ONCE UP ON A MAKERSPACE:

ELEMENTARY STUDENTS DOCUMENT THE STORIES OF THEIR THINKING

By

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ABSTRACT

My school district designed and implemented a makerspace to increase student-driven learning. Our makerspace is an evolving learning environment where students can create, innovate, and educate. Children experiment with elements of coding, engineering, digital literacy, and video production through both "plugged in" (technology-based) or "unplugged" (hands-on experiences) lessons. The makerspace is designed to be an open-ended learning environment where students work with community experts, peers, and teachers through play-based learning (Britton, 2012).

Most of the initial proposed and completed projects were teacher-driven and not student-generated. Examples of projects included Lego engineering modules, guided coding sessions, and arts integrated digital storytelling workshops with the local community theatre. The staff established a greenhouse and garden to grow food, which the school then donated to the local food bank. Students could also design simulations of different communities with Minecraft. Education Edition. While students were motivated and engaged during these experiences, they were not yet generating projects of personal interest or designing solutions to real world problems.

Because makerspaces are a relatively new design in public schools, some would argue they are a fad in education with little empirical research to support this student-driven learning model. Furthermore, the majority of studies conducted to date were implemented in informal learning environments like museums, community centers, or public libraries, whereas the remaining studies conducted in formal education settings were derived mainly from higher education, high school, and middle school learning environments (Vossoughi & Bevan, 2014).

This study employed mixed methods with a design-based research methodology to develop a deeper understanding of the learning ecology in the elementary makerspace-learning environment. Building upon the emerging body of research that documents both formal and informal learning outcomes in makerspaces, contributions of this study include advancing our understanding of how making thinking visible and peer feedback support students' design thinking, how student preferences for tools and their situational interest are leveraged to create projects and relationships, and how students articulate their design process within the context of the elementary makerspace-learning environment. Educators can reference the study's outcomes as they design the physical space and develop curricula for the makerspace-learning environment.

Keywords: makerspace, elementary education, Flipgrid, Maker Mindset, Agency by Design Framework, Agency by Design Thinking Routines, peer feedback, peer model, verbal peer feedback, peer proximity, engagement, metacognition, documentation, making thinking visible, Makey Makey, Lego, Minecraft, cardboard, design thinking, Chromebook, designerly learning, design thinking

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As our society continues to become more reliant on a global economy and digital resources, it is important for adult learners to evolve and continue to grow in their skillsets. Educators must be fluid and flexible in their thinking to serve our society's changing needs. Pursuing a doctoral degree in the Design of Learning Environments has been an inspiring process and I look forward to sharing the vast experiences and research I have studied to cultivate learning opportunities for both children and adults.

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CHAPTER 1: INTRODUCTION

Despite the recent adoption of the federal Every Student Succeeds Act (ESSA), which supports school innovation at the local and state levels, schools are increasingly leaning towards an emphasis on standardizing curricula and determining student and teacher success by test scores (Beane, 2013). Meanwhile, the call from government and business for increased innovation in schools in the 21st century contradicts this movement. From its naissance, the term *innovation* lacked a clear definition and operationalization of what innovation looks like in K-12 schools (Schoen & Fusarelli, 2008). A recent publication, "*The U.S. Education Innovation Index: Prototype and Report*," defined innovation in schools as, "the implementation of a new or significantly improved product, process, policy, organization type, organization model, or organization practice" (Weeby, Robson, & Mu, 2016, p. 23). Schools demonstrate innovation when they create and foster opportunities for entrepreneurship and invention; reframe school climate problems with viable solutions; or even explore emerging technologies. Furthermore, the New Jersey Student Learning Standards and Next Generation Science Standards, both priorities under the ESSA law, require children to be critical thinkers who can analyze and synthesize information to support solutions and recommendations to various problems. Students are expected to integrate knowledge across disciplines in order to demonstrate understanding and create new ideas.

America's public schools are caught in the middle of this tension as they face the rigor and complexities of the accountability policies while best practice and reform movements indicate students learn best through student-driven learning (Krajcik, McNeil, & Reiser, 2008). This approach to education assumes students demonstrate agency in directing their learning while socially engaging with other people to solve problems (Snape & Fox-Turnbull, 2013).

Agency is defined as students having the ability to make choices and act with intention, both individually and collectively, to create change (Bandura, 2000, 2006; Kangas, Vesterinen, Lipponen, Kopisto, Salo, & Krokfors, 2014). As schools continue to espouse new student-driven programming, student agency is critical in order for students to navigate the intricacies of the modern elementary school experience. While not every school ascribes to agentic engagement in learning, meaning the school system expects "students' constructive contribution into the flow of the instruction they receive" (Reeve & Tseng, 2011, p. 258), in the schools where educators do embrace agentic engagement, students can personalize their learning and act with intentionality in determining the content and rationale of what is being learned.

As schools grapple to achieve a balance between accountability and innovation, some schools are integrating makerspaces into their curriculum (Sheridan, Halverson, Litts, Brahms, Jacobs-Priebe, & Owens, 2014). A makerspace is "an informal site for creative production in art, science, and engineering where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products" (Sheridan et al., 2014, p. 505). Bowler (2014) presented another view of the makerspace as a place of creation rather than consumption. Designed to cultivate creativity and digital literacy for all learners, the makerspace-learning environment also serves as a catalyst for shaping participants' involvement with a variety of technical tools focusing on coding, engineering, and problem solving (Bowler, 2014; Brennan, Resnick, & Monroy-Hernandez, 2010). Sheridan et al. (2014) referenced national initiatives including former President Obama's Educate to Innovate campaign, the Next Generation Science Standards, and the National Core Arts Standards as catalysts stimulating the growth of makerspace-learning environments in schools and communities. All three initiatives require students to engage in critical thinking skills through design across content areas.

According to Chris Anderson, author of ***Makers: The New Industrial Revolution***, the very idea of making has now created a paradigm shift in our society leading to significant economic impacts. He wrote, "The Maker Movement is beginning to change the face of industry, as entrepreneurial instincts kick in and hobbies become small companies" (Anderson, 2012, p. 19). Mark Hatch, author of ***The Maker Movement Manifesto***, also acknowledged this shift in the economy and referenced examples of how entrepreneurs have leveraged local makerspaces to access different tools to launch new businesses or design temporary co-working spaces to develop new products.

Initially, makerspaces began as non-academic, community learning environments to foster social collaborations based on personal interests and virtual tools (Fleming, 2015). In schools, libraries, and museums across the country, makerspaces are quickly evolving into learning environments where people can create, innovate, and educate. With space and funding at a premium, educational leaders are refashioning their schools with flexible makerspace-learning environments, also referred to as FabLabs, DIYs (Do It Yourself), Little Makers, and Creative Spaces (Fleming, 2015). In response to the call for redesigned learning spaces, my school district designed and implemented a makerspace in 2015 to further develop our capacity to increase student-driven learning. Our makerspace is an evolving learning environment where students can create, innovate, and educate. Researchers at Stanford University documented that implementing curriculum-based making in the formal context of school encouraged students to develop knowledge related to technology and science (Chu, Angello, Saenz, & Quek, 2017). We created opportunities in our school's curriculum for children to experiment with elements of coding, engineering, digital literacy, and video production through both "plugged in" (technology-based) or "unplugged" (hands-on experiences) lessons. Our makerspace is designed to be an open-ended learning environment where students work with community experts, peers, and teachers through play-based learning (Britton, 2012).

Problem of Practice

During this study, the school's makerspace had entered its third iteration and developed into an entity where exciting explorations focused on engineering, arts integration, technology, and video production were common practice for over 400 students in grades K-3. The makerspace was utilized as a weekly enrichment/media lab for each student. The makerspace team consisted of the Media Specialist and her instructional assistant who facilitated each makerspace experience. The district continued to enhance the makerspace where students from different grade levels, community experts, teachers, and families could collectively work on shared learning objectives and projects with a variety of technology, media, and physical tools.

Most of the proposed and completed projects in the makerspace had been teacher-driven and not student-generated. Projects included Bricks 4 Kidz Lego engineering modules; coding sessions via Code.org; arts integrated digital storytelling with a local community theater; and gardening through Project Pollinator (See Appendix A). During these experiences, there was an adult facilitator who visited the class and provided either a directed or guided project for students to complete. For example, when working with the Bricks 4 Kidz facilitator, students were presented with a Lego kit. In the kit were pre-selected pieces such as Lego blocks, gears, and motors, as well as step-by-step directions detailing how to build the object. The facilitator explained the purpose of the build (e.g. a motorized Ferris wheel) and developed background knowledge as to the engineering components of working with axles and gears. She showed them the actual artifact they would create and then let them start building. Step-by-step directions were represented graphically and students worked together in pairs. The Bricks 4 Kidz facilitator and the makerspace teachers monitored student progress and provided support when needed.

Although students were motivated and engaged during these experiences, they had not yet generated projects of personal interest or designed solutions to real-world problems. According to Martinez and Stager (2013) and Dougherty (2016), when participants work in the makerspace, 20% of the projects should be explicitly focused on *directed projects* such as learning how to use a particular makerspace tool (e.g. Lego motors and gears, 3-D printer, coding blocks, etc.); 30% of projects should be *guided projects* in which participants engage in learning tasks with explicit instructions and scaffolds to complete a project (e.g. Bricks 4 Kidz Lego modules, Makey Makey design challenge tasks, etc.); and finally 50% of the projects should be *open projects* where participants can pursue projects of personal interest through creative design thinking and technology skills sets learned during the direct and guided project work. Although more research is needed to provide clear support for these recommendations, this framework provides guidelines to formalize informal learning experiences in the elementary school setting to encourage more student-driven projects.

While evaluating the current makerspace-learning environment, the makerspace staff and I specifically examined both the physical and instructional design features that could help cultivate a learning environment that could generate and sustain student agency to complete more *student-driven or open projects*. Although pleased with the physical design of the space, which had been reconfigured to include more collaborative learning spaces and areas dedicated to tinkering, engineering, video production, coding, and gardening, the staff and I were concerned with the lack of student choice demonstrated in the makerspace. Although little research existed about agency in the makerspace setting, some research in early elementary science classrooms indicated students who investigated and researched their own questions demonstrated increased metacognitive awareness as evidenced by their ability to articulate their approach to the research and exploration process (Metz, 2011). Research conducted by Chinn and Malhotra (2002) advocated for authenticity in scientific experiment designs where students themselves performed complex tasks in response to research questions or topics. Edelson, Reiser, and Sawyer (2006) also suggested engaging learners in authentic practices enabled them to develop a context, application, and understanding of a particular body of knowledge or practice. According to Brown (1992), in order to establish an intentional learning environment, students must be given authentic opportunities and agency to act as researchers and to self-monitor their progress. Teachers in this type of environment provide guided discovery and model active inquiry so that students can emulate this type of behavior and be empowered to direct their own learning. This body of research justified the Benefits of student-driven learning in the makerspace pertaining to scientific concepts related to technology, engineering, and biology, and it served as a foundation for encouraging student-driven learning in other content areas occurring in the makerspace.

Purpose of Research

Because makerspaces are a relatively new design in public schools, some would argue they are a fad in education with little empirical research to support this student-driven learning model. Furthermore, the majority of studies conducted to date were done in informal learning environments like museums, community centers, or public libraries, whereas the remaining studies conducted in formal education settings were derived mainly from higher education, high school, and middle school learning environments. The research outcomes of this study in the makerspace builds upon the emerging body of research that documents the informal learning outcomes and iterative nature of the learning process through making, specifically for elementary school students.

