Learners use their peer networks to make contributions to their designs
- Learners utilize home and community based knowledge into the design
- Learners are focused on the development of their investigations

Evidence for lack of investment

- Learners are distracted from the task
- Learners do not spend much time and effort on their investigations
- Learners want to quit the task
- Learners are easily swayed into other tasks or ideas.
- Learners do not invest time or effort on the task at home
- Learners do not rely on their peer networks to make contributions.

Evidence for personal goals

- Learners have tasks they want to accomplish, both in the moment and pre-determined.
- Learners have a reason(s) they are in Kitchen Chemistry
- Learners have specific interests they pursue
- Learners tell others of their goals

SQ3: What are the initial characteristics of ownership and how do these characteristics change over time for learners as they participate in design activities in science learning?

Evidence for the contributions of science

- Learners see ways that science makes positive contributions to everyday aspects of their lives.
- Learners see science as helping create a better life
- Learners see science as important because it tells us information about ourselves.
- Learners see science as important to helping in the design of their investigations and projects

Evidence for the lack of contributions of science

- Learners have a difficult time expressing how science contributes to their lives
- Learners see science as being important, but not connected to everyday life
- Learners have a difficult time articulating how the different aspects and processes of science contribute to their everyday life.

Evidence of pride in science and design

- Learners are proud of their designs and make outward positive expressions to others about their work
- Learners want to make their designs publically known and seek acknowledgment for their contributions
- Learners use their designs as a means of representing themselves to their peers, families, facilitators and school community

Evidence for the lack of pride in science and design

- Learners do not make outward expressions to others about their work
- Learners may show negative views and not want to associated with science
- Learners may design something, but not want to tell others of it

Evidity of self-identity and views of self

- Learners engage themselves in the community
 - Learners take on the cultural practices of a community
 - Learners participate in community practices
 - Learners can also be disengaged with certain aspects of a community
 - Learners might be participating in community practices, but are doing so out of obligation or coercion.
- Learners imagine themselves within the broader community
 - Learners see themselves as designers, investigators, scientists, explorers, cooks, etc.
 - Learners see themselves as knowers, users, contributors, and creators of science
 - Learners imagine what others like themselves may be doing.
 - Learners see themselves as having access to science
 - Learners see themselves in positive roles for science, such as teachers, problem solvers, investigators, people who know science, and people who are able to convey science to others.
 - Learners may also have a difficult time seeing themselves as a scientist or investigator when compared to professional scientists.
- Learners align themselves with a broader purpose
 - Learners coordinate their perspectives and actions to a broader purpose
 - Learners take on the practices of the broader community
 - For science, learners may align their practices as how they see scientists, designers, and investigators.
 - Learners may engage in the practices of a community, but have a difficult time aligning themselves with a broader community (e.g., does the cooking, does not see himself as a cook).

SQ4: How might the features of Kitchen Chemistry potentially impact and influence how ownership takes place in learners?

Features of Kitchen Chemistry to examine

- Facilitation
- Choice Day
- Semi-structured activities
- Whole-group discussions
- Technology usage

Features of school environment to examine

- Classroom influences
- Teacher influences
- Technology in school

Features of home environment to examine

- Parental influences
- Hobbies and activities
- Science at home or in other non-schooling environments (e.g., museums, camps)
- Technology at home

Appendix G: Coding Set One for Axial Coding

Question	Code categories
<p>SQ1: What aspects of the design activities (e.g., technology, products, ideas) do learners have ownership of when they are given the chance to design in a guided inquiry science environment?</p>	<p>Target of ownership: What do the children control and gravitate towards</p>
<p>SQ2: At what points during the design activities do learners begin to take ownership of what they own?</p>	<p>Actions in Kitchen Chemistry: What behaviors do learners exhibit in Kitchen Chemistry</p> <p>Actions that indicate ownership: What behaviors and actions might indicate ownership</p> <ul style="list-style-type: none"> • Choices and decisions • Investments and responsibilities <p>Affect: What emotional state do the children exhibit</p> <p>Goals: What goals do children have</p> <p>Expectations: What do learners expect of Kitchen Chemistry</p>
<p>SQ3: What are the initial characteristics and outcomes of ownership and how do these characteristics change over time for learners as they participate in design activities in science learning?</p>	<p>Self-identity: How do the children perceive themselves (Designers, Investigators, Scientists, Cooks)</p> <ul style="list-style-type: none"> • Talents: What do the participants and stakeholders think the children's talents are • Likes: What do the children like in general • Dislikes: What do learners not like in general • Difficulties: What difficulties do learners have • Areas for improvement: What do the participants and people in their lives say about what the children need to improve in <p>Learning: What do the participants and stakeholders think the children are learning?</p> <p>Perspectives of science: What do the children say about science</p> <ul style="list-style-type: none"> • Contributions of science • Pride in science
<p>SQ4: How might the features of Kitchen Chemistry and the learner's own environment potentially impact and influence how ownership takes place in learners?</p>	<p>Kitchen Chemistry</p> <ul style="list-style-type: none"> • Facilitators: What are the perceptions of the facilitators • Technology: What do the children think about the technology • Actions that occurred in Kitchen Chemistry • Social dynamics: What social dynamics and interactions exist in Kitchen Chemistry <p>Home</p> <ul style="list-style-type: none"> • Cooking at home: How does cooking happen at home • Science at home: What is science like in the home environment • Parents: What do the children say about their parents

For the code “affect”, I focused on the emotions that the children conveyed throughout the interviews and the video recordings. Similarly, for “actions”, I examined what behaviors the children exhibited in the environment. For these two codes, I examined and interpreted what gestures (e.g., body, facial) the children made, what tone and pitch the children spoke in, what social interactions were present, and what the specific text stated in context was. Sometimes, the children would indicate in the interviews literally how they felt (e.g., “I’m upset”, “I’m so angry”) or what they did (“I measured”, “I cooked”). Other times, I had to make interpretations of the children’s affect and actions based on the factors I listed.

Appendix H: Coding Set Two for Axial Coding

Target of ownership

- Tangibles
 - Product: Foods, technology
 - Space / Territory
- Non-tangibles
 - Ideas
 - Processes and techniques
 - Time
 - Relationships
 - Acknowledgements

Outward behaviors

- On and off vs. stable
- Ownership assurance
 - Idea protection (Anonymity, authorship, idea stealing, recognition for ideas)
 - Assurance
- *Choice and agency*
 - Wants to make choices and decisions
 - Has trouble making choices and decisions
- *Investments and responsibilities*
 - Takes on more responsibilities
 - Does not take responsibilities
- Social behaviors
 - Giving and sharing
 - Group dynamics
 - Positive
 - Negative
 - Roles learners take on: Leader, follower, multiple roles, low responsibility, primary idea
 - Idea discussion
 - Talks about KC with others
- Affect and emotion that may indicate ownership or no ownership
 - Negative: Anger, boredom, mistreated, impatience, etc.
 - Positive: Curious, determined, etc.
 - Other?

Personal views

- *Expressions of pride*
 - Proud of product
 - Invitation to discovery
 - Share in idea development
- *Contributions of science*
 - Science contributes to everyday and personal life
 - General societal benefits
- Perceptions of science
 - Everyday vs. Authoritative knowledge
 - Science communication
 - Who is good at science?
 - What do children think science is?

Self-identities – Developing within communities of practice

- *Imagination (extended identity), engagement (participate), and alignment (goals and purpose)*
 - Designers
 - I am or am not a designer
 - Cooks
 - I am or am not a cook
 - Investigators
 - I am or am not an investigator
 - Scientist
 - I am or am not a scientist
 - Other: Arts and music, dreamer, technology wiz, gamer, etc.
- *Communities of practice*
 - School
 - Science in the classroom
 - Teachers
 - Home
 - Family life in general
 - Cooking at home: Social experiences, Independence, Experiences in general, Changes occurring, and Limitations
 - Science at home
 - Kitchen Chemistry
 - Facilitators: Authority figures, positives (helpful), negatives (too much constraints)
 - Technology
 - Activities: Cooking, investigation actions, Choice Day
 - Areas for improvement of KC

Personal Goals

- Expectations of KC
- Social goals
 - Friends
 - Family
- Development goals
 - Tangible: Food, cooking
 - Non-tangible: Ideas, science processes, technique
- Non-science goals: Arts, games, etc.

Learning

- Investigation development
- Life skills

Personality and profiles for learners

- Affect and emotion
- Difficulties children have
 - Discipline and self control
 - Social skills
 - Investigation development
 - Academic skills
- Likes and Dislikes
- Talents

First, I changed “outward behaviors” into “engagement and alignment”. Under this broader category, “affect”, “attention”, “assurance”, “choice”, “investments”, and “social behavior” all reflected the behaviors that I could observe that showed engagement and alignment to community practices. Second, I changed “personal views” and created the broader category, “imagination”. Under this category, I placed subcodes that focus on learners’ views and perceptions. I also changed “Perception of science” changed to “relationship to science”. Under the broader “imagination” category, I put “pride”, “contributions”, “relationship to science”, “goals”, and “self-identities” as the subcodes.

For “Profiles of the learners” so that I could distinguish the codes between ownership of learning and codes that help me develop a profile of the children. In this second meeting, more codes were collapsed while other codes were further reorganized into the themes of the framework. I also put codes such as “talents”, “likes”, “dislikes”, and “difficulties children had” under the profiles category. Under outward behaviors, I placed codes “collaboration”, “ownership assurance”, and “roles” into this section. The code, “views of science” was placed under personal views. I reorganized personal goals to reflect “expectations of learners”, “social goals”, and “goals for science.” The category for self-identities developing in communities of practices split into “views” and “communities”. Under the category of learning, I split up learning into “science”, “general skills”, “perceptions of learning”, and “articulation of learning.”

Appendix I: Coding Set Three for Axial Coding

Target of ownership

- Tangibles
 - Materials in KC
 - ~~KC Products~~ Personal products
 - Space / Territory
 -
- Non-tangibles
 - Ideas
 - Processes and techniques
 - Time
 - Relationships
 - Acknowledgements and authorship
 - Intrinsic rewards

Outward behaviors Engagement and Alignment

- Attention
 - ~~Attention difficulties~~
 - ~~Sole attention, determined~~
 - Focused
 - Unfocused
- ~~Ownership assurance~~ Assurance
 - Idea protection (Anonymity, authorship, idea stealing, recognition for ideas)
- Choice and agency
 - Choices made
 - Decision making processes
- Investments and responsibilities
 - Takes on more responsibilities
 - Does not take responsibilities
- Social behaviors
 - Giving and sharing
 - Collaboration difficulties
 - Positive group dynamics
 - Independence
 - Roles learners take on: Leader, follower, multiple roles, low responsibility, primary idea
 - Talks and sharing about KC with others
- Affect and emotion that may indicate ownership or no ownership
 - Negative: Anger, boredom, mistreated, impatience, etc.
 - Positive: Curious, determined, etc.
 - Other?

Personal views Imagination

- Expressions of pride in science
 - Proud of product
 - Invitation to discovery
 - Share in idea development
- Contributions of science
 - Science contributes to everyday and personal life
 - General societal benefits
- Relationship to science
 - Authoritative knowledge
 - Hands-on
 - Western perspective
 - Fun
- Personal Goals
 - Expectations of KC
 - Social goals
 - Friends
 - Family
 - Development goals
 - Tangible: Food, cooking
 - Non-tangible: Ideas, science processes, technique
- Self-identities – ~~Developing within communities of practice~~
 - Designers
 - What do I think designers do
 - I am or am not a designer
 - Cooks
 - What do I think cooks do
 - I am or am not a cook

- Investigators
 - What do I think investigators do
 - I am or am not an investigator
- Scientist
 - What do I think scientists do
 - I am or am not a scientist
- Other: Arts and music, dreamer, technology wiz, gamer, etc.

Communities of practice

- School
 - What science is like in the classroom
 - Teachers
- Home
 - Family life in general
 - Cooking at home: Social experiences, Independence, Experiences in general, Changes occurring, and Limitations
 - Science at home
- Kitchen Chemistry
 - Facilitators: Authority figures, positives (helpful), negatives (too much constraints)
 - Technology
 - Activities: Cooking, investigation actions, Choice Day
 - Areas for improvement of KC

Learning

- ~~Investigation development~~ Science skills
- General skills
- Perceptions of learning
- Articulation of learning

Personality and profiles for learners

- ~~Affect and emotion~~ Personality
- Difficulties children have
 - Discipline and self control
 - Social skills
 - Investigation development
 - Academic skills
- Likes and Dislikes
- Talents
- Technology usage

Appendix J: Coding Set Four for Axial Coding

1. **Communities:** Communities are the places in which children reside, participate, and socially engage. For this study, home and school are “communities of practice”, that is they are well-established and long-standing settings in which the children spend a lot of time in. Kitchen Chemistry is an afterschool “community” that is shorter in time and practice.
 - a. **Home → Cooking:** These codes refer to the experiences of cooking in the home for the children.
 - i. Changes: Changes that are occurring in the cooking experience for the children
 1. Can't eat gluten: Cooking has changed because the child can't eat gluten.

2. Asks more questions: The learner asks more questions at home.
 3. Focus: The participant is more focused in the kitchen or in cooking at home.
 4. Wants to help out more: The participant is helpful at home.
 5. Kitchen technology: Learners want to play with more of the kitchen technology (e.g., mixers, ovens).
 6. More active: Children became more active in the kitchen at home after KC.
 7. Process: Wants to learn more about the process of cooking at home.
 - ii. Differences: These codes refer to the differences between home cooking and KC cooking.
 1. Cooking at home is different than KC: The experience of cooking at home is different than at KC.
 2. No one to work with: At home, there is no one to work with on food investigations.
 - iii. Experiences: Codes referring to the experience of cooking at home
 1. Cook to eat: Cooking is practical; no experimentation
 2. Cook with family: I cook with someone in my family.
 3. Cooking all the time: A lot of cooking at home with the participant.
 4. Hard to cook at home: I have difficulties cooking at home, especially independently.
 5. Imagination: I cook and use my imagination while I'm doing it.
 6. Helps out: Participant helps out with cooking.
 7. Some cooking: Some cooking, a decent amount.
 8. Trying new combinations: Making new recipes, trying new food combinations.
 - iv. Independence: Codes referring to the independent nature of home
 1. Develops own investigation: Develops new cooking investigation at home by themselves.
 2. Initiates the cooking at home: Learners initiates the cooking at home.
 3. More independent: Becomes more independent in the kitchen, wants to do more tasks.
 4. Some independent cooking: Participant sometimes independently cooks at home.
 - v. Limitations: Codes referring to limitations of cooking at home.
 1. Fewer limitations: At home, I have fewer limitations about cooking and what I want to do.
 2. Supervision: Supervision occurs at home to cook.
 3. Time constraint: It's hard to cook at home, there's no time.
 - vi. Social: Codes referring to the social nature of cooking at home.
 1. Making conclusions: Working together with parent to make a conclusion about cooking or food investigation.
 2. Conversations: Conversations about cooking and food.
 3. Observations: I make observations with my parent at home.
- b. **Home → Parents:** Codes referring to interactions with parents and family at home.
- i. Boring conversations: Conversations at home can be boring and long.
 - ii. Family helps me: Family helps me when I need help.
 - iii. Parent likes KC: Parents have overall positive view of KC.
 - iv. Parents wants STEM: Parent wants child to be in more STEM fields and classes.
 - v. Parents get mad: My parents can get frustrated at me.
 - vi. Respects parents: Learner shows respect towards parents.
- c. **Home → Science:** Codes referring to science experiences at home
- i. Communication: Codes referring to communication about science at home.

1. Debate and argument: I debate and argue over my observations at home.
 2. Doesn't bring much home: Does not bring much science schoolwork or interest to home.
 3. Family asks questions: Family will ask questions about science, KC, and other topics to the learners.
 4. Make statements: Learner makes declarative statements about how ingredients or processes might work with family.
 5. Some science: Some science conversations are going on at home.
 6. Talking science is tough with family: Explaining science concepts can be difficult from parent to child.
 7. Talks about KC only after it has ended: Talks about KC immediately after he or she comes home.
 8. Talks to parents about KC or own investigation: Talks to parents about the investigations and experiments.
- ii. CS (Cooking-Science): Codes referring to the science and cooking at home
1. Cooking and food as reminders of science: Talking about cooking transitions into science.
 2. Cooking as science at home: Cooking and mixing things together as experimentation or science at home.
 3. Difficult science at home: It's difficult to do or be a scientist at home.
 4. Does not think about cooking questions: Doesn't have questions about food or cooking at home.
 5. Kitchen: I can do science in the kitchen, the physical space. The kitchen is where I do my science work.
 6. Personal Investigations: Conducts his or her own personal investigations at home. Can be food based or not.
 7. Replication: Wants to replicate the experiments at KC at home.
- iii. Family: These codes refer to family experiences with science at home.
1. Astronomy: My family provides me astronomy at home.
 2. Documentaries: I can learn about science through documentaries; I watch them with my family or myself.
 3. Math: My family wants me to do more math activities.
 4. Museums and zoos: My family takes me to museums and zoos.
 5. More STEM work: The parent makes work or finds opportunities for academics and science and math.
 6. Science books: My family gets me books on science and experimentation
 7. Science Kits: I have science kits (e.g., physics, chemistry, biology) that I play with at home.
 8. Science with family: I engage with science with my family.
 9. STEM parent: The parent involved in some STEM career.
- d. **Kitchen Chemistry → Activities:** These codes refer to the likes and dislikes of the children pertaining to the activities in KC.
- i. Dislikes
 1. Discussion time: Learners have negative views of discussion time.
 2. KC sometimes boring: Learners express that sometimes KC is boring.
 - ii. Likes
 1. Choice Day: Learner likes Choice Day and has fun.
 2. Choices and decisions: Learners likes making choices and decisions in KC.