Design-based research. This study employed mixed methods with a design-based research (DBR) methodology to develop a deeper understanding of the learning ecology in the makerspace (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). DBR provides opportunities for educators and researchers to refine current practices or launch new design features to enhance the existing learning environment (Collins, Joseph, & Bielaczyc, 2004). Always mindful of current learning theories and best practices in education, researchers engaging in DBR understand that the very nature of DBR is iterative and takes place in the natural and often messy setting of an actual classroom. DBR "is premised on the notion that we can learn important things about the nature of and conditions of learning by attempting to engineer and sustain educational innovation in everyday settings" (Bell, 2004, p. 242).

I proposed an initial instructional and assessment plan, and acknowledged that these may have changed in light of data gathered. That is, I anticipated unexpected outcomes leading to changes in the procedures or objectives of the original study (Cobb et al., 2003). In order to measure the effectiveness of design features and meditating processes impacting students' informal learning in the makerspace setting, I analyzed students' behaviors and their artifacts with experiences and measurements similar to the ones outlined in the conjecture map (Figure 1).

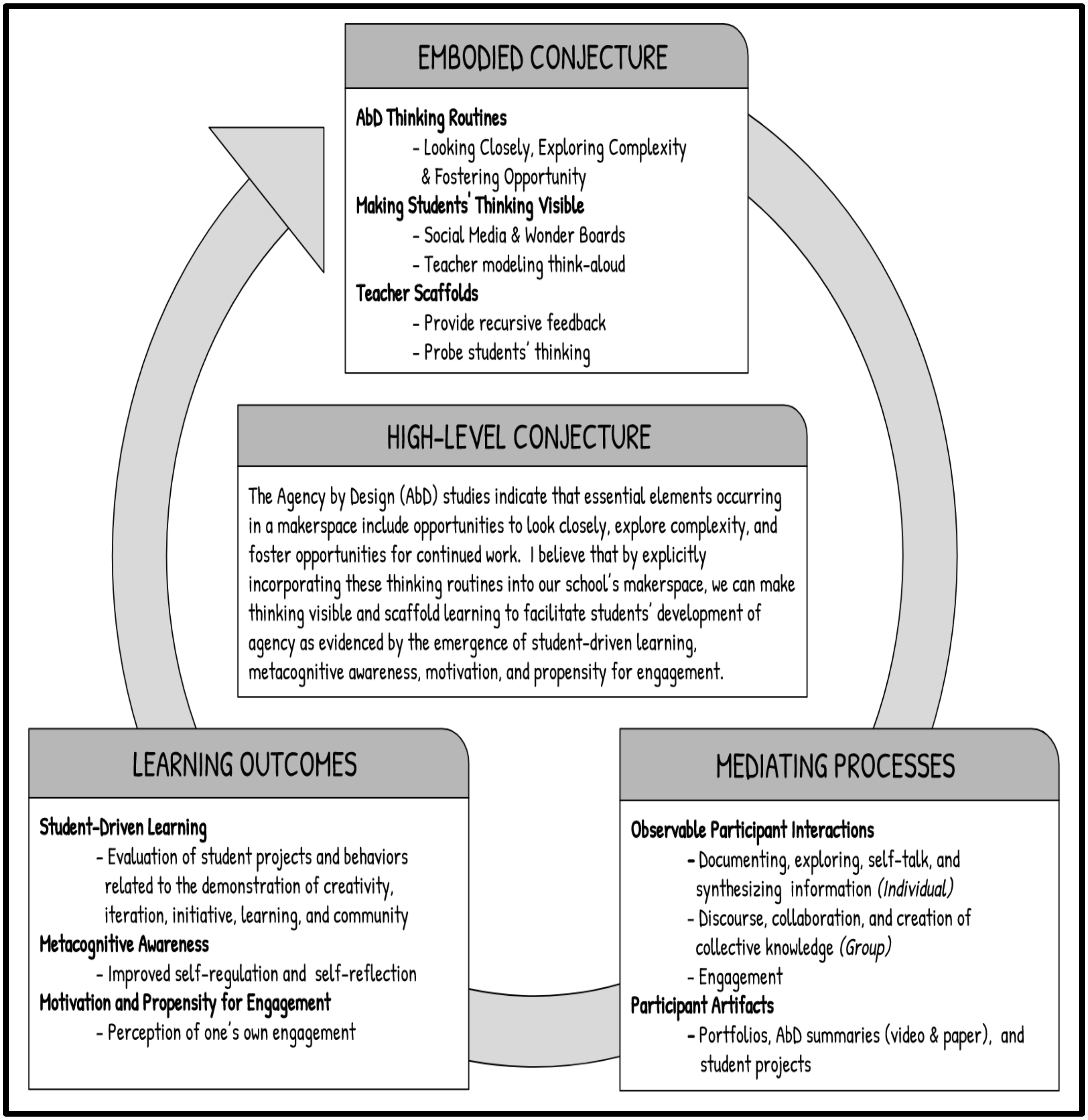

Figure 1. Embodied conjecture for creating student agency in the elementary makerspace.

Conjecture mapping. Prior to implementing DBR, Sandoval (2004, 2014) outlined steps to create a conjecture map with theories, embodiment of tools or objects, mediating processes, and learning outcomes to help plan for different design prototypes. A conjecture map helps researchers articulate a hypothesis grounded in theoretical frameworks to create design features and outcomes expected to occur in a particular learning environment (Sandoval, 2004, 2014). Careful data analysis and argumentative grammar are inherent to the process of DBR in order to show that a particular intervention correlated to the desired outcome or contributed to an unexpected outcome. Manifestations of the theories are recognized in the embodiment or design of the conjecture which detail participant structures or tools that might be used. The next element is the infusion of meditating processes that predict observable interactions and participant artifacts. Finally, expected outcomes are also listed to help the researchers clarify the desired results.

High-level conjecture. When working in a makerspace, two distinct processes occur: making and tinkering. Making refers to the physical act of actually making an artifact whereas tinkering is more of a mindset — “a playful way to approach and solve problems through direct experience, experimentation, and discovery” (Martinez & Stager, 2013, p. 32). Maker-centered learning can lead to student agency (Clapp, Ross, O’Ryan, & Tishman, 2016), meaning students have the ability to make choices and act with intention both individually and collectively to create change (Bandura, 2000, 2006; Kangas, Vesterinen, Lipponen, Kopisto, Salo, & Krokfors, 2014). Socially constructed, agentic engagement (Reeve & Tseng, 2011) further expanded the idea that students can act with intentionality while personalizing their own instruction in school to design individually and collectively relevant experiences. Student engagement can be evaluated by examining four aspects of engagement: agentic, behavioral, emotional, and cognitive (Reeve & Tseng, 2011). Agentic engagement refers to “students’ constructive contribution into the flow of the instruction they receive” (Reeve & Tseng, 2011, p. 258). This means students can personalize their learning and act with intentionality in determining the content and rationale of what is being learned. Elements of engagement related to behavior (on-task attention, effort, persistence, lack of conduct problems), emotion (presence of interest and enthusiasm, absence of anger, anxiety, and boredom), and cognition (use of strategic and complex learning strategies, active self-regulation) can serve as a foundation upon which to build agentic engagement.

Over the past three years, learning and happenings in the makerspace had been documented through informal observations, anecdotal records, posts on Twitter, and photos. My colleagues and I recognized the need to enhance opportunities for students to demonstrate agency in the makerspace setting. All makerspaces encourage participants to become a member of a community; research real-world problems and design solutions to these problems; and work collaboratively with a variety of tools, including digital media (Sheridan et al., 2014; Clapp et al., 2016). The potential for students to develop agency is clearly available in the makerspace, yet my staff and I continued to wonder how we could reframe the context of learning in the makerspace to encourage more student self-directedness and choice in their learning. Project-based learning (PBL) experiences could achieve this objective through explorations that include time for students to investigate topics of interest (Puntambekar, Stylianou, & Goldstein, 2007). Within the elementary makerspace setting, Smay and Walker (2015) found the integration of makerspaces, design thinking, and PBL to successfully impact student-driven learning by fostering inquiry, discovery, multiple iterations, and the development of both creative and critical thinking skills. According to Kilpatrick and Rugg (Ravitch, 2001) the curriculum studies must begin with the child's interests and be student-initiated — both which the makerspace-learning environment encourages, particularly through independent and collaborative PBL experiences.

Work conducted at Harvard University's Project Zero regarding the Agency by Design (AbD) studies indicated that essential elements occurring in a makerspace, referred to as the *AbD Thinking Routines*, included opportunities to look closely, explore complexity, and foster opportunities for continued work. Consistent integration of thinking routines as part of a learning environment provided a structure for students develop metacognitive awareness, as well as a pathway to make their thinking visible (Ritchhart, Palmer, Church, & Tishman, 2006). I believed that by explicitly incorporating these routines into the school's makerspace, my staff and I could make students' thinking visible to encourage the emergence of student-driven projects and ultimately student agency to create personalized learning environments.

Furthermore, in my role as school principal, the makerspace staff and I supported a *Maker Mindset* as the basis of the makerspace to encourage students to develop their own projects. The *Maker Mindset* explicitly expects students to play, experiment, and pursue their interests (Dougherty, 2016). "Makers believe in their own individual agency to act and create change in their own lives and their community" (Dougherty, 2016, p. 144). In order to develop this mindset, the design process is actually valued just as much, if not more so, than the final product or artifact a maker creates. Makers must acknowledge the design process is iterative and sometimes messy. Chu, Quek, Sourabh, Bhangaonkar, Ging, and Sridharamurthy (2015) implemented a study in which students could tell stories through digital applications offered in The Maker Theater kit. The researchers conducted two children's workshops on two consecutive Saturdays with 23 girls and boys ranging from eight to ten years of age. As the participants created stories utilizing the digital kit, the researchers identified three maker capacities to support the Maker Mindset: self-efficacy, motivation, and interest. Participants believed in their ability to make, followed their want to make, and expressed their enjoyment of making.

In order to cultivate this mindset, students in this study actively participated in AbD Thinking Routines (Figure 2). Initially, the AbD Thinking Routines were implemented during the directed and guided portions of the makerspace instruction; however, the staff and I had hoped that as students explored design thinking, they would internalize and transfer the routines to generate student-driven projects.

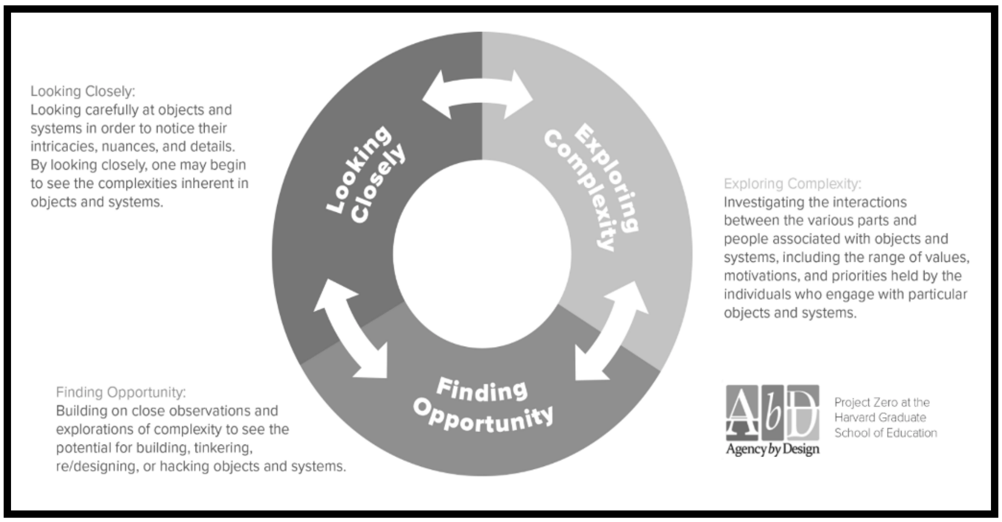

Figure 2. Agency by Design Thinking Routines. Retrieved from: www.agencybydesign.org.

Embodiment and design. Task structures featured the teachers planning for and providing opportunities for students to engage in AbD Thinking Routines; making students' thinking visible; and teacher scaffolds to probe students' thinking and provide recursive feedback.

AbD Thinking Routines. The AbD Thinking Routines are part of the Harvard Graduate School of Education's Project Zero and directly support the criteria necessary to develop agency in the makerspace: looking closely, fostering complexity, and finding opportunity. Each attribute featured a series of questions that could help the learner to carefully examine objects and objects within systems (See Appendix B). Examples of thinking routines for students included questions similar to the ones outlined below:

a. What are its parts?
b. What are its various pieces or components?
c. What are its purposes?
d. What are the purposes for each of these parts?
e. In what ways could it be made to be more effective?
f. In what ways could it be made to be more efficient?
g. In what ways could it be made to be more beautiful?
h. What perspectives can you look at it from?
i. How are you involved?
j. What connections do you have? What assumptions, interests or personal circumstances shape the way you see it?
k. How does this person understand this system and their role within the system?
l. What is this person's emotional response to the system and to their position within it?
m. What are this person's values, priorities, or motivations with regard to the system? What is important to this person?

During this study, the teacher provided time in class for students to look carefully at objects and systems in order to notice their intricacies, nuances, and details. Students collaborated with a peer partner or in small peer groups — no more than four — to actively use the AbD Thinking Routines. This means they conversed with one another as they used the AbD Thinking Routines to guide their discussions and record their observations. They explored simple objects brought in from home and complex makerspace tools such as Legos, Lego machines, Tinkering Area tools, Makey Makey kits and projects, and greenhouse tools.

The teacher **explicitly modeled** how to look closely during a whole class direct mini-lesson (10 minutes). Then she provided time for students to select an object and practice the looking closely routines using the “Parts, Purpose, Complexity” activity. This strategy continued in subsequent weeks with the Exploring Complexity and Fostering Opportunity routines. The teacher modeled through a **“think-aloud,”** meaning she self-talked as she made observations and detailed how she represented her thinking – photos, drawings, and journal entries. Eventually, students had the opportunity to self-select routines if they so chose to help develop their own thinking as they participated in design challenges or pursued self-directed projects during each rotation.

Making students’ thinking visible. All making projects create some evidence of learning (Dougherty, 2016, p. 194). Student projects and artifacts provide tangible evidence. In order to identify intangible learning outcomes such as metacognitive awareness, students in this study were expected to document their thinking and learning as a formal participant structure. First, they were invited to contribute to the Wonder Boards where they could post questions, thoughts, pictures, and comments about their work or one of their peers’ work. As a school, the staff and I had created process-based bulletin boards throughout the hallways to showcase the thinking process, so students did have some familiarity with the idea of documenting thinking. However, the research team and I thought the Wonder Boards would more interactive as students would be the primary contributors rather than the teachers. Students investigated interactions between the various parts and people associated with objects and systems. They did this by visiting different learning areas in the makerspace and/or by self-selecting items or systems in the school.

Demirbilek (2015) found that as students posted digital photos or videos of their work on

Wiki and Facebook, their peers provided a variety of feedback that encouraged students to revise or re-evaluate their work, ultimately leading to improved artifacts. In addition, the peers critiquing each other also had to develop critical thinking skills when providing specific feedback about another peer's work. Casey and Wells (2015) posited that in both the high school setting and the pre-service teacher higher education setting, the integration of social media permitted students to "learn by doing" and provided peer-to-peer modeling of different strategies for learning supports. Both groups demonstrated how remixing social media tools improved feedback loops and ultimately student learning through blogs, online groups, chat tools, and research tools. Furthermore, "remixing" social media, the sharing of content across different content areas and learning environments, could scaffold critical friend feedback and reflective practice (Casey & Wells, 2015).

Students also had the opportunity to post their thoughts, questions, or plans about different objects or systems on social media such as Flipgrid and Google Drive, as well as physical displays on the makerspace Wonder Boards. In order to effectively utilize social media, the teacher explicitly modeled how to use the comment features in Google Drive through direct instruction and guided practice. She provided opportunities for students to use commenting features with her, and once they knew how to provide reciprocity in commenting or resolving questions, she encouraged students to converse with one another through the Google Drive comments feature. The teacher also posted topics on Flipgrid and students responded. According to Common Sense Media, Flipgrid is:

> A website that allows teachers to create "grids" of short discussion-style questions that students respond to through recorded videos. Each grid is effectively a message board where teachers can pose a question and their students can post 90-second video responses

that appear in a tiled "grid" display." (Retrieved from https://www.commonsense.org/education/website/flipgrid on November 11, 2018) She modeled how to use the technology features of recording and posting a video, while also teaching public speaking skills. She provided graphic organizers to help students generate their ideas prior to posting their responses.

Finally, the teacher created locations around the makerspace to physically post thoughts and ideas via writing on post-its, sentence strips, or even through drawings or photos. She modeled how to do this and encouraged both students and other staff members to participate. She demonstrated how to provide responses and showed students the tools.

Teacher scaffolds. To further develop and sustain the desired authentic PBL opportunities, students need to engage in feedback with peers and teachers to strengthen their learning and agency (Demirbilek, 2015). Throughout this study, the teachers monitored students during the different learning areas (e.g. Tinkering Studio, Lego modules, coding, etc.) to scaffold or extend students' thinking. The teachers used discussion probes from the AbD Thinking Routines as appropriate to further query students' application of knowledge and synthesis of ideas. Possible probes included: *What are its parts? What are its various pieces or components? What are its purposes? What are the purposes for each of these parts? In what ways could it be made to be more effective? In what ways could it be made to be more efficient? In what ways could it be made to be more beautiful?* The teachers engaged and monitored Wonder Board postings and online feedback related to students' social media inquiry, and provided recursive feedback (descriptive, evaluative, motivational, formative).

Mediating processes. As students worked in the makerspace they created a variety of artifacts and engaged in behaviors aligned to the AbD Thinking Routines.

Observable interactions. Further undergirding the mediating processes is the need to analyze observable interactions between the participants and their learning environment. AbD supports the iterative cycle of observation in which students *look closely*, *explore complexity*, and *find opportunity*. It was my expectation that when students found the opportunity to expand their understanding of how objects functioned and worked as part of a system, they would demonstrate agency by applying their observations to create something new. Work conducted in the elementary science classroom by Puntambekar, Stylianou, and Goldstein (2007) also demonstrated positive learning outcomes for students who were given time to analyze objects and connect those objects to more abstract concepts (such as systems). The researchers found students were more aware of big ideas and core principles about a particular unit. Specific observable interactions of both individuals and collaborative teams could have been categorized into three overarching areas: documenting, exploring, and synthesizing information.

According to Sairanen and Kumpulainen (2014), preschool and first-grade students' sense of agency increased when given opportunities to provide a visual narrative about their work through photos and sketches. Students were empowered by their abilities to use tools such as cameras, and validated by making their thinking visible. When *documenting* their learning or thinking processes in this study, students may have demonstrated the following behaviors:

- Thinking visibly – sketches and drawings
- Writing lists
- Recording their thoughts and observations
- Taking pictures or video of their objects
- Planning and prototyping
- Designing storyboards

While *exploring* the various materials in the makerspace or interacting with different design tasks or challenges, students may have exhibited the following actions:

- Building, making, and using tools
- Learning and using domain specific language
- Noticing details
- Taking things apart
- Mapping parts and interactions
- Role-playing
- Brainstorming ideas for projects or ideas
- Testing prototypes
- Materials exploration
- Collaborating
- Designing
- Researching the who, where, when, how, why about the parts & people through interviews or research — Analyzing information

Learning communities are formed around common goals, activities, and relationships (Bielaczyc & Collins, 1999). Through discourse, collaboration, and creation of artifacts, relationships are cemented and thus build on the collective knowledge of a community of learners. Communities of learners can only be established when students are active and take on the roles of researchers rather than passive recipients of knowledge (Brown, 1992). Similarly, stemming from the research on Collective Cognitive Responsibility (CCR) by Zhang, Scardamalia, Reeve, and Messina (2009), CCR posited the need for students and teachers to collaborate on the creation of new knowledge. Reflective of authentic practices in the real world, CCR fosters distributive and opportunistic collaboration in the school setting between teachers, students, and community members. As students worked in groups or independently to persist through challenges or develop deeper understandings about how objects and systems function, they may have actually *synthesized* their thinking or generated new ideas in the following ways:

- Reconsidering initial observations & designing/implementing new iterations of prototypes
- Noticing inter-connected systems and transferring observations to personal projects

Throughout the study, students *self-talked* about their learning experience as it related to their projects. Students were expected to explain their projects specifically noting how they conceived of the project idea; how they selected different materials and tools to conduct their projects; why they worked in a certain area in the makerspace; how they implemented their projects; and/or why they abandoned their projects. This information was collected through teacher observations, student focus-panel interviews, Flipgrid posts, and video recordings. Ideally, I had hoped students would cite the AbD Thinking Routines, teacher scaffolds, or making their thinking visible as sources of inspiration. It was expected that their usage of domain-specific vocabulary related to the AbD Thinking Routines, teacher scaffolds, or feedback from making their thinking visible would be included as they articulated their metacognitive awareness of the project design. For example, a student might have said, "When I look closely, I noticed…" or "After considering the feedback from a peer on the Wonder Board, I decided to…"

The social surround of the learning environment could have impacted participant engagement (Patrick, Ryan, & Kaplan, 2007). When students physically manipulated tools, or interacted with one another, their engagement could be observed through affect and behaviors. When engaged and motivated in a learning task, students may have displayed emotions such as joy, pride, disappointment, or frustration (Bevan, Gutwill, Petrich, & Wilkinson, 2015). Students could have also requested to remain in the makerspace after appearing “finished” and then started something new. In addition, spending time in tinkering activities could also have indicated engagement as students played, envisioned, explored materials, or tried something over and over.

Participant artifacts. It was expected that while in the makerspace, students would actually be creating artifacts to demonstrate learning, thinking, and understanding. Students could have created electronic-portfolios, summaries of their AbD Thinking Routines, and student-driven projects. For example, students could have summarized and reflected upon their use of AbD Thinking Routines on Flipgrid to highlight their learning process and articulate next steps for exploration or new ideas. This could have helped to launch the creation of electronic portfolios that might have included videos, photographs, audio files, and personal narratives, as well as recursive feedback (descriptive, evaluative, motivational, formative) from peers, teachers, and community experts.

Finally, students could have generated ideas for student-driven projects. Based on the design features, students could have built on their close observations of complexity by refining or remixing their observations/results to create something new or another iteration of the project design. For example, after working with Bricks for Kidz modules, they could have designed Lego machines or Lego models to demonstrate or expand their thinking. Projects could initially begin as independent work, such as when prior to the study, students created a marble pinball/maze game made from cardboard pieces. As peers piloted or played with the game, they could have given the inventor some feedback. These interactions could have led to another iteration of the initial concept, thus supporting feedback as a stimulus for refining the original design.

The evolution of the participants' artifacts was iterative in nature further elevating the importance of process, not just product. All artifacts were measured with a rubric which rated creativity, iteration, initiative, learning, and community. With permission from The Digital Harbor Foundation, we used the Maker Project Rubric (See Appendix C) for this study, which explicated the differences between *emerging creativity* such as a student following directions to create a project and *exemplary* projects in which students' ideas or projects were explored and expressed in multiple ways. This same rubric defined the varying degrees of perseverance, synthesis of new knowledge, and sharing learning outcomes. Clearly, the described mediating processes could have contributed to this body of knowledge as well.