3. Co-design: Learners likes the idea of co-designing the technology with the adults.
 4. Cooking: Learner likes cooking and aspects of cooking in KC.
 5. Cooking and science: Learner likes the combination of cooking and science together in KC.
 6. Cooking and technologies: Learner Likes the combination of using technology and cooking in KC.
 7. Creativity: Learner likes the opportunities for creativity in KC.
 8. Eating: Learner likes to eat in KC.
 9. Experiments: Learner likes the experiment portions of KC.
 10. KC: Learners likes Kitchen Chemistry in general.
 11. Less pressure: Learner likes the low pressure environment of KC.
 12. Making stuff: Learners likes the making stuff aspect of the activities.
 13. New things: Learner likes trying new things in KC.
 14. Whole group conversation: Learners likes the whole group conversations.
- iii. Opportunities: These codes refer to what opportunities learners perceive can occur in KC.
1. Designing foods: KC gives learners the chance to try designing foods.
 2. Science in KC: KC gives learners a chance to do science.
 3. Problem solving: KC gives learners a chance to solve problems.
- e. **Kitchen Chemistry → Facilitators:** These codes refer to the activities of the facilitators and the opinions about the facilitation in KC.
- i. Difficulties
 1. Concern about leading: Facilitator feels concerned about leading the learners
 2. Defer to authority: Learners defers to adult authority.
 3. Frustrated: The facilitators show signs of frustration towards the learners.
 4. Not able to listen: Facilitator isn't able to listen to what the learner is saying
 - ii. Support
 1. Choice and decision: Facilitators help with choice and decision-making.
 2. Create and supportive of ideas: Facilitators helped learners create new ideas and were generally supportive of ideas.
 3. Facts: Facilitators tell learners a lot of facts.
 4. Gets things started: The facilitators help the learners get started on their projects or activities
 5. Helping out: The facilitators act as helpers for the learners. For example, they might make suggestions, gather materials, work together with learners, cook with the learners, etc.
 6. Justification: The facilitators give reasons and justifications for the decisions they make to the learners.
 7. Let me rest: The facilitators allow the learners to rest when they feel tired.
 8. Negotiates: The facilitator and the learner negotiates their decisions together
 9. Prompts and scaffolds: Facilitator provides prompts and scaffolds for the learners. Prompts can include questions, hints, guides, small steps, and transitions.
 10. Reminder of ownership: Facilitators have to remind learners about who owns the project (e.g., this is your project).

11. Reminder of science: The facilitators have to remind learners of the science in their food investigations. This is not just cooking; this is science.
 12. Reminder of social dynamics: Facilitators have to remind learners of the social cues and dynamics of KC, particularly when they are off task or behavior is not good.
 13. Steps back: Facilitator takes a step back and does not want to have too much control.
- iii. Characteristics
 1. Authority and limitations: The facilitators need to act as an authority figures. They often place limitations on the learners. Learners might also perceive the facilitators as limiting or authority figures.
 2. Happy and fun: Learners state that the facilitators are nice, happy, fun, and positive
 3. Facilitators are friendly: The facilitators are referred to as friendly, nice, positive descriptors.
 4. Flexible: The facilitators allow for flexibility for the learners
 5. Smart: Learners state that facilitators are smart and knowledgeable
 - iv. Uses technology: Facilitator is the one using the technology during KC.
- f. **Kitchen Chemistry → Improvement:** These codes refer to what improvements are needed in KC.
- i. Extensions and materials: Someone wanted to see more extensions and materials passed out.
 - ii. Get parents more involved: Parents wanted more involvement.
 - iii. Too short: KC is too short. People wanted more time.
 - iv. Less experiments: Participants wanted less experiments in KC.
 - v. More independent work: KC should allow children to do more independent task.
 - vi. New technology: KC should always use new technologies
 - vii. Room: The room needs improvement in KC
 - viii. Small interval discussions: KC should have small interval discussions.
 - ix. Wants options: KC should provide more options and ways for me to choose.
- g. **Kitchen Chemistry → Technology:** These codes refer to the technology usage in Kitchen Chemistry.
- i. Feelings: These codes are about the learners' feelings about KC technology.
 1. Cautious: Learner is cautious using the technology in KC.
 2. Distracting: Learner finds technology to be distracting
 3. Fun: Learner finds the technology in KC to be fun
 4. Likes tech in KC: Learner likes using iPad in KC
 5. Likes recording data: Learner likes using iPad in KC for recording data.
 - ii. SING: Codes referring to SING usage
 1. Answers: Learners interact with the answers portion of SING.
 2. Design investigation: Learner uses SING to design an investigation.
 3. Home use: Learner used SING at home
 4. Hypothesis: Learner posts a hypothesis in SING.
 5. Learner uses SING: An interaction occurs between the learner and SING, but it is unclear what exactly the interaction is.
 6. Likes questions: Learner likes posting questions on SING.
 7. Looking at contributions: Learner looks at the contributions of others.
 8. I do not use SING at home: Learner does not use SING at home.
 9. Post resources: Learner posts resources on SING.
 10. Questions: Learner posts questions on SING.
 11. Tough transition: Learners have a tough transition in SING.

- iii. StoryKit: Codes referring to StoryKit usage
 1. Audio Record Positive: Learners enjoy the audio portion of StoryKit.
 2. Copy and paste info: Learners copy and paste info into StoryKit.
 3. Difficult input: Learners have a difficult time inputting into StoryKit.
 4. Learner uses StoryKit: An interaction occurs between the learner and StoryKit, but it is unclear what exactly the interaction is.
 5. Playful: Learner acts playful with StoryKit.
 6. Recording data: Learner or facilitator uses StoryKit to record data.
 7. Write stories: Learner writes and composes stories or aspects of stories.

- iv. Usage: These codes refer to general usage of technology in KC.
 1. Technology difficulties in KC: Difficulties occur using technology in KC.
 2. Uses search engine: Learner uses search engine in KC.
 3. Uses tech frequently in KC: Using technology frequently and often in KC.
 4. Watching videos: Learner watches videos in KC.

- v. Zydeco: Code referring to Zydeco usage
 1. Learner uses Zydeco: Learner uses Zydeco: An interaction occurs between the learner and Zydeco, but it is unclear what exactly the interaction is.
 2. Not engaged: Learner is not engaged with Zydeco.

- h. **School → Science:** These codes refer to the science aspect of school learning
 - i. Characteristics: These codes refer to the characteristics of the school-learning environment.
 1. Asks questions: Learner can ask questions in science classes.
 2. Choice: Learners can choose and make decisions in classes.
 3. Explanations: Science in school is used to give learners opportunities to explain phenomenon in the natural world.
 4. Guidelines: Guidelines and structures are put in place in the classes for the children.
 5. Hands on: Science classes provides opportunities for hands on experiences
 6. Ideas: Science classes allow learners to give ideas.
 7. Independent work: School gives learners a chance to do independent work, with less structure and more freedom.
 8. Learning – Content Knowledge: Learning in science classes is based on content knowledge of terms, definitions, processes, and subject area.
 9. Less hands-on 6th grade: The school will have less hands on and independent learning starting from the 6th grade.
 10. Models: Learners build models for their science classes.
 11. No grades: No grades are given in the school.
 12. No homework: Little to no homework is given to the learners
 13. Older and younger children mix: Older and younger children are in the same classroom.
 14. Open curriculum: Curriculum in the school is open; less structure, more integration.
 15. Topic choices: Learners are given a choice of what topic they will choose for an assignment.
 16. Traditional: Science classes at the school is traditional, focused more on content knowledge.
 17. Working with teachers: Teachers work directly with learners.

- ii. Difference: These codes refer to the differences learners express between KC and school science.
 - 1. The teachers do not laugh: Learner makes comment that the teachers do not laugh when compared to facilitators of KC.
 - 2. Different purpose: The purpose of KC and science classes is different.
 - iii. Missing: These codes refer to what participants say is missing or not present in school science.
 - 1. Don't do much science: Little science is done at the school.
 - 2. Don't solve problems: Problem solving in school is very little.
 - 3. Few choices: The school / classes offers little choices in science projects, learning, etc.
 - 4. Haven't heard much: Parents have not heard much about the science they do in the school.
 - 5. Investigative projects: Learner does not do as many investigative projects.
 - 6. Not trying new things: Learner does not experience as much new things or trying out new things in science classes.
 - iv. Topics: These codes refer to the topics of learning covered in school.
 - 1. Biology
 - 2. Math
 - 3. Physical science
 - 4. Weather
 - v. Workload: These codes refer to the workload the children receive in school.
 - 1. Experiments: Experiments are done in school.
 - 2. Note taking: Learner develops outlines for class.
 - 3. Presentations: Learners make presentations in class.
 - 4. Research reports: Learners writes research reports for class.
 - 5. Work done at school: Learners do most of their work at school.
 - 6. Worksheets: Learners complete worksheets.
2. **Engagement and Alignment:** Engagement is process of how a member participates in the community. Alignment is the process in which members take actions to align themselves to the goals and purpose of the community. Both of these are together because they are processes that can a person can attempt to observe.
- a. **Affect:** The affect code refers to symptoms that display emotions and psychological state in the participants. Affect can be seen through physical gestures, tone and volume of voice, what a learner says, facial expressions, or how a person describes the emotional state of another person. Affect belongs under *Engagement and Alignment* because the emotional state of a person can indicate how a learner participates in a community and how they align (or do not align) themselves to a community. Affect is not a mutually exclusive and may overlap with a learner's general disposition (Profiles: Personality) and or how they show emotions in a social situation (EA: Social).
 - i. Negative – Acts difficult: Working with the learner can be difficult in KC and other aspects, the learner shows evidence of acting difficult and not easy to work with. Learners exhibit emotions that make it difficult to work with them.
 - ii. Negative – Frustration and Upset: Learners show evidence of emotional frustration in KC and other aspects. They might raise their voice, make demands, show stress, anger, grumpiness, tiredness, argument, etc.
 - iii. Negative - Anxious / Nervous: Learners show evidence of being anxious and nervous in KC and other aspects of their lives. They might be hesitant to perform a task or show anxiety.

- iv. Negative – Disappointed: Learners show emotions of disappointment in KC and other aspects of their lives.
 - v. Negative - Feels mistreated and misunderstood: Learners show emotions that they feel mistreated and misunderstood
 - vi. Negative – Not confident and hesitant: Learners show evidence of being hesitant and not confident of their abilities. They are often cautious and risk averse.
 - vii. Negative – Impulsive: Learner exhibits emotions that show impulsivity. Usually this shows being impatient, frustrated at not being able to conduct an action, wanting to do things quickly
 - viii. Negative – Stubborn: Learner exhibits feelings and emotions that show stubbornness. Learners may be frustrated at not getting their way, be persistent towards a particular way, want to do thing their way only, refuse to change, etc.
 - ix. Positive – Curious: Learner shows feelings and emotions of curiosity. Curious can be displayed through questioning, excitement over a discovery, pursuit of a question, etc.
 - x. Positive – Calm and easy going: Learner shows emotions and feelings that exhibit calmness. The learner can be quiet, soft-spoken, patient, etc.
 - xi. Positive – Excited: Learner shows emotions that convey excitement. They might raise their voice, speak fast, show rapid body movement, etc.
 - xii. Positive – Maturity: Learners exhibit emotions and feelings that they are mature. They might show patience, calmness, and quietness.
- b. **Assurance:** This code refers to what assurances learners ask for. Learners often go to the facilitators and ask them questions to make sure that certain goals or conditions are met in KC.
- i. Anonymity: Learners wants data, stories, etc. to remain anonymous.
 - ii. Assurance of Choice: Learners want to make sure that they are still able to make choices.
 - iii. Assurance of quality: Learner wants to make sure the choices they make will lead to a quality product.
 - iv. Authenticity: Learner wants to make sure the activities they conduct are authentic to science.
 - v. Authorship: Assurance that steps taken will make sure authorship of idea belongs to the learner.
 - vi. Stolen ideas: Learners make sure that ideas cannot be taken or stolen.
- c. **Attention:** This code indicates if learners pay attention and have focus. Evidence for attention or lack of attention can include how learners react to others in conversation, do learners look focused or engaged in activity, and whether or not that focuses lasts long or stays short. Attention is part of *Engagement and Alignment* because how a learner stays focused shows whether or not they are engaged or aligned with the practices of the community. Attention is not mutually exclusive and may be shown in social situations (EA: Social) or how focused a learner might be (EA: Investment and Responsibilities).
- i. Attention difficulties: Learners exhibit evidence of having attention difficulties. They are distracted, they do not listen, they go off to another task. Others might talk about how distracted they are.
 - ii. Demands attention: Learner demands that others pay attention to him or her.
 - iii. Focused: Learners are focused and determined in the activities they are doing. They have productive conversations with others that are on the same topic. They can work independently and quietly for a long time on a given task. They do not tend to switch topics or activities, but stay at a given area of work for a longer duration. They might also be focused on a goal or specific piece of the investigation. Being focused is similar to being “invested”. Being focused is different than being “stubborn.”

- iv. Forgetful: Learners show evidence of being forgetful. They express, “I forget.”
 - v. Multitasking: Learners claim they can do multiple tasks at once
 - vi. On and off: Learners show evidence of being engaged in one moment, and disengaged the next moment.
 - vii. Primary idea: Learner shows evidence of pursuing a specific idea. The idea is primary and forefront to the learner.
 - viii. Tired: Learners shows evidence of being tired or fatigued.
- d. **Choice – Choice-making processes:** These codes refer to how learners make decisions and choices in the KC learning environment. These codes look at specifically the processes that children went through during Choice Day to see how they came up with their decisions.
- i. Choice based on what I like: Learner makes decisions based on what they like and what preferences they have.
 - ii. Little discussion on decision making: Learners make decisions on their investigations or activities in KC with little discussion or consultation. Decisions may be impulsive.
 - iii. Decisions originated from learners: Decisions about KC come from the learners.
 - iv. Difficulties
 - 1. Difficulty in keeping time: Learners' decisions and processes are hampered because they have a tough time keeping time.
 - 2. Difficulty in seeing the big picture: Learners' decisions and processes are hampered because they can't see the big picture.
 - 3. Difficulty in general of making decisions: Decision making is difficult for the learners
 - v. Facilitator inspired: Decisions to make are inspired by the facilitator.
 - vi. Follow someone else's decisions: Learner follows someone else's choice
 - vii. Integrating goals into decisions: Learners use goals into making decisions.
 - viii. Limitations of design: Some procedures are limiting or some ingredients aren't present. Choices have to be made for this compensation.
 - ix. Help and structure: Learners need help and structure in making decisions.
 - x. Negotiation on choices: Learners negotiate for decision making. They may negotiate with each other or the facilitators
 - xi. New direction: Learner makes a drastic decision that changes the course of the investigation and the role he or she plays.
 - xii. Simple decisions: Learners make simple decisions in their investigations – Yes or No, picks an option, etc.
- e. **Choice → Choices made:** These codes refer to the decisions and choices children made during Choice Day.
- i. Asking questions: Learners choose to ask questions for the investigation.
 - ii. Authorship: Learners make decisions about how to name and attribute things.
 - iii. Cooking decisions: Learners make decisions about cooking. They choose things based on taste and their preferences.
 - iv. Cooking, not experiment: Learners choose to cook and not experiment. Cooking decisions are prioritized over science based decisions
 - v. Design investigation question: Learners choice in development of an investigation question.
 - vi. Develop organization: Learners choice in how they want to organize their investigations
 - vii. Examine another group: Learners choose to go visit another group and see what they are doing
 - viii. Goes back: During the investigation, the learner may have wandered off and chooses to go back to the original task.
 - ix. Investigation setup: Codes referring to how children setup their investigations.