Learning outcomes. Although makerspaces can be fun and interesting to visit, district stakeholders demanded to see the value and impact of the actual learning happening in the makerspace. In order to continue support for the makerspace, the learning outcomes needed to be measurable and visible. Areas assessed by this study included the analysis of student-driven learning, metacognitive awareness, motivation, and engagement.

Student-driven learning. Students selected an area in which to work to explore their own questions or develop solutions to real-world problems through their projects. Students' projects were evaluated using a rubric that identified informal and formal learning outcomes, and behaviors aligned with the original research questions. Critical attributes examined included initiative, creativity, iteration, perseverance, and collaboration. The teacher facilitator and I evaluated how the different design features impacted students' initial conception of their ideas, implementation of their project ideas, or abandonment of their project concept.

I fully expected that there would be variations in the projects in terms of materials used as well as the complexity of the projects themselves. For example, some students had prior experiences outside of the school with tools like Makey Makey kits or Minecraft: Education Edition (Minecraft); therefore, their prior knowledge may have been more advanced in comparison to students who were novices with these tools. The differences in skill sets could have led to higher levels of initiative for the more experienced participants as those students might be able to “encounter complications with a positive attitude and persevere to problem-solve independently without needing to seek assistance” (Maker Project Rubric, Appendix C). Similarly, students who implemented the AbD Thinking Routines as part of self-directed learning experiences may have demonstrated exemplary levels of iteration as they “completed their product having improved the design and/or aesthetics over time” (Maker Project Rubric, Appendix C).

Metacognitive awareness. As students made their thinking visible throughout the study, I expected metacognitive awareness as a learning outcome for student-participants. Metacognition shapes a learner’s ability to self-regulate, meaning a productive learner can navigate through procedural, declarative, and conditional knowledge to monitor and direct their learning experience (Winne & Azevedo, 2006). “To help learners engage in productive self-regulated learning, learning environments should be designed to foster effective metacognitive strategies” (Winne & Azevedo, 2006, p. 80). Based on posts to Flipgrid and the Wonder Boards, as well as the utilization of the AbD Thinking Routines, students could have monitored their thinking processes to strategically reach different learning goals. As part of this study, I evaluated the use of these tools and the emergence of students’ metacognitive awareness.

Motivation and engagement. In order to design learning environments that are motivating and engaging, Järvelä and Renninger (2014) recommended integrating relevant and scaffolded learning experiences that are grounded in personalization of activities, as well as domain specific content. Student initiative and intentionality of the learning process can be evaluated through observations of students persevering to achieve goals in the face of setbacks or frustration (Bevan et al., 2015). Participant engagement was evaluated by examining how students displayed investment in their learning through affect or behavior. Specific measurements for this study included observations of video recordings of students interacting in the makerspace, as well as pre and post engagement surveys filled out by students and student focus-panel interviews. Vongkulluksn, Matewos, Sinatra, and Marsh (2018) reported situational interest in a particular topic led to self-efficacy and engagement in the private school elementary makerspace setting. The researchers studied 100 children in Grades 3-6 and contended that situational interest could be triggered by current events, personal interests, or even challenges or frustrations when working in the makerspace. Vongullusksn et al. (2018) also reported that teachers needed to provide scaffolding and support in order to ensure *triggered* situational interest became *maintained* situational interest.

Research Questions

To date, there has been very little research to operationalize how to implement an elementary school makerspace, specifically focusing on fostering informal learning outcomes such as student agency. Therefore, I proposed that the physical design features, instructional strategies, and learning scaffolds in the makerspace would foster an environment that cultivated opportunities for students to pursue studies of personal interest and give them ownership over their learning.

Research questions undergirding this study included:

1. What types of makerspace projects do students create?
2. Which design features scaffold the learning trajectory of students' makerspace projects from conception to completion?
3. When describing their projects, how do students articulate the design process? Do they recognize or cite the design features as influencing their project outcomes?
4. What elements of project planning and implementation do students find motivating or engaging?

This study provides evidence about how the makerspace-learning environment in the elementary school setting can foster and sustain opportunities for the emergence of student agency. The quantitative and qualitative data collected in this study can be used to improve makerspace-learning environments and offer relevant evidence for educators about how students can develop metacognitive awareness, motivation, and engagement through student-driven learning experiences.

CHAPTER 2: LITERATURE REVIEW

In order to identity relevant literature to address the research questions and support the proposed design features for this study, extensive searches were conducted through the Rutgers University Library services, Google Scholar, and recommended literature from colleagues. Because the implementation of makerspaces in schools is a relatively new phenomenon, most of the material available consisted of personal narratives, case studies, blogs, and websites that focused on how to establish and sustain a makerspace. Despite the lack of empirical research around makerspaces (at the time this study was conceived), there are some unifying themes which seem to consistently emerge including: becoming a member of a community, researching real-world problems and designing solutions to these problems, and working collaboratively with a variety of tools, including digital media (Clapp et al., 2016; Sheridan et al., 2014). In order to draw upon a wider scope of empirical studies to support the emergence of student agency and of making students' thinking visible in the makerspace, I expanded the literature review to examine broader theories of learning, rather than just on makerspaces themselves. Many of the empirically based makerspace studies grounded their research in theoretical frameworks such as constructivism, constructionism, and connectivism, and these studies can be organized into three categories: Design Frameworks, Collaborative Communities, and Making Students' Thinking Visible.

While implementing the research study, new research conducted in elementary makerspaces was published. I have updated the literature review to include the most recent national and international studies, which specifically focus on design thinking in elementary makerspaces and how to engage and motivate young makers. In the following paragraphs, I explain how the theories of constructivism, constructionism, and connectivism frame the learning in the makerspace-learning environment.

Theoretical Frameworks

The makerspace-learning environment involves a continuous and iterative evolution of both design and learning. Makerspaces themselves are learning environments that inherently strengthen and nurture opportunities for students to actively construct, understand, and communicate knowledge. Framed within the tenets of constructivism, constructionism, and connectivism, makerspaces support individualized and collaborative experiences through technology resources, community mentors, and personal learning networks.

Constructivism. Constructivism suggests knowledge is actively constructed by the learner through experience and is ongoing — mirroring the iterative nature of the makerspace-learning environment. As students use prior experiences to integrate new findings (Lemlech, 2006) and manipulate tools to further create cognitive meaning (Quintana, Shin, Norris, & Soloway, 2006), they fully engage in creating their own body of knowledge to apply and synthesize information as they make meaning of their world. Whereas Dewey proposed the evaluation of practical transformation of concepts, and Vygotsky valued the social-cultural experience of constructing meaning (Roth & Jornet, 2014), both merit attention in the makerspace-learning environment as vehicles to help participants personalize learning paths.

Calling for education to be grounded in experience, Dewey is often cited as the founder of constructivism. "If you have doubts about how learning happens, engage in sustained inquiry: study, ponder, consider alternative possibilities and arrive at your belief grounded in evidence" (Dewey, 1998, as cited in Mapes, 2009, p. 11). The makerspace-learning environment cultivates experiential learning where the participants can design, explore, and connect to the materials and scenarios based on their own curiosity and with a community of learners.

In addition to students exploring and tinkering with objects and ideas, they can also explore and develop relationships with experts. The idea of community experts serving as resources is supported by educational theorists like Vygotsky and transcends all socio-economic barriers. Vygotsky claimed cognitive development was a socially mediated process from which children directly learned from the adults in their immediate family and community (Berk, 2000). According to Vygotsky, working with more knowledgeable members of society allows students to develop thinking and behaving (Berk, 2000) which reflect the values and beliefs of a particular community. Additional opportunities for the development of participatory culture of learning occurs through guided participation or scaffolding, allowing the student to work within his or her Zone of Proximal Development (ZPD) (Gestwicki, 1999) to actively engage with project-based learning. ZPD refers to the difference between what a learner can do independently and what the learner can do with help from a mentor or expert. Within the makerspace-learning environment, each participant and facilitator can work within his or her own ZPD and seek help from the physical and virtual community to scaffold learning.

Constructionism. Further extending the idea of constructivism is the embodiment of students' thinking through constructionism. A core premise of the theory of constructionism is that learners should actually build an artifact to demonstrate learning (Papert & Harel, 1991), whereas constructivism emphasizes the mental constructs a learner creates. In the makerspace-learning environment students learn "by constructing knowledge through the act of making something shareable" (Martinez & Stager, 2013, p. 21). Constructionism focuses on how ideas are connected and developed between the learner and the educator. In the makerspace-learning environment, students can design, explore and connect to the materials and scenarios based on their own curiosity and with a community of learners.

As students become comfortable and familiar with the tools provided in the makerspace-learning environment, they can develop *maker literacy.* Chu, Deuermeyer, Martin, Quek, Berman, Suarez, & Banigan (2017) conducted a study in three elementary science classrooms (Grades 3-5) to analyze maker literacy skills. They defined maker literacy as a student's ability to apply maker *skills*, create *mental models,* and engage in *practices* in order to represent different concepts.

The researchers had already worked with the students in the study (Grades 3-5) as part of another three-year long science study. Prior to this study beginning, students had 1.5 years to develop *skills* with various maker tools including computers, wires, circuits, coding tools, LED lights, and other items. The researchers asked students to build a diorama model with various digital tools (wires, circuits, LED lights, etc.) to represent different science concepts (e.g. thermal energy or mechanical energy) for each unit of study in their grade. As students created *mental models* of their projects or ideas, they had to troubleshoot as they explored possible materials, think through a variety of maker possibilities, and deconstruct their proposed artifact component by component. As students engaged in their making activities, their *practice* was evaluated as their ability to self-identify as a maker, collaborate with others, and using making as an important aspect of their project. The researchers found that in order for students to be maker-literate, they had to be effective at all three levels.

Connectivism. As the digital natives utilizing the makerspace have grown up in a world where technology has always existed, their personal experiences are also derived from technology resources. Further framing the study is the theory of Connectivism (Boitshwarelo, 2011), which posits that people learn together through similar interests in both virtual and real time worlds to create connected community-learning networks. The connectivist learning community constructs knowledge and then distributes that knowledge across multiple individuals (Boitshwarelo, 2011). Kop and Hill (2008) proposed that as information can be networked and stored across multiple formats, knowledge needed to be shared in a variety of ways with diverse audiences and co-collaborators. As the technologies rapidly change, so too must the expectations of schools and how they evolve with technologies (Davis, Eickelmann, & Zaka, 2013).

Siemens (2005) suggested that information must be connected to the right people at the right time and in the right context in order for learning to occur. Connectivism embraces constructivism as its base, but expands beyond the tenets of constructivism to recognize that humans can interact with one another as well as with non-human resources (e.g. databases, websites, social media, avatars, etc.) to gather, synthesize and create information (Siemens, 2005). The sociocultural implications of makerspaces support the idea of a participatory culture of learning (Bevan et al., 2015; Jenkins, Clinton, Purushotma, Robinson, & Weigel, 2010) in which participants integrate technology to share ideas, conduct research, ask questions, or create solutions.

Connectivism also supports scaffolded learning through the use of communities of practice facilitated through emerging technologies and social networks (e.g. Skyping, Flipgrid, Twitter, Google Hangouts, blogs, etc.). These cloud-based and virtual forums cultivate opportunities for immediate connections to create ideas, relationships, and artifacts despite geographical, personal, or physical boundaries. Social media tools can support effective feedback by offering students of all ages the ability to manipulate information from different resources and cultures to synthesize and create new artifacts of learning and ultimately knowledge for the collective whole (Casey & Wells, 2015). Connections on social media can establish a learning network that goes beyond the classroom, further supporting the ideas of people learning together through similar interests virtually and in real time. As technologies and devices are continually redefined, providing new applications each day, learners must adapt and find new uses in order to connect to the actual devices and one another. "The co-evolution of education and digital technologies is defined by the interaction between the evolution of digital technologies applied within education; both are evolving and so changes in one tend to stimulate changes in the other" (Davis, Eickelmann, & Zaka, 2013, p. 440).

These theories serve as the foundation of the makerspace-learning environment. The next section examines the evolution of makerspace design frameworks providing guidelines for how both the physical and instructional components of a makerspace-learning environment can be scaffolded.

Design Frameworks

"Makerspaces are not defined by a specific set of materials or spaces, but rather a mindset of community, partnerships, collaboration and creation" (Turner, Welch, & Reynolds, 2013, p. 226). Makerspaces can be situated in museums, schools, and libraries (Vossoughi & Bevan, 2014). According to a recent case study in the elementary makerspace setting, the physical spaces of a makerspace convey the types of behaviors it can support and promote (Bers, Strawhacker, & Vizner, 2018). Anderson (2012) argued that makerspaces could also be digital Do-It-Yourself (DIY) environments where makers could establish "network effects: when you connect people and ideas, they grow" (p. 21), creating a virtual circle of communication, sharing, and even trade. Regardless of the physical location, all makerspaces recognize the iterative nature of the work occurring in a makerspace. These learning environments were established with the understanding that through collaboration, feedback, and open-ended projects or outcomes, the makers could explore, analyze, and create projects of interest, or develop solutions to real-world problems. As participants work in the makerspace environment and engage in design thinking, they progress through different paths to play, tinker, design, and create. There are a variety of design frameworks that outline physical features and consistent practices and framework elements available in all makerspaces. The first framework I present, User-Centered Design, provides a structure for makerspace facilitators to evaluate the implementation of their makerspace and outlines explicit steps to refine the initial designs of the makerspace-learning environment. The remaining frameworks, Agency by Design, uTec Maker Model, Studio Framework, and Tinkering for Learning Dimensions Framework, identify specific participant behaviors that can be observed in the makerspace-learning environment to help design and sustain viable experiences.

User-Centered Design. Kurti, Kurti, and Fleming (2014) suggested employing a user-centered design (UCD) approach in the makerspace *implementation phase*, encouraging makerspace designs reflective of students' interests. Kurti et al. (2014) outlined five cyclical components to incorporate in planning. First, *understanding* the targeted learners was critical when determining developmental readiness and social context of the learning scenarios. Once the learners were identified, the makerspace facilitators could *assess* existing materials, resources, and curricula that could support student-driven inquiry in the makerspace. Items could include science kits, technology tools such as iPads or Chromebooks, or even Legos for building models. After participants and existing materials were selected, the makerspace facilitators *considered* best practices, current research, and global trends to frame possible making experiences. Examples of this included experimenting with computer coding and designing items to be used outside of the immediate school building. As the makerspace evolved, facilitators *developed* thematic units of study that established systems for students to share resources, or collaborate on different projects. Finally, the researchers recommended conducting an assessment to *evaluate* additional items to support the makerspace. The entire process was repeated continuously as an evolving curriculum. Herro (2015) suggested the need for a shift in classroom culture where the teacher acts as coach or facilitator versus instructor. In order to support this shift, Koh and Abbas (2015) defined the competencies of teachers in the makerspace as learning, adapting to changing situations, collaborating, and advocating for the needs of the learning space.[1]

Agency by Design. In order to understand how things work, students in makerspaces need to spend time examining objects and how their hidden mechanics work (Clapp et al., 2016). For example, students can draw a screw from different perspectives, or they can take apart a typewriter to understand how the keys and carriage move. Sensitivity to design acknowledges that "being attuned to the designed dimension of objects and systems, with an understanding that the designed world is malleable" (Clapp et al., 2016, p. 117). To help teachers and students develop sensitivity to principles of design thinking, the Agency by Design Framework (Clapp et al., 2016) cited three maker capacities: *looking closely*, *exploring complexity*, and *finding opportunity*.

The authors examined different makerspaces across 30 states and 150 schools to document that by integrating these three elements, students could transition to a systemic view of design thinking rather than just isolating details about one specific object. For example, in an eighth-grade classroom, students looked closely at telephones leading to an understanding of the complexity of telephone production, the evolution of cell phones, and ultimately how the cell

[1] My staff and I evaluated our makerspace through the UCD framework to identify areas of success and to define areas in need of improvement. Outcomes were outlined and aligned to each of the UCD criteria (See Appendix D).

phones were situated within the world of communication. In a third-grade class studying electricity, a teacher shifted her practice from telling students how a light bulb works to letting students look closely at a light bulb before beginning the unit of study. Students were expected to take the bulb apart, and examine its contents. They used this exploration to deepen their understanding about electrical circuit systems. In a fifth-grade classroom, students looked closely at the physical design of their classrooms, and eventually found the opportunity to collaborate with architects to reconfigure and redesign their classroom.

uTEC Maker Model. Derived from observations in public library makerspaces, the uTEC Maker Model (Loertscher, Preddy, & Derry, 2013) evolved into linear progression of work in the makerspace. First, the participant entered the makerspace at the *Using* level, engaging with relatively basic exploration of something someone else had created for a specific purpose, such as a computer game or a step-by-step building activity. As the participant became more comfortable, he or she moved on to the *Tinkering* level, playing with things for different purposes than the inventor or creator initially intended. Examples included altering code or creating shortcuts in a game. When the participant purposefully created something new and added to the world's knowledge base, he or she progressed to the *Experimenting* level. The learning transpiring at this phase encourages multiple iterations of a design or product in order to prove theories, or make something useful. Once the experiment proved to be useful or purposeful, the user moved to the *Creating* level where there were actual results derived from the *Experimenting* level (e.g. creation of a new video game or a new musical score). The purpose of this study was to identify the learning trajectory in a makerspace setting enabling teachers and makerspace facilitators to leverage participants' personal expertise, cooperative group work, and collaborative intelligence to sustain makerspace-learning environments and experiences.

Tinkering Learning Dimension Framework. Bevan, Gutwill, Petrich, and Wilkinson (2015) established the Tinkering Learning Dimension Framework (TLDF) to operationalize the attributes of learning occurring in the makerspace environment, specifically in the museum setting. The researchers identified various learning dimensions, indicators, and descriptions of learner behaviors focusing on engagement, initiative and intentionality, social scaffolding, and development of understanding. Each dimension provided measurable indicators such as: setting personal goals, seeking feedback, persevering, requesting help, and explaining. When developing a coding scheme for data collection, Bevan et al. (2015) further operationalized each indicator with observable behaviors such as: play, interactions with peers, and seeking community mentorship. The authors conducted an 18-month study and collected video recordings of over 50 individuals participating in three makerspace activities including: circuit boards, wind-tubes, and marble machines. Although this study was conducted in the museum setting, the framework supports the social and collaborative nature of the elementary school makerspace-learning environment.

"Another contribution of the study is the operationalization of the social and collaborative nature of the tinkering setting. The Framework draws explicit links between the social group and the social individual, by noting the dynamic interplay within the tinkering setting as ideas and tools travel" (Bevan et al., 2015, p. 18). Although the researchers acknowledged the TLDF required further research, Bevan et al. (2015) contended that specific behaviors participants might exhibit as part of tinkering activities in a makerspace could help support learning and scaffolds. The study explicitly outlined behavioral outcomes related to tinkering which may include: (a) persisting toward their goals in the face of setbacks or frustration; (b) persisting to optimize strategies or solutions; (c) actively seeking out feedback or inspiration from materials or environment; (d) demonstrating innovating approaches in response to feedback from peers or teacher; (e) anticipating further outcomes; (f) disagreeing with each other's strategies, solutions, or rationales; and (g) trying something while indicating a lack of confidence in the outcome.

Studio Framework. Sheridan et al. (2014) suggested that the physical structure of makerspaces should reflect elements of studio spaces where people work with a variety of materials, and in different groupings (e.g. independent, partners, small groups, etc.) (Halverson & Sheridan, 2014). The Studio Framework proposed four key elements required in studio learning environments: demonstration lectures, students-at-work, critiques, and exhibitions of student work (Hetland, Winner, Veenema, & Sheridan, 2013). In the Studio Framework, community experts provided mentoring through demonstrations, feedback, and partnerships. In addition, social interaction also occurred when students worked with one another or experts, as well as when presenting their artifacts to real audiences.

Framework recommendation. In order to determine the best makerspace design framework to support this study's focus on student agency and student-driven projects, I analyzed the frameworks previously described and then coded indicators related to the emergence of student engagement or self-directedness, feedback, evidence of student thinking, and instruction. I did not include the User-Centered Design because that is only to be referenced for the implementation phase of the makerspace. The disaggregated indicators are outlined in Table 1.

Each makerspace design framework consisted of indicators that aligned with the attributes of direct instruction, feedback, evidence of student thinking, and demonstration of student agency. When providing explicit instruction regarding makerspace tools, the AbD, Studio, and UTec Maker Model Frameworks all targeted this indicator but the Tinkering

Learning Dimensions Framework did not. All four frameworks did encourage feedback, documentation of student thinking, and student agency; however, only the AbD Framework's indicators clearly aligned to each of the four areas of importance for this study. Therefore for the purpose of this study, I grounded the design interventions in the AbD Framework.

Table 1

Disaggregation of Makerspace Design Framework Indicators

Framework	**Instruction**	**Feedback**	**Evidence of Student Thinking**	**Demonstration of Student Agency**
Agency by Design (AbD)	Look closely Explore complexity Foster opportunities			
Tinkering Learning Dimensions Framework		Seeking feedback and requesting help	Explaining	Setting personal goals
Studio Framework	Demonstration lectures by teachers	Critiques	Exhibitions of student work	Students at work
UTec Maker Model	Using	Using, Tinkering, and Experimenting	Using, Experimenting, Tinkering, and Creating	Tinkering, Experimenting, and Creating

The next section documents how makers work together in collaborative communities by fostering opportunities for common goals, mentorship, and project-based learning. In addition, the manifestation of collective cognition and responsibility are explored as outcomes of these collaborative communities. Finally evidence from a recently published international research study supports how people work together in collaborative communities to engage in design thinking and collective knowledge processes in the makerspace-learning environment.

Collaborative Communities

As members of the makerspace work together, they can collaboratively discover, problem-solve, and provide solutions to meaningful events, happenings, and conflicts in their immediate communities. In order to further leverage learning opportunities in various makerspace communities, Fleming (2015) advocated for stakeholders to maximize connections. The partnerships between an expert learner and novice learners potentially enhance the process and products created in a makerspace. Sheridan et al. (2014) designed a comparative case study of three makerspaces with different demographics in terms of setting, funding, and targeted participants. The researchers reported seeing:

> Evidence in each makerspace of a hybrid model that include(d) many of the ways of seeing, valuing, thinking, and doing found in participatory cultures, yet incorporate(d) pedagogical structures found in more formal studio-based settings such as demonstration, facilitated workshops, and critique. (Sheridan et al., 2014, p. 527)

The researchers contended the diverse factors of the makers themselves and their resources strengthened the research to be applicable to other makerspaces as the case studies examined a variety of environments. However, they also acknowledged the results of the study may not be reliable for all makerspaces as the individual makerspaces observed had unique participants and varied financial resources, possibly leading to inequities and disparities of available materials, tools, physical space, and, ultimately, maker outcomes.