1. Original ideas: Participant comes up with insightful ideas and follows through on them to.
 2. Procedures: Learners sets up the investigation by developing their own recipes and procedures.
 3. Quantities: Learners make choices in what quantities to use in their investigations.
 4. Variables and ingredients: Learners make decisions on what variables and ingredients they will manipulate.
 - x. Leaves: Learner chooses to leave the original investigation and do something else.
 - xi. Measurement: Learners make decisions of the measurements they will make.
 - xii. New investigation: Learners switch to a new investigation that is not the original investigation they chose.
 - xiii. Observations: Learners choose to make particular observations and focus on certain phenomenon.
 - xiv. Start the investigation: Learners choose a particular point to start the investigation.
 - xv. Wants to choose groups: Learners want to choose who ever they want to work with.
- f. **Investment and Responsibility:** This code refers to whether the children were invested or not invested in their Choice Day projects. Investment occurs when children spend time on their projects, talk about their work, focus on seeing their projects through, and completing menial tasks to see that their food investigations are accomplished. Non-investment can be seen as learners do not spend time on their tasks and become distracted.
- i. Invested
 1. Asking for opportunities: Learners ask and seek for opportunities to keep working on their investigations.
 2. Checking facilitators: Learner reminds and checks in with the facilitator. Sometimes they correct the facilitator or remind them about what to do.
 3. Concern about investigation: Learner shows evidence of showing concern about the progress of an investigation.
 4. Menial tasks: Learners perform menial tasks to continue their investigation. Tasks could include fetching objects, stirring, repeating a set of procedures, washing the cookware, etc.
 5. Methodical and organized: Learners perform their tasks and investigation with organization and methodical behavior.
 6. Participation: Learners fully participate and engage in their tasks.
 7. Reflection: Learners take time to reflect on their tasks and investigations
 8. Responsibility: Learners take responsibility for their investigations. They take on tasks and attempt to make sure things get done and accomplished.
 9. Stays around: Learner does not want to leave, wants to finish their investigation.
 10. Using technology appropriately: Learner uses technology appropriately in KC. They are not distracted by it.
 - ii. Not invested
 1. Learner does not feel invested: Learners do not feel invested in the investigation. They may be distracted, they may say they do not want to work on their projects anymore, and they may end up giving up on their work.
 2. Less menial work: Learner does not want to do the menial work.

3. Low responsibility: Learner does not want to take responsibility for the work
- g. **Social:** These codes refer to how learners interact with each other. As part of engagement and alignment, learners' social interactions with facilitators, other learners, and other people shows how learners participate in the community. Learners can show difficulty working with others, they can act positively in collaboration, and they may enact certain roles in groups.
- i. Difficulties: These codes refer to the difficulties learners faced in their social interactions.
 1. Annoyed and frustrated: Learners are annoyed and frustrated at each other or others in social situations.
 2. Avoid discussion and activity, get started fast: Learners are impulsive and want to avoid discussions to get started on the activity faster.
 3. Concedes argument: Learner frustratingly gives up in the argument and no longer wants to argue anymore.
 4. Concern about what others think: Learner feels self-conscious and cares about what others think.
 5. Concerned about other people's behavior: Learner shows evidence of being concerned about other people's behavior.
 6. Difficult group dynamics: Learners have difficulties in group dynamics. They might be loud, interruptive, not listening, show frustration, show rudeness, etc.
 7. Distracted: Learners are distracted in social situations.
 8. Fighting: Learners are fighting and arguing with each other.
 9. Goofing off and being distracted: Learners goof off and act silly, which causes them to be distracted.
 10. Loud and interruptive: Learners are being very loud and interrupt each other in discussion or talking.
 11. Needs a buffer and intervention: Learners may need a buffer, separation, or intervention to prevent disruptions.
 12. Not supportive: The learners might not be supportive of each other. Sometimes they make disparaging remarks
 13. Others must listen to ideas: Learners contend that others must listen to their ideas.
 14. Selfish ownership: Learners show evidence of being selfish and not willing to share or compromise. They can act very stubborn sometimes.
 - ii. Interactions: These codes are general interactions that occur in the group.
 1. Acknowledgement of ownership: A learner acknowledges someone else's ownership.
 2. Answers: Learners answer questions in social situations.
 3. Ask questions: Learners ask questions in social settings.
 4. Ask permission: Learners ask for permission to do something.
 5. Chit chat: Just talking, nothing specific.
 6. Consulting with each other: Learners consult and check with each other or facilitators.
 7. Conversations about KC: Learners have conversations about KC. Conversations can include how to run the experiment / investigation, what is going on in the processes, what is going on that day in KC, how they like or dislike KC, etc.
 8. Conversations about cooking and food: Learners have conversations just about cooking and food. This does not include talk about the investigation.
 9. Conversations about science: Learners have conversations about science. This could include the science aspects of their investigation,

making observations, talking about phenomenon, making an argument about phenomenon, etc.

10. Declaration of ownership: Learner declares something is his or hers.
11. Does not voice opinion: Learner is quiet and does not voice an opinion.
12. Fair and equal: Learners ask that interactions be fair and equal.
13. Goofy interactions, but not distracting: Learners act goofy, but it is largely not a big distraction.
14. Ideas: Learners tell others about their ideas.
15. Independence: Learners want to interact independently. Sometimes they want to work alone. Sometimes they want to work quietly.
16. Interview: Learners interview each other. Facilitators might interview learners as well.
17. Helped: Learner claims he or she helped another group.
18. No communication: Learner does not want to communicate to others what they have done.
19. Observation: Learner spends time in social groups making observations.
20. Research: Learner spends time researching something in a group.
21. Science argument: Learners makes claims, evidence, and reasoning for a science argument.
22. States facts: Learner states facts about a topic in the group.
23. Tasting: Learners spend time tasting the foods together.
24. Voice opinions: Learner will voice their opinions.
25. Waiting for turn: Learner will wait patiently for his or her turn.

iii. Positive: These codes refer to the positive interactions that supported collaboration in groups.

1. Common goal: Learners work together towards a common goal. Goals could include getting the investigation done, starting a recipe, finishing an investigation, etc.
2. Calm: Learner is polite and does not interrupt in conversations and social interactions. Learner is calm, quiet, and patient.
3. Friendly conversations: Learner has friendly conversations with others in their social environment.
4. Helps to buffer: Learner acts as a buffer in social situations to help others who are loud, distracted, or interruptive.
5. Invitation to join: Learner invites others in to their investigation. Learners want others to share in their discoveries.
6. Responsible in groups: Learner acts mature and responsible in groups. Learner will do menial tasks for the investigation, quietly focus on the work, tell others in groups to not interrupt, etc.
7. Selfless ownership: Learner is willing to share things they possess or own. This can include tangibles and non-tangibles.
8. Some are nice: Learner indicates that some learners are nice.
9. Some are friends: Learner indicates that some of the other learners are friends.
10. Working together: Learners work together with others and each other.

iv. Roles: These codes refer to the roles learners take on during their time in Kitchen Chemistry.

1. Defining roles: Learner is attempting to define or question the roles in the social situation.
2. Equal partnership: Learners attempt to work together in equal roles and partnership.
3. Follower: Learner takes on a follower role.
4. Helper: Learner wants to help out and support the investigation.

5. Leadership: Learner takes on a leadership role.
 6. Gives instructions: Learners give instructions to others. This can occur as a learner gives instruction to an adult.
 7. Multiple roles: Learner claims to be in multiple roles and situations. They can be both leader / follower, independent / dependent, etc.
 8. Recording and using the technology: Learner takes on the roles of using the technology
 9. Strong participant: Learner takes on the role of being a strong and assertive participant. Generally not passive, more willing to be vocal, lead, be stubborn, etc.
 10. Usually the only girl: Learner tends to be the only girl in the social situation.
3. **Imagination:** Imagination is how a member themselves as connected (or not connected) of the broader community. Here, learners imagine themselves as part of the community and gain a sense of connection with others. Imagination connects towards an extended identity and involves seeing ourselves within a larger purpose and community. The codes refer to how learners see themselves, their goals, contributions, and roles.
- a. **Contributions:** The codes indicate if learners feel as though they have made contributions to KC and the group.
 - i. Feels they contribute: Learner has the perception they make contributions in KC.
 - ii. Ideas contribution: Learners make contributions by giving and sharing and developing new ideas.
 - b. **Goals → Learning and development:** These codes refer to the goals learners have in development. Development could focus on building, making, creating, and developing a project or learning something new.
 - i. Accomplish project: The goal is to finish the project, investigation, or activity.
 - ii. Cooks and eats food: The goal is to make food and to eat it.
 - iii. Creative: Learner's goal was to make something creative, not normal, something different and unique.
 - iv. Exploration and experimenting: The learner's goal is to explore and experiment to see what is possible, to answer a question, or just to observe a phenomenon.
 - v. Goal not met: A learner's development goal is not met. It did not turn out the way it was planned.
 - vi. Learning a new technique: The learners' goal is to learn a new technique in cooking or science.
 - vii. Making goals for investigation: Learners come up with goals for their investigation.
 - viii. New goal develops: A new goal for the learner develops out of the investigation.
 - ix. Rewards driven: Learner is driven by extrinsic rewards (e.g. food, people's applause), instead of intrinsic values.
 - x. Science goals: Learner is driven by a question or observation about phenomenon.
 - xi. Wants a tangible product: Learners want to come away with the investigation with a tangible product.
 - xii. Wants to cook from scratch: Learners want to make their products from scratch.
 - xiii. Wants to learn: Learners' goals are to learn more to help them with their food investigations.
 - c. **Goals → Expectations:** These codes refer to the expectations what learners want out of KC.
 - i. Boring: Learners / parents thought KC would be boring.
 - ii. Cooking: Learners / parents expected to cook in KC.
 - iii. Cooking < Science: Learners / parents expected more science activities than cooking.