In their comparative case study of two Reggio Emilia inspired early childhood makerspaces in Denmark and the United States, Bers et al. (2017) reported that the student artifacts and photos of students engaged in work or of students' work displayed in the makerspace setting inspired community building for the students. When students in both settings saw the artifacts or photos, they engaged with peers to discuss the objects or photos. In many cases this led them to pursue interests of their own such as when an American student saw a peer's collection of drawings about crutches. She found the drawings interesting, and asked the child why she drew them. She explained that she was interested in helping people with disabilities. This inspired the other student to start sketching models of hearing aid devices, and another group inspired by these same drawings tried to design models of wheelchairs and elevators out of Rig-a-majig (A wooden building kit with assorted birch planks in different shapes and connecting tools like yarn or plastic pieces - https://rigamajig.com/products for more details) and KIBO robotics (a screen free robotic building kit for children ages 4-7 – for more details visit https://kinderlabrobotics.com/kibo/). In Denmark, students observed a student-created sculpture displayed in the room along with a photo of the child working on the sculpture. This photo served as a provocation for other students to talk about how the project and how this child was part of their community. Then the students suggested they also post pictures of their work, which in turn led to more conversations and community connectedness in the school.

In the next section I explain how communities are supported in makerspaces through communities of practice, project-based learning, cognitive apprenticeship, collective knowledge and responsibility, and design thinking.

Communities of practice. Edelson and Reiser (2006) suggested engaging learners in authentic practices enabled them to develop a context, application, and understanding of a particular body of knowledge or practice. This can be accomplished in the makerspace-learning environment by immersing learners in a collaborative culture of learning which scaffolds learners across the gulf of expertise through construction, situated cognition, discourse, and community (Quintana et al., 2006). Learner-centered design (Quintana et al., 2006) is an example of participatory culture as it specifies the need for active construction, social cognition, discourse, and community as key elements in learning. Social interactions and meaningful, authentic tasks addressed in these elements further connect learning across a community of learners.

Project-based learning. The idea of a community-of-learners model includes both children and adults who rely on one another's talents and expertise to problem solve and work in project-based learning scenarios (Berk, 2000). Project-based learning (PBL) invites learners to address a problem with real world applications while they are learning by doing (Krajcik, McNeill, & Reiser, 2008). PBLs can encompass rigorous standards and authentic problems through a learning-goals driven design model (Krajcik et al., 2008) by collaboratively developing learning goals, acquiring materials, and gathering feedback from both learners and facilitators. Integration of PBL can lead to improved metacognition and agency provided learning environments are structured with developmentally appropriate and relevant learning goals, scaffolds to support both students and teachers, ongoing formative self-assessments and revision, and frequent social interaction and participation (Barron, Schwartz, Vye, Moore, Petrosino, Zech, & Bransford, 1998). The social interactions in PBL help to achieve "the best learning results … when teachers, students, and community members work together in a situated activity to construct shared understanding" (Krajcik & Shinn, 2006, p. 278).

Cognitive apprenticeship. At the core of the makerspace ideology is the mobilization of culture, reflective of each individual school community. Scaffolded learning opportunities with teachers, peers, community mentors and family members encourage students to literally make something that matters for themselves or their communities. Cognitive apprenticeship (Collins, 2006) affords students the opportunity to learn from community experts through situated learning experiences in order to solve real problems impacting one's community. Situated learning refers to the idea of students becoming apprentices as they engage in legitimate peripheral participation with mentors (Hmelo-Silver, Duncan, & Chinn, 2007; Lave & Wenger, 1991).

Similarly, learning through intent participation (Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo, 2003) supports the idea of multi-generational experiences where children observe adults in the natural work setting (e.g. planting a garden or building a structure), and then mirror the adults' actions. Authentic practices cultivate a growth-mindset, which can provide meaningful context and content (Edelson et al., 2006), further influencing the learner outside of the learning environment, and, more practically, within one's community. Stakeholder mentorship scaffolds and cements learning in authentic situations when the stakeholder experts work with students in the various fields of study (Sheridan et al., 2014).

Collective intelligence and responsibility. As students connect in role-play, design models of real world problems and solutions, and experiment in social contexts, students are multi-tasking to enhance their personal learning networks in collaborative experiences to create a collective intelligence and distributed cognition. Frequently students must navigate across different media resources and critically evaluate the reliability and validity of information presented. In order to develop 21st Century learning skills, students must be involved in fluid and flexible learning environments where they can socialize and collaborate to create a collective cognitive responsibility for both public and individual knowledge (Scardamalia, 2002; Zhang, Scardamalia, Reeve, & Messina, 2009).

When students engage with a particular inquiry or topic in the makerspace, the elements of play are evident as topics are recontextualized within the makerspace environment to reflect the social norms of that environment based on access to media (e.g. browsers, devices, district permissions, and policies), funding (e.g. digital subscriptions to different online resources and devices provided), and global trends (e.g. importance of coding). As students tinker, experiment, or create in the makerspace, they can appropriate, multi-task, and distribute cognition when interfacing with a variety of digital sources.

Collectively their overall intelligence is enhanced as they collaborate with others and infer judgment as to validity and reliability of the multimedia tools and information evaluated. Students are expected to traverse a variety of media resources and social networks as they navigate multiple perspectives when actively engaging with a particular topic or PBL module. In order to further develop and sustain rich and authentic PBL opportunities students will need to engage in feedback with peers and teachers to strengthen their learning and agency (Demirbilek, 2015).

Design thinking and collective knowledge. According to a recent study by Hughes, Morrison, Kajamaa, and Kumpulainen (2019) “Makerspaces are rooted in design disciplines, so they align with the concept of problem solving through open-ended approaches to create unique learning opportunities for students” (Hughes, et al., 2019, p. 345). Students in Canada and Finland engaged in design thinking to explore solutions to real world and imaginary problems through project-based learning and they utilized digital platforms to demonstrate and build collective knowledge.

Canada*.* At The Canadian Maker Lab, 15 participants ranging in age from 7-14 participated in a five-day camp to engage in design thinking. The researchers instructed students to utilize an adapted version of the *Education is Elementary* engineering design process (https://www.eie.org/overview/engineering-design-process) to create projects by either working independently or with a peer. The process involved five steps: Ask, Imagine, Plan, Create, and

Improve. The researchers implemented a new part of the design framework each day. First participants had to *ask* themselves to identify a personal project or problem that needed to be solved. Then they had to *imagine* a solution based on things that already exist and/or ways to reinvent those items to resolve the problem. Next they had to *plan* which materials they required and sequence of steps in designing their artifacts. After that, participants had to *create* a prototype of their artifact or idea. Finally they identified how they could *improve* their final artifacts. Participants had agency to create their own projects such as designing solutions to real-world problems including how to efficiently train a puppy to relieve itself outdoors. They could also imagine ways to improve upon fictitious objects such as a Harry Potter magic wand. The researchers reported that their research and analysis "revealed that the makerspace is a space where students can develop global competencies such as problem-solving, collaboration, empathy, and communication" (Hughes, et al., 2019, p. 351).

Finland. At the Finnish site 94 students between the ages of 9-12 participated in a year-long hybrid class featuring the digital platform FUSE Studio (https://www.fusestudio.net/). The course was designed as a hybrid where students could independently select challenges on the FUSE Studio website and make different artifacts or perform different challenges related to science, technology, engineering, art, and/or mathematics (STEAM) with physical tools in the classroom or digital tools available on the Internet. The researchers collected videos of the participants and teachers engaging in the different learning activities. For the most part students followed directives from the FUSE Studio website or from the teacher facilitators. However, the researchers did find evidence where students questioned or refused the suggested ways of making a particular artifact or completing a challenge. The researchers claimed a few of the participants demonstrated "horizontal knowledge breaking," which means the students questioned established norms and derived new ways of doing things rather than following teachers' suggestions of how something should look or be designed.

Designerly learning. Building upon design thinking, Gourlet and Decortis (2017) worked with 26 first-graders (ages six to seven) in France for six months to create *designerly learning* in the elementary makerspace setting. *Designerly learning* is defined as "the way pupils engage in making activities," (Gourlet & Decortis, 2017, p. 32). According to the researchers, educators who created designerly learning opportunities for their students encouraged student agency and understood the systemic and socio-cultural dynamics of the makerspace-learning environment. Gourlet and Decortis (2017) did not describe the actual student project outcomes; rather they focused on how to design the makerspace-learning environment to encourage student agency and communities of learners. They acknowledged the impact of digital technologies as a means for students to document their thinking and create collaborative partnerships when working with pre-fabricated digital kits. The researchers contended that as students worked with tools, two things occurred to cause an *instrumental genesis*. First the students worked with the makerspace tools themselves to design or create artifacts. Second, as the students continued to refine and enhance their projects, they developed relationships and with other students as a community of learners. The tool was transformed by the maker into a vehicle for students to immerse themselves in problem solving situations to design solutions based on personal schema (experience) or connections. Throughout the study students' agency continued to emerge as they were able to independently access materials and store materials over an extended period of time, document their thinking through videography, and provide feedback to their peers about their projects.

Collaborative communities offer designers of makerspaces opportunities to empower student learning by maximizing and enhancing available resources to promote student-driven projects and the capacity to make one's thinking visible. The makerspaces themselves can evolve based on community resources, physical location, student body, and needs of a particular school community. The next section describes how educators can help students make their thinking visible.

Making Students' Thinking Visible

In order to support students' thinking, and improve students' metacognitive awareness, students must be taught to make their thinking visible. Within the elementary makerspace setting, this can be done through feedback, embodiment, and documentation.

Feedback. According to Butler and Winne (1995), self-regulated learning is largely shaped by both internal and external feedback received. Internal feedback can help the learner reframe the problem when encountering challenges by predicting new outcomes, modifying the goals, or abandoning the task. Externally provided feedback typically focuses on learning outcomes; however, in a makerspace-learning environment, peers can provide feedback as they *co-critique* a project to help develop new iterations or collaboratively solve problems (Clapp et al., 2016). Hattie and Timperley (2007) identified three target areas for feedback questions: (a) *Where am I going?* (b) *How am I going?* and (c) *Where to next?* They claimed that these questions created a model to help bridge the gap between students' current proficiencies and the ultimate goal of learning. "Peer-supported making and tinkering activities have been shown to have a positive effect on youth because of the potential for "feedback-in-practice," which contributes to deep and transformative learning (DiGiacomo and Gutiérrez, 2016)," (Bers, Strawhacker, & Vizner, 2017, p. 76).

Online environments can also be created to research a particular topic or idea emerging from the makerspace through friendship-driven and interest-driven groups (Litts, Halverson, &

Bakker, 2016). Litts et al. (2016) analyzed the Midwest Makers' public Google Group's online forum posts (n=370 posts) related to makerspaces based on discourse analysis conducted by Gee (2013). The researchers found that majority of online communication pertained to information sharing/advice giving (38%), followed by advice seeking (14%).

Embodiment. As students articulate their ideas, they need to externalize their vision. Kangas, Seitamaa-Hakkarainen, and Hakkarainen (2011) found that when students worked with actual artifacts, as well as their "envisioned" embodiment of the artifact (e.g. sketches, drawings, models, etc.), and posted these embodiments to the online Knowledge Forum platform, students were able to elaborate their learning process. Through a structured and scaffolded instructional approach, teachers and design experts explicitly showed students how to develop a deeper understanding of both function and design. Students designed lamps with experts guiding them throughout the design process. The students demonstrated increased usage of domain specific vocabulary, as well as improved understanding of how the lamps functioned.

Documentation. "Documentation as the practice of observing, recording, interpreting, and sharing through a variety of media the processes and products of learning in order to deepen learning" (Krechevsky, Rivard, & Burton, 2009, p. 65). Teachers and students can document the learning process by curating and displaying student students' artifacts that might include quotes, pictures, photos, sketches, or even published pieces (Krechevsky, Mardell, Rivard, & Wilson, 2013; Ritchhart, 2015).

In addition to physically documenting evidence of learning, Ritchhart, Church, and Morrison (2011) contended that teachers must explicitly identify and label students' thinking behaviors or actions in order for students to make their thinking visible. For example a teacher could highlight when a student proposes a new theory, observes a pattern in math or texts, or even connects ideas across domains on panel boards or other curated displays in the school.

Schools immersed in the Reggio Emilia philosophy, where listening to students and creating relationships with students frequently make students thinking visible, acknowledge the importance of documentation as a means to further enhancing the learning process (Krechevsky et al., 2013). Teachers in Reggio Emilia inspired schools share documentation with students and their families in order to deepen and extend learning (Krechevsky et. al, 2013). When students and teachers document the work involved through the learning process students have increased opportunities to reflect and refine their work, examine changes in thinking over time, and acknowledge the iterative nature of works in process (Wurm, 2005).

Summary

Grounded in theories of constructivism, constructionism, and connectivism, this literature review highlights the empirical intersections between design frameworks, collaborative communities, and making students' thinking visible. This body of research will help to support the design features of this study, *Once Upon a Makerspace: Elementary Students Document the Stories of their Thinking*, specifically related to the AbD Thinking Routines, making students' thinking visible, and teacher scaffolds.

CHAPTER 3: METHODOLOGY

In this chapter, I explicate the methodology of the research study to guide the reader through the study's timeline, the research context and targeted participants, and the materials and procedures for implementation of the design. In addition, I outline the data collection plan, establishing initial methods, tools, and coding protocols to analyze the data.

Overview of Project Timeline

As the reader will recall, I had proposed three design features to promote increased student agency as evidenced by student-driven learning, metacognitive awareness, motivation, and engagement.[2] The three design features, AbD Thinking Routines, making students' thinking visible, and teacher scaffolds, were implemented over the course of two rotations beginning in March 2018 and ending in June 2018. Each rotation began with one completely student-driven exploration with little or no teacher scaffolding, followed by two or three explicit instruction experiences utilizing the AbD Thinking Routines, accompanied by guided-instruction lessons with makerspace materials and activities (Tinkering Studio, TV Studio, Lego walls & Motors, etc.). During the last three sessions students developed their own projects, sometimes with teacher scaffolds regarding access to tools and directives to complete Flipgrid posts each week. During both rotations, students produced artifacts to make their thinking visible virtually on tools like Flipgrid, and in the makerspace on the Wonder Boards. When working on explicitly taught AbD Thinking Routines (Weeks 2 - 4), students were expected to post video summaries on Flipgrid (90 seconds or less in duration) detailing their experiences with the AbD Thinking

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[2] For more details regarding the development of the design features, the reader may refer to Chapter 1, *Figure 1*. Embodied conjecture for creating student agency in the elementary makerspace setting.

Routines, or they could post their drawings and sketches to the makerspace Wonder Boards. For the remaining three weeks (Weeks 5-7), the students made their thinking visible via Flipgrid and the Wonderboards. They may have responded to peers' postings or reflected on feedback people gave them regarding their posts. Finally, the teachers, a Media Specialist (MS) and an Instructional Assistant (IA), scaffolded conversations and provided feedback using the AbD Thinking Routines (Appendix B) to probe students' thinking and enhance their learning outcomes. The sequence of the implementation of the design features for both rotations is outlined in Table 2.

Pacing and tasks in the second rotation changed based on data collected in the first rotation, thus embracing the iterative nature of DBR as being fluid and responsive to the participants in this learning environment. For example, in the second rotation students did not use the Wonderboards as the students in the first rotation did not display interest in them during the first rotation. In addition, due to school scheduling conflicts, the second rotation only spanned six weeks. My staff and I also noted that students in the first rotation did not provide feedback to one another on the Flipgrid posts so during Week 4 in the second rotation, the teachers explicitly directed the students to provide feedback to randomly assigned peers. This ensured every participant both received and gave feedback. More details about changes from the first rotation to the second rotation will be discussed in Chapter 4.

Table 2

Sequence of Research Design Features

<table>
<tr><th>First Rotation</th><th>Second Rotation</th><th>AbD Thinking Routines</th><th>Making Students' Thinking Visible</th><th>Teacher Scaffolds</th></tr>
<tr><td>Week 1</td><td>Week 1</td><td>Students selected their own makerspace activity. The AbD Thinking Routines were not yet introduced.</td><td>Students posted a video summary (90 seconds or less in duration) on Flipgrid describing what they did during the makerspace session.</td><td>Teachers did not provide formal scaffolds. Teachers monitored students' learning experiences and addressed any safety concerns that emerged.</td></tr>
<tr><td>Week 2</td><td>Week 2</td><td>Routine 1:
Looking Closely</td><td rowspan="6">In Weeks 2-4, students were expected to document their use of AbD Thinking Routines on Flipgrid.

In Weeks 2-7, students were also expected to document their thinking during guided or self-directed makerspace activities with one of the tools below:
• Flipgrid
• Wonder Boards
• Google Suite
• Twitter</td><td rowspan="6">Teachers were expected to use the AbD discussion probes to guide and scaffold conversation for students while working the makerspace.

In addition, teachers continued to monitor students' postings on social media and on the Wonder Boards. When appropriate, teachers provided feedback to students.</td></tr>
<tr><td>Week 3</td><td>Week 3</td><td>Routine 2:
Exploring Complexity</td></tr>
<tr><td>Week 4</td><td>Did not complete</td><td>Routine 3:
Fostering Opportunity</td></tr>
<tr><td>Week 5</td><td>Week 4*</td><td rowspan="3">Students participated in self-directed makerspace activities.

*Students in the second rotation provided feedback to peers on Flipgrid.

They could self-select different AbD Thinking Routines to articulate their learning process and guide the development their projects.</td></tr>
<tr><td>Week 6</td><td>Week 5</td></tr>
<tr><td>Week 7</td><td>Week 6</td></tr>
</table>

Context of Study

The study was conducted in the natural makerspace setting (Creswell, 2014) in a New Jersey suburban district, which was recognized by the New Jersey Department of Education as a model school district in the ***Future Ready*** program. ***Future Ready*** is a national initiative that invites superintendents from districts across the country to commit to digital learning and to provide mentoring to other districts through shared projects, professional support, and ongoing communication, both virtually and in real time.

The school had an enrollment of 409 students who were primarily Caucasian (93%), with the remainder of the student body identifying as Multiracial (5%) and Asian, Hispanic, Pacific, or Black (<2%). There were only three students (<1%) who qualified as Title I, and there was just one English Language Learner (<1%) in the total student population.

The teachers, a Media Specialist (MS) and her Instructional Assistant (IA), collaboratively created and sustained learning opportunities with students, researching best practices and leveraging professional networks to enhance students' learning. The MS had a master's degree in Media Instruction and worked in this school setting for six years. She was a staunch advocate for innovative practices in elementary school settings to benefit her students and to design an engaging learning environment. The IA worked part-time in the makerspace to support the MS with instruction and some clerical responsibilities related to library book circulation.

The makerspace teachers worked with almost 400 students in grades K, 1, 2, and 3. All students in grades K-3 were assigned individual Gmail accounts and used these accounts to login to Chromebooks for various explorations, research, publishing, gaming, and collaborative learning experiences. The entire district was also considered a Google campus and actively integrated Google Apps for Educators (GAFE) to support both student and teacher learning and communication. Students worked together on Google Suite to create projects, and teachers submitted unit plans via Google Docs to provide a feedback loop with administrators. The school had a 1:1 Chromebook to student ratio in grades 2 and 3 for homeroom instruction and all students (K-3) used Chromebooks during media instruction in the makerspace. Kindergarten and first-grade students had access to classroom sets of new iPad Air 2s in their individual classrooms, and students utilized the iPad apps to support learning in all content areas. In special areas like art and music, students were also utilizing technology through Google Classroom and iPad Air 2s to create portfolios and record music. Students had access to RAZ Kids, Spelling City, Connect ED, WeVideo, Newsela, i-Ready, and other digital subscriptions to enhance instruction and learning.

Prior to the study launching, teachers throughout the school had increased their use of social media, tweeting class happenings, and leveraging their Twitter accounts to sustain family engagement using the district's hashtag. In order to enhance student motivation, family connectedness, and public awareness of the school community's accomplishments, teachers' website design continued to evolve through Weebly and Google Classroom. Students engaged with QR codes, digital photography, iMovie, and Aurasma to create augmented reality learning environments.

Targeted Participants

All students in Grades K-3 attended a weekly enrichment time in the makerspace for 45 minutes. In addition, once per school year, students were assigned an extra weekly sixty-minute rotation for a seven-week period. During this extra rotation, students' homeroom teachers attended a professional learning community with other colleagues, and the students worked with each of the special area teachers (Art, Makerspace, Music, World Language, and Physical Education/Health) for enrichment purposes. This study leveraged that enrichment time to incorporate the recommended design features in the makerspace. By isolating these design features to this enrichment rotation, the teachers and I gradually introduced the different design features and monitored how the design features potentially impacted a particular group of students.

Participants

In total 67 students in grades 2 and 3 participated in the study (Table 3). Girls comprised 54% (36) of the total participants and boys 46% (31). Third-grade students comprised 52% (35) of the participants and second-grade students 48% (32). The majority of participants, 96% (64), identified as White, 3% (2) identified as Asian, 1% (1) identified as Black, and there were no English Language Learners. One student (1%) was identified as economically disadvantaged.

Eighteen percent (12) of the total participants were classified with special needs (including cognitive and behavioral) and received special education services in the school setting. Each grade level featured one general education (GE) class and one in-class resource (ICR) class. The ICR settings had two co-teachers and some paraprofessional support in the homeroom. Both special education and general education students were assigned to the ICR classes. When the students attended sessions in the makerspace, they had one teacher with some instructional support from the IA and the homeroom paraprofessional, who also accompanied her assigned student to the special area classes. The GE settings had one teacher in the homeroom classroom and no paraprofessional support. There were no special education students assigned to GE classes; however, some students in these classes did receive 504 plan accommodations that supported medical issues impacting student learning. These issues included Attention Deficit

Hyperactivity Disorder or severe food allergies requiring frequent breaks, increased time on testing, or preferential seating.

Table 3

Demographics of the Participants

Demographic	**Girls**	**Boys**	**Total**
Total Participants	36 (54%)	31 (46%)	67 (100%)
Grade 3	19 (28%)	16 (24%)	35 (52%)
Grade 2	17 (25%)	15 (22%)	32 (48%)
White	33 (49%)	31 (46%)	64 (96%)
Black	1 (1%)	0	1 (1%)
Asian	2 (3%)	0	2 (3%)
Economically Disadvantaged	1 (1%)	0	1 (1%)
Special Education	4 (6%)	8 (12%)	12 (18%)

Students visited the makerspace once a week for 60 minutes, spanning six to seven weeks. While participating in the study, they explored makerspace tools and materials, learned how to implement AbD Thinking Routines, and eventually created projects independently or in small groups. Class rotation dates are summarized in Table 4.