- iv. Cooking > Science: Learners / parents expected or were more excited by the cooking than the science.
 - v. Experiments: Learners / parents expected to conduct experiments.
 - vi. Fun: Learners / parents expected KC to be fun.
 - vii. KC is not a class: Learners / parents expected that KC is not a class like school.
 - viii. No expectations for KC: Learners / parents had no expectations for KC.
 - ix. Useful for school: Learners / parents have expectations that KC will be good for future schooling.
 - x. Technology: Learners / parents expect that technology will be used in KC.
- d. **Goals → Social:** These codes refer to goals that focus on social aspects of KC.
- i. Goes to KC for friends: Learners come to KC because their friends are there.
 - ii. Goes to school just to go to KC: Learner comes to school just so they do not miss KC.
 - iii. Wants to be more social: Learner wants to be more social with others.
- e. **Relationship to science:** These codes refer to learners' perspective and relationship towards science and science learning.
- i. Authority: Learners have a perspective of authority in science
 - 1. Degree: You need a degree to do science
 - 2. Job: Being engaged in science means being in a job of a scientist
 - 3. Math: To be a good scientist, you must be good at math
 - 4. Power: Adults have higher power and roles in science
 - ii. Failure in experiments: Learner does not like when experiments fail in science
 - iii. Epistemology: Learner's perspective about knowledge in science.
 - 1. Abstract: Knowledge in science is abstract and disconnected from my life
 - 2. Answer: Science knowledge can be found as an answer. The adults know the answer. An answer exists in science.
 - 3. Authoritative knowledge: Science knowledge is authoritative and comes from other sources. It comes from sources like books, the internet, the facilitators, and experts. Knowledge is possessed here and distributed.
 - 4. Everyday knowledge: Science knowledge can be based in everyday experiences and observations. It can be personal and relevant to my life.
 - iv. Hands on: Learners have a perspective of science being hands on.
 - 1. Experiments: The hands on experience in science is based on experiments
 - 2. Explosions: The hands on experience in science is based on explosions and excitement
 - 3. Mixing things together: The hands on experience in science require mixing things together.
 - 4. Plays with lab equipment: The hands on experience in science require playing with lab equipment.
 - 5. Science by doing: The hands on experience in sciences means that science is learned by doing. Science is an experience.
 - v. I do science in KC: In KC, learners have a perspective of doing science here.
 - vi. Science: Learners' perspective of science in general
 - 1. Authentic: Science learning should be authentic and meaningful. It should connect to problem solving or something personal.
 - 2. Cooking and science: Learners perceive a relationship between cooking and science.
 - 3. Long wait: Science is a long wait and requires scientists to be patient.
 - 4. Observations: Science is about making observations of the world.

5. Diversity of things: Science is fun because of the diversity of things to do.
 6. Einstein-like: Good scientists tend to be white males, older, good at math, and famous (e.g., Einstein, Stephen Hawking).
 7. Outcome importance: In science, the outcome of experiments and investigations are very important.
- f. **Pride:** These codes refer to how learners express pride in Kitchen Chemistry.
- i. Confidence: Learners express confidence at some task or themselves.
 - ii. Excited about KC: Learners show excitement about KC. They show enthusiasm at being a part of KC, the activities, the investigation, etc.
 - iii. I am proud: Learner shows pride about being in KC.
 - iv. No change in interest: Learners show little evidence of change in interest in KC.
 - v. Talks to others about KC: Learner talks to other people about KC and show their enthusiasm
- g. **Imagination of self → Chef:** Codes referring to self-identity as a chef and cook.
- i. Chef as self
 1. Slow progress: Learners show evidence that becoming a chef is slow progress
 2. Sometimes: Learners shows evidence they may or may not identify themselves as a chef
 3. Yes: Learners shows evidence they identify themselves as a chef
 - ii. I don't want to be a chef: Learners like cooking, but they don't necessarily want to be a chef
 - iii. Tasting: Chefs spend a lot of time tasting and eating their creations. This is something I like.
- h. **Imagination of self → Designer:** Codes referring to self-identity as a designer.
- i. Build: Designers build things.
 - ii. Build apps: As part of KC, learners helped in co-design of building new apps.
 - iii. Come to life: To be a designer, whatever you build has to come to life. It cannot just be an idea alone.
 - iv. Design and cooking: Designers can make new foods and new ideas about food.
 - v. Critical of design: Designers can be critical of other designs.
 - vi. Designer as self
 1. No: Learner shows evidence they do not see themselves as a designer.
 2. Sometimes: Learner shows evidence they sometimes see and not see themselves as designers.
 3. Yes: Learners shows evidence they think of themselves as designers
 - vii. Draw: To be a designer, you have to be able to draw.
 - viii. Engineering: Engineers are a kind of designer.
 - ix. Everything: Designers design everything you see.
 - x. Happy: Learners want to design things to make others happy.
 - xi. I design: Learners see themselves designing things all the time.
 - xii. Ideas: Learners can be a designer with a lot of ideas. Learners don't have to have them come to life.
 - xiii. Imagination: Learners use their imaginations to design.
 - xiv. Implementation of design – Not sure: Learner is unsure how to implement their ideas in design.
 - xv. Improve: Designers can improve on prior designs
 - xvi. Legos, models, and toys: Learners mention Legos, models, and toys as part of design
 - xvii. Less complicated: The goal of designers it to make things less complicated
 - xviii. Technology: Learners design technology or see themselves designing technology

- i. **Imagination of self → Investigator:** Codes referring to self-identity as an investigator.
 - i. Clues: Learners state that investigators use clues to solve problems.
 - ii. Conclusions: Investigators make conclusions about some evidence.
 - iii. Crime: An investigator solves crimes.
 - iv. Explanations: An investigator comes up with explanations.
 - v. Exploration: An investigator goes around searching and exploring for information.
 - vi. Investigator as self
 - 1. No: Learner shows evidence they do not take on an investigator self-identity.
 - 2. Slow progress: Learner shows evidence they do not quickly adopt an investigator self-identity.
 - 3. Sometimes: Learner shows evidence they may or may not take on an investigator self-identity.
 - 4. Yes: Learner shows evidence they may have taken on an investigator self-identity.
 - vii. Mathematicians: A mathematician is a kind of investigator.
 - viii. Observe things: An investigator makes observations.
 - ix. Research: An investigator researches and looks for evidence or the origin.
 - x. Retrace steps: An investigator retraces his or her steps.
 - xi. Sherlock Holmes: An example of an investigator is Sherlock Holmes.
 - xii. Solve problems: Investigators help to solve problems.
 - xiii. Truth: Investigators are in the search for truth.

- j. **Imagination of self → Other:** Codes referring to self-identity in other roles.
 - i. Arts and music: Learner imagines themselves in the role of arts and music (e.g., dancer, musician, actor, etc).
 - ii. Big impossible ideas: Learner sees themselves as coming up with big and impossible ideas.
 - iii. Dreamer: Learner shows evidence of being a dreamer.
 - iv. Helping people: Learner imagines themselves as helping people
 - v. STEM career: Learner shows evidence of being in a STEM career one day, doesn't have to be a scientist.
 - vi. Technology: Learner's self-identity is based on technology and interactions with technology.
 - vii. Unsure: Learner shows evidence of being unsure about exactly what they want to be when they grow up or how they specifically identify themselves.

- k. **Imagination of self → Scientist:** Codes referring to self-identity as a scientist.
 - i. Communication
 - 1. Complicated words: Scientists use complicated words when they speak and communicate.
 - 2. Different: Scientists communicate differently than other people
 - 3. Regular words: Scientists can communicate using layman's language and regular words.
 - 4. Similar: Scientists can communicate similarly to other people.
 - 5. Spread: When scientists communicate, their ideas and words spread out.
 - ii. Scientists: Codes about what learners think and imagine about scientists.
 - 1. Curious: Scientists are often curious about phenomenon and the natural world. They have lots of questions.
 - 2. Disciplined and patient: Scientists are disciplined and patient.
 - 3. Discover and explore: Scientists discover and explore new knowledge.
 - 4. Interacts with nature: Scientists are able to interact with nature.

5. Hang out and relax: Scientists can hang out and relax. They are known to have fun.
 6. Make conclusions: Scientists come up with conclusions based on evidence.
 7. Reflective: Scientists are reflective in their practice. They spend time thinking about how to solve problems.
 8. Research: Scientists research and look up information and connect information together.
 9. Smart: Scientists need to be smart to do science.
 10. Thought experiments: Scientists can make thought experiments.
- iii. Scientist as self
1. I like science: Learner likes aspects of science and science learning.
 2. Interest: Learner shows an interest in science. They engage in science learning outside of school or have science learning as a hobby.
 3. No: Learners do not see themselves as a scientist.
 4. Yes: Learners shows evidence of scientist as part of self-identity
 5. Sometimes: Learners shows evidence of being a scientist sometimes.
 6. Young: Learner shows evidence of being a scientist since he or she was very young.
4. **Learning:** This code focuses on learners' perspectives on learning.
- a. **Articulation:** These codes refer to how learners articulate what they think they are learning.
 - i. Articulation difficulties: Learners have a difficult time describing what they think they learned.
 - ii. Difficulties understanding: Learners have a tough time understanding what they were supposed to learn
 - iii. Explanations: Learners are able to give an explanation for the phenomenon they are describing.
 - iv. Forgetful: Learners are forgetful about the details and what they think they learned.
 - v. Remembering: Learners can remember and explain some of the details of their investigations.
 - vi. Vocabulary: Learners uses vocabulary from KC to explain what's going on. Often times, the vocabulary is misused.
 - vii. Understanding: Learners knows what is going on in the KC activities.
 - b. **General:** These codes are referring to what general learning is going on with the learners. These codes are not science specific.
 - i. Applying knowledge: Learner uses prior knowledge from another experience and applies it to a specific situation.
 - ii. Collaboration of ideas: Learners collaborate and develop their knowledge. Ideas are generated as learners talk to each other or to the facilitators.
 - iii. Cooking – Cook: Learners are learning to cook and the process of cooking
 - iv. Cooking – Ingredients: Learners are learning what the role of the ingredients are
 - v. Expanding and developing ideas: Learners are creating, exploring, and developing new ideas.
 - vi. Heightened awareness: Learners are developing a heightened awareness of learning in the kitchen. A framework provided now so that children can begin to ask questions about food and science.
 - vii. Increased curiosity: Learners are developing new curiosity about science.
 - viii. Making adjustments: Learners are making adjustments and changes to adapt to a situation.
 - ix. Practical life skills: Knowledge of cooking is a practical life skill.
 - x. Problem solving: Learner is developing problem solving skills.
 - xi. Social skills: Learners are developing new social skills.

- xii. Technology: Learners are learning the role of technology.
- c. **Perception:** These codes are referring to how learners perceive their own learning.
- i. Answering personal questions: Learning means being able to answer your personal questions.
 - ii. Make claims about learning: Learners makes claims about learning.
 - iii. Content knowledge: Learning is making sure to know about the content knowledge of a given subject matter.
 - iv. Cramming knowledge: Learning is about cramming knowledge in and making sure you remember.
 - v. Doing and thinking: Doing and thinking must occur together. Hard to think without doing some hands on action.
 - vi. Failure: Learners see failure as an opportunity to learn
 - vii. Learned a lot: Learner says he or she learned a lot.
 - viii. Product focus: Learning means how to make things and be able to make things.
 - ix. Remembering: Learning is about remembering the content and the knowledge. Learner thinks of learning as taking in knowledge or absorbing knowledge.
 - x. Slow progress: Learning is slow progress.
 - xi. Sneaky learning: Learner does not like formal lessons. He or she wants to learn through activities, hands on, conversations, etc. Learner wants indirect learning.
- d. **Science Skills:** These codes are referring to the science skills learners are developing.
- i. Building an investigation: Learners are learning how to build an investigation.
 - ii. Careful experimental setup: Learners examine what it means to have a careful setup for their experiments.
 - iii. Categorization: Learners are developing categorization skills.
 - iv. Critique investigation: Learners start to critique the issues about their investigation.
 - v. Measurement:
 - 1. Skills: Learners develop skills in measuring
 - 2. Creativity: Learners develop creative ways to measure
 - vi. Mechanism
 - 1. Detailed: Learners show signs of mechanistic reasoning and tying together causality and effects.
 - 2. Simple: Learners show signs of simple mechanistic reasons with some causal claims and effects.
 - vii. Mental models: Learners develop mental models of a given phenomenon.
 - viii. Observations: Learners are developing observations skills and making detailed claims.
 - ix. Questions: Learners generate new questions about their investigation or ideas they wonder about.
 - x. Thinking logically: Learners develop a logical cohesion for arguments and claims
 - xi. Variable selection: Learners begin to choose their variables carefully with logic, instead of being haphazard.
5. **Profiles:** These codes refer to the development of a profile of the focal learners. Here, I examine what difficulties learners face, what talents they exhibit, what they like and dislike, and what technologies they are familiar with.
- a. **Difficulties:** These codes refer to the difficulties learners have in their home, school, and afterschool program.
- i. Skills
 - 1. Hard to do independent work: Learner has a difficult time doing independent work. They might lose track of time, not be interested later, etc.

2. Language arts: Learner has difficulties with tasks such as writing, learning language, reading, etc.
 3. Making decisions: Learner has difficulties making decisions, especially when it comes to independent projects.
 4. Multitasking: Learners have difficulty multitasking and doing multiple things at once.
 5. New ideas: Learners have a tough time coming up with new ideas.
 6. Physically unable to cook: Learners is physically unable to cook. They might be too short or not physically able to use the oven, etc.
- ii. Social
1. Attention: Learner has attention issues.
 2. Blunt: Learner is too blunt and doesn't think first about what he or she says.
 3. Discipline and self-control: Learner needs to be more disciplined and have self-control. Learner is too impulsive.
 4. Empathy: Learners needs to develop social skills in empathy and understanding
 5. Flexibility: Learner needs to be more flexible and understanding.
 6. Open to ideas: Learner has difficulties being open to ideas. He or she might not be receptive to new ideas.
 7. Patience: Learner tends to be impatient. Not willing to wait. Shows issues of impulsivity.
 8. Peer to peer comparisons: Learners put pressure on him or herself through comparisons with other people.
 9. Reading social cues: Learner needs work reading social cues from others. Often they are unaware of what others are thinking.
 10. Social interactions: Learner may have difficulties working in groups. Social interactions can be tough for the learner.
- b. **Dislikes:** These codes refer to what children dislike in their lives.
- i. Social
 1. Ideas not considered: Learner does not like when his or her ideas are not considered.
 2. Limitations: Learners do not like it when there are limitations placed upon them.
 3. Long explanations: Learners do not like long explanations and / or long lectures.
 4. Repeating too much: Learner get bored and dislike when things are repetitious and repeating.
 5. Sitting down: Learner does not like sitting down to learn.
 - ii. Inefficient technology: Learners do not like inefficient technologies.
 - iii. School
 1. Homework: Learner does not like homework from school.
 2. Problem-based learning: Learner does not like problem based learning or open challenges.
 3. Reading comprehension: Learner does not like reading comprehension tasks in school.
 4. Science in public school: Learner did not like science in the public school system.
 5. Tests: Learner does not like tests in the schools.
 - iv. Sports: Learner does not like sports.
- c. **Likes:** These codes refer to what children generally are fond of.
- i. Learning
 1. Exploration and curiosity: Learner likes exploring and being curious.

2. Figuring out and solving problems: Learner likes problem solving and figuring out solutions.
 3. General: Learners likes learning in general
 4. Ideas: Learners like coming up with ideas, discussing ideas, sharing ideas, etc.
 - ii. Hands on activities
 1. Activities: Learner really likes activities that are hands on.
 2. Mixing things: Learner likes activities that are hands on and allows for mixing things.
 - iii. Hobbies
 1. Arts and music: Learner enjoys arts, music, dance, acting, etc.
 2. Cooking: Learner likes cooking and things associated with cooking.
 3. Cub Scouts: Learner enjoys the Cub Scouts.
 4. Legos and playmobiles: Learner likes playing with Legos and playmobiiles.
 5. Reading and writing: Learner likes reading and writing stories.
 - iv. Roles
 1. Helper: Learner likes to take on a helper role.
 2. Being the only girl: Learner enjoys being the only girl in certain situations.
 - v. School:
 1. General: Learner enjoys school in general
 2. Math: Learners enjoys math at school
 - vi. Science
 1. Biology: Learner likes biology in school.
 2. Chemistry: Learner enjoys chemistry.
 3. Close observations: Learner enjoys the processes of science in close observations.
 4. Physical science: Learner enjoys physical sciences in school.
 5. Reading about science: Learner likes reading about science.
 6. STEM general: Learner enjoys science, math, technology, engineering in general.
 - vii. Skills
 1. Creativity: Learner likes being creative and being quirky in ideas.
 2. Designing: Learner indicates they like designing things.
 3. New questions: Learner likes coming up with new questions.
 4. Problem solving: Learner likes to problem solve.
 - viii. Social
 1. Answering questions: In social situations, learner likes to answer the questions that come up.
 2. Fun: Learner likes having fun with other people.
 3. Independence: Learner likes to be independent from other people.
 4. Less pressure: Learner likes social situations that do not present a lot of peer pressure.
 5. Order and calm: Learner likes social situations that are calm and ordered.
 6. Presentations: Learner likes giving presentations in front of people.
 7. Sharing ideas: Learner likes sharing their ideas in front of others.
 8. Working with older children: Learner likes to work with older children.
- d. **Personality:** These codes refer to the personality and trait of the learner.
- i. Accepting: Learner shows evidence of being passive and accepting of others requests.
 - ii. Asks for help: Learner tends to ask for help of others.
 - iii. Assertive: Learners has an assertive and strong personality. This can be evidenced by how much they want a particular thing.

- iv. Becoming less conservative: Learner is becoming more casual and less conservative in dress and style.
 - v. Smart: Learner (or others) describe the learner has bright, smart, or other positive traits for cognition.
 - vi. Calm: Learner shows evidence of being calm and not overly excited.
 - vii. Cautious: Learner is hesitant to take risks, shows signs of being cautious.
 - viii. Competitive: Learner show signs of being competitive with others.
 - ix. Friendly: Learner generally acts friendly.
 - x. Funny: Learner acts funny and goofy.
 - xi. Happy: Learner shows signs of being happy.
 - xii. Immature / acts young: Learner often acts immature or acts younger than what he or she seem.
 - xiii. Not spontaneous: Learner does not like spontaneity; generally prefers to plan ahead
 - xiv. Outgoing: Learner acts gregarious, social, excited, etc.
 - xv. Polite: Learner acts polite and shows manners
 - xvi. Quiet and shy: Learners act quiet or shy in certain situations. Sometimes they will just work quietly by themselves.
 - xvii. Sensitive: Learners are sensitive to the actions of others.
- e. **Talents:** These codes refer to what the learners and others say are their talents and strengths.
- i. Character
 - 1. Creative: Learner shows evidence of creative thinking
 - 2. Curiosity: Learner exhibits evidence of being curious and show this as a talent
 - 3. Enthusiastic: Learner's talents include showing off enthusiasm
 - 4. Imaginative: Learner's talents include being imaginative and dreaming up big ideas.
 - 5. Logical: Learner's talents include being logical and having strong problem solving skills.
 - 6. Passionate: Learner's talent includes being passionate about what he or she is interested in.
 - 7. Perceptive: Learner is known to be perceptive and observant of his or her surroundings.
 - 8. Responsible: Learner is responsible in certain areas in his or her life
 - 9. Wide interest: Learner is known to have a wide array of interests
 - ii. Skills
 - 1. Academics: Learner is skilled in academics, such as completing school work or being proficient in school work.
 - 2. Artistic: Learner is skilled in arts and music.
 - 3. Building things: Learner is skilled at building models and other items.
 - 4. Finishes work: Learner is skilled at finishing his or her work and seeing a task through.
 - 5. Making videos: Learner is skilled at making videos.
 - 6. Math: Learner is skilled at math and solving math problems.
 - 7. Research assignments: Learner is skilled at completing research assignments.
 - 8. Science: Learner is skilled at science and investigations.
 - 9. Spatial awareness: Learner is known to have spatial awareness
 - iii. Social
 - 1. Compassionate: Learner shows compassion to others.
 - 2. Diplomatic: Learner is diplomatic towards other.
 - 3. Listens respectfully: Learner is known to respectfully listen to others.
 - 4. Loyal: Learner is known to be loyal to others.

- f. **Technology usage:** These codes refer to what technologies the children use.
- i. Likes
 1. Apple: Learner likes Apple products.
 2. Cars: Learner likes cars.
 3. History of technology: Learners enjoys the history of technology
 4. Initial testing: Learner enjoys the initial testing and playing around with a new piece of technology
 5. Making videos: Learner likes making videos.
 6. Multifunctions: Learner likes the multiple functions of computers and technology
 7. Social: Learner likes the social aspect
 8. Technology in general: Learner likes using digital technology in general
 9. Video games: Learner likes video games.
 - ii. Uses
 1. Computer: Learner uses computer.
 2. Phone: Learner uses iPhone.
 3. Search engine: Learner uses search engine.
 4. Use when necessary: Learner uses search engine.
 5. Video games: Learners plays video games.
 6. YouTube: Learner uses YouTube.
6. **Target of ownership:** This code focuses on the state where an individual feels as though an object or non-tangible thing (e.g., ideas, process) is his or hers. A target of ownership manifests itself in emotions commonly associated with ‘my’, ‘mine’ and ‘our.’ Here, individuals might “feel” as though the target of ownership is theirs. Feelings of ownership are a complex state that represents a condition of thoughts, beliefs, attitudes, emotion and affective sensation. Learners can show ownership towards these targets through attempting to control the target, investment into the target, willingness to share or not share a target, and show pride for a target. Other participants can acknowledge the target as well (e.g., this is your project).
- a. **Non-tangible targets:** Targets can get non-tangible and non-material. These include ideas, projects, relationships, etc.
 - i. Able to make parents happy: Learner shows evidence of wanting to make their parents happy. Learners show this by being excited or happy when their parents show positive views about what they do. Ownership occurs through pride in the learners work.
 - ii. Being creative: Learner shows evidence that being creative and coming up with new ideas is a goal and target for him or herself. Learners are proud of being creative, show others they are creative, want to invest into being creative, and take control about their creations.
 - iii. Coming up with technique: Learner’s target is coming up with his or her own technique in the investigation / cooking. Learners are often create in their techniques, want to spent time developing the techniques more, show meticulous care about the organization of their technique, are able to manipulate and control the technique, and are proud of their technique.
 - iv. Developing own organization: Learner’s target and pursuit is to develop his or her own organization of the investigation. Learners spent time pre-planning the organization of the investigation. They invest time into developing the organization, they control the organization, they are prideful about their work, etc.
 - v. Project accomplished: Learner sets up a target of ownership as getting the project done and accomplishing his / her goals. Learners might take responsibility for the tasks, focus on organizing ways to see the project through, assign tasks to others, etc. Getting the project done is important to the learner.

- vi. Ideas – Design: The learner’s target of ownership is the development of ideas for designing the investigation. Learners want to keep developing ideas focused on creation and design. Learner exhibits ownership as they continuously engage in ideas for development and may want authorship for those ideas. Learners are also vocal about what they want for the design of the investigation.
- vii. Ideas – Explanation: Learner’s target of ownership is the ideas in which he or she uses as an explanation of a phenomenon. Learners might exhibit ownership of these ideas through sharing of the ideas (or need to share the ideas to others), authorship, pride, investment, and control.
- viii. Mastering a technique: Learner’s target of ownership focuses on mastering and learning a technique. Learners show ownership of mastering a technique through spending time practicing a technique, wanting to learn a technique, inviting others to come see a technique they are learning, etc.
- ix. Own project: The project / investigation is what learners own. Learners should this through investment into the project, control over the project, inviting others to come share in the project, declaring authorship, exuding pride about the project, etc.
- x. People care: Learners seek other’s approval. The target they choose to own is what others think. Learners are concerned what others think about what they do.
- xi. Question: Learners have ownership of a question they have developed. They feel importance about this question, they feel the question is personal, they want to answer the question, they want to share the question with others, they want to take time to invest into the question, and they are proud of the question.
- xii. Schedule: Learners want to control their schedule. They want to choose when to do things, the rate at which a project needs to be accomplished, etc.

b. **Tangible:** Material objects can also be targets of ownership.

- i. Cooking equipment: Learners take possession and control of the cooking equipment. They direct who has control of what equipment, who uses what materials, etc.
- ii. Personal products: Learners want to create personal products from their cooking investigations. Evidence of ownership includes:
 - 1. Learners want to take home a product they created in KC.
 - 2. They are excited over this product, want to show the product off, tell others about the product, and control how to distribute the product.
 - 3. Learners are also excited about the creativity of the product.
 - 4. Learners also know a lot of details and facts about the creation of their personal products. They know key features about their products and they may even offer suggestions on how to better improve it.
 - 5. Learners want to spend more time on the product and invest into it.
- iii. Space and area: Learners develop territories of certain spaces and areas in the room. They will invite others to the space, spend long periods of time in the space, control what goes on in the space, and make choices when they want to engage in the space.
- iv. Technology: Learners take control of aspects of the technology in their lives. Learners might take control and ownership of personal artifacts he or she creates. In Kitchen Chem they choose when to record, when to input, when to share, when to not use it, etc. Learners may also have an affinity towards helping to design aspect of the app (co-design). Technology also includes the digital stories and artifacts created in the iPads (e.g., StoryKit, SING, Zydeco entries). Learners have a chance to shape and mold their own usage in technology.

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