Table 4

Rotation Dates

Class	Type	Rotation	Dates (2018)	N
2A	ICR	1	3/7, 3/14, 3/21, 3/28, 4/18, 4/25, 5/2	18
3A	GE	1	3/6, 3/13, 3/20, 3/27, 4/17, 4/24, 5/1	20
2B	GE	2	5/2, 5/9, 5/16, 5/23, 5/30, 6/6	14
3B	ICR	2	5/1, 5/8, 5/15, 5/22, 5/29, 6/5	15

The participants had the opportunity to engage in this research study in several ways. First, all participants answered pre and post surveys to determine engagement in the makerspace setting. Second, all participants engaged in a learning environment with design features including the AbD Thinking Routines, making students' thinking visible, and teacher scaffolding. Third, I selected a sample of students from grades 2 and 3 to be featured in both case studies and student focus-panel interviews. It was my intention to interview the student-participants and also analyze the artifacts they created in response to the design features.

This type of sampling supports the collection of rich and detailed information, particularly with new phenomena or social changes including makerspaces and social media tools (Palinkas, Horwitz, Green, Wisdom, Duan, & Hoagwood, 2015). The actual sample size of students provided comprehensive and personal stories about students' experiences and teachers' interactions with students in different classes and grade levels. When possible, students with varied race, ethnicity, and SES were selected; however, this community was not very diverse. In addition, data regarding academic performance cultivated opportunities to represent varied backgrounds. As a practitioner on site, I was familiar with all students and could gauge students' current literacy levels and examine school data including InView scores, iReady reports, DIBELS assessments, Fountas & Pinnell reading levels, standards-based report cards, formative assessments, and anecdotal information provided by teachers and parents. I also participated in weekly professional learning communities with the grade level teams and the MS during which they discussed students' performance, interests, and targeted interventions to impact student progress.

Materials and Procedures

The materials and procedures utilized in this study influenced student learning and helped the research team to develop measures demonstrating the emergence of student agency in the makerspace. Materials specific to the actual research design features, as well as procedures for implementation, and items available in the learning environment itself are outlined below.

AbD Thinking Routines (Appendix B). As previously explained, the MS and IA explicitly modeled how to utilize the AbD Thinking Routines through a *think-aloud*. The MS and IA worked with me prior to the first session to determine pacing, topic, and features of the object or system to be examined.

Students formally practiced using the AbD Thinking Routines during Weeks 2, 3, and 4 of the study focusing on looking closely, exploring complexity, and fostering opportunity. Students posted video summaries about their experiences utilizing the AbD Thinking Routines on Flipgrid. These video entries were available for analysis during the study and after the study was completed. The teachers explicitly modeled the AbD Thinking Routines for the first 10 minutes of each class. Then students transitioned to their work areas and used the AbD Thinking Routine on a self-selected object. The transition time was about five minutes. They answered the questions listed in the AbD Thinking Routines and created sketches to show their thinking. They were given 30 minutes to complete the routines. If they finished earlier than the prescribed time allocated they selected another object or began work on designing a project of interest. For the last 15 minutes of class, students were expected to post a video summary about their assigned AbD Thinking Routines. Details regarding the sequence of instruction are outlined in Table 5.

Table 5

Sequence of Instruction for Weekly AbD Thinking Routines

AbD Thinking Routine	Sequence of Instruction (60-minute class)
Week 2 Looking Closely **Week 3** Exploring Complexity **Week 4** Fostering Opportunity	**8:45 - 8:55 am (10 minutes)** MS & IA explicitly modeled weekly AbD Thinking Routines as a whole class lesson. **8:55 - 9:00 am (5 minutes)** Students selected one object brought from home or available at school (or their projects in the second rotation) and transitioned to their work area. **9:00 - 9:30 am (30 minutes)** Students looked closely at the object and completed the weekly AbD Thinking Routine. They were encouraged to sketch, draw, write, take photos, or video/audio record their thoughts. **9:30 - 9:45 am (15 minutes)** Students made their thinking visible by posting their AbD summaries as videos in a teacher- created class Flipgrid and/or posting artifacts to Wonder Boards posted in the makerspace.

Wonder Boards and social media. Teachers informed students that they could post sketches, drawings, photos, ideas, and questions about their projects on the physical Wonder Boards in the makerspace and self-created videos on the Flipgrid platform. They modeled how to actually post items on the Wonder Boards and they showed students how to access the digital “grid” designated for this research study through the teacher’s class website. As a reminder to the reader, according to Common Sense Media, Flipgrid is:

> A website that allows teachers to create "grids" of short discussion-style questions that students respond to through recorded videos. Each grid is effectively a message board where teachers can pose a question and their students can post 90-second video responses that appear in a tiled "grid" display." (Retrieved from https://www.commonsense.org/education/website/flipgrid on November 11, 2018).\

Participants and school staff were also invited to respond to students' weekly video posts and materials posted on the Wonder Boards. The research team referenced the Wonder Boards and Flipgrids to detail the continuum of when a project idea was conceived and how the feedback received or ideas posted may have resulted in the creation of student-driven projects. The MS and IA were also able to provide *recursive feedback* on the Wonder Boards and Flipgrid posts. This included specific complimentary feedback, questions, or the discussion probes listed in the next paragraph.

Discussion probes (Appendix E). Teachers used the Agency by Design (AbD) Framework to probe discussions with students and scaffold discussions between students while planning for or working on projects in the makerspace setting. In addition, teachers could use the same discussion probes to help frame *recursive feedback* opportunities. These questions came directly from the AbD Thinking Routines of *Looking Closely, Exploring Complexity, and Fostering Opportunity*. Examples of probes included:

- What are its parts?
- What are its various pieces or components?
- What are its purposes?
- What are the purposes for each of these parts?

- In what ways could it be made to be more effective?
- In what ways could it be made to be more efficient?
- In what ways could it be made to be more beautiful?
- What perspectives can you look at it from?
- How are you involved?
- What connections do you have? What assumptions, interests or personal circumstances shape the way you see it?
- How does this person understand this system and their role within the system?
- What is this person's emotional response to the system and to their position within it?
- What are this person's values, priorities, or motivations with regard to the system? What is important to this person?

Makerspace activities (Appendix F). In addition to the design features previously described, when visiting the makerspace students had opportunities to experiment with a variety of tools and activities. These tools and activities were accessible to students throughout the study.

Lego walls and motors. Students built or designed different objects or systems utilizing assorted Lego pieces, Lego motors, and the Lego walls. Outside of the study's makerspace sessions, students continued to work with the Bricks 4 Kidz prescriptive modules that explicitly directed students how to incorporate different engineering functions and necessary pieces (e.g. axles, gears, pulleys, etc.) to complete the tasks. Students had the opportunity to create their own tasks or projects utilizing the Lego materials as models during the study's makerspace sessions.

Tinkering Studio. The Tinkering Studio was dedicated to carpentry and building. Students had access to a variety of small tools including hammers, nails, screwdrivers, small saws, vises, and other tools to help build new objects or refine the functioning/use of existing objects. An example of some work already completed included making birdhouses and sculptures for the school garden.

TV Studio. In the TV studio, students had access to a green screen, iPads, Padcaster, tripods, and microphones. They could have recorded clips in front of the green screen or taken the camera on location in the school or on school grounds. They also had access to video editing software including iMovie and WeVideo.

Chromebooks. Students had individual access to Chromebooks. They used Google Drive tools like Docs, Sheets, Forms, Drawings, etc. to help convey their ideas and research new topics. They were familiar with the commenting features when working on Docs and Slides, and often gave each other feedback as part of their homeroom instruction. In addition they used the Chromebooks to post video summaries onto Flipgrid.

Minecraft. The school had access to Minecraft: Education Edition. Students were familiar with navigation and the program itself. They created different “worlds” in this program and some of them collaborated with peers in real time and virtually to play or create games.

Makey Makey kits. The Makey Makey kits were a new purchase for the makerspace. The MS and IA had previously shown the students how to use the kits, and depending on their interest and skill sets, the students could reference different design challenges or games on the Makey Makey website (https://www.instructables.com/makeymakey/). Examples of Makey Makey design challenges included designing simple circuits, creating game controllers and games, or even exploring soundscapes by creating underwater music scores.

Gardens and greenhouse. Students were familiar with the concept of gardening and how to care for plants in the gardens. When the study began, they had not yet used the greenhouse or actually designed the gardens. Teachers planned for the students to use the greenhouse in the spring to begin seedlings. Teachers also invited students to design new parts of the garden to leverage sunlight, water absorption, and soil space to gain a bigger harvest.

Self-directed projects. Students themselves could have selected an area in which to work to explore their own questions or develop solutions to real-world problems to design and create self-directed projects. They were able to utilize materials available in the makerspace to implement their projects. This had not been implemented prior to the study beginning; however, during the study, many students selected to create self-directed projects.

Data Sources

A variety of qualitative and quantitative tools were utilized to paint a comprehensive picture of the learning occurring in the makerspace. By triangulating the different data sources, the results of the study are likely to be more valid as the different data points can be cross-referenced to support or negate a particular design feature as being successful in impacting the emergence of student agency or the trajectory of students' projects in the makerspace setting.

Pre and post engagement surveys (Appendix G). Prior to Week 1 of each rotation, students completed the engagement survey on Google Forms in their homerooms on their Chromebooks. I provided the link to the Google Form for students to access. Immediately following the last session of each rotation, students completed the same engagement survey on Google Forms in their homerooms utilizing their Chromebooks. Once again, I provided the link to the Google Form for students to access. Questions were based on the Reeve & Tseng (2011) Protocol, which specifically examined four aspects of engagement: agentic, behavioral, emotional, and cognitive. In the original study, the various attributes were measured with 1-7 response scale ranging from strongly disagree (1) to strongly agree (7). For the purpose of this study, students selected from a 1-3 response scale ranging from (1) always or most of the time, (2) sometimes, and (3) rarely or never. Examples of items evaluated by the students are outlined below.

Items to assess agentic engagement

1. During class I ask questions.
2. I tell the teacher what I like and what I don't like.
3. I let my teacher know what I'm interested in.
4. During class I express my opinion.
5. I offer suggestions to make the class better.

Items to assess behavioral engagement

6. I listen carefully in class.
7. I try very hard in school.
8. The first time my teacher talks about a new topic, I listen carefully.
9. I work hard when we start something new in class.
10. I pay attention in class.

Items to assess emotional engagement

11. I enjoy learning new things in class.
12. When we work on something in class, I feel interested.
13. When I am in class, I feel curious about what we are learning.
14. Class is fun.

Items to assess cognitive engagement

15. When doing schoolwork, I try to relate what I'm learning to what I already know.
16. When I study, I try to connect what I am learning with my own experiences.
17. I try to make all different ideas fit together and make sense when I study.
18. I make up my own examples to help me understand the important concepts I study.
19. Before I begin to study, I think what I want to get done.
20. When I'm working on my schoolwork, I stop once in a while and go over what I have been doing
21. If what I am working on is difficult to understand, I change the way I learn the material.

Students' projects. Students' projects were evaluated using a rubric (Appendix C) that identified informal and formal learning outcomes and behaviors aligned to the original research questions. Critical attributes examined included initiative, creativity, engagement, perseverance, and collaboration.

Participant interviews. As qualitative interviews allow for unstructured and open-ended questions (Creswell, 2014), the Media Specialist randomly selected 11 students from the second rotation of the study to participate in the student focus-panel interviews that I administered. The two teachers also participated in a participant interview that I administered.

Student focus-panel interviews (Appendix H). At the end of the second rotation I facilitated two student focus-panel interviews with student-participants in the study. Participation in focus-panel interviews can facilitate increased comfort levels for the students and allow for scaffolded conversation with peer support (Patton, 2002). Both third-grade and second-grade students were interviewed in their grade level homerooms and brought their physical artifacts with them for reference. If they had digital artifacts, they returned to the makerspace after the interviews so that the videographer could film any details pertaining to the interviews. During the interviews students answered questions related to how they used and understood the AbD Thinking Routines, the types of feedback they received from teachers, the learning activities they enjoyed most, how they conceived and implemented their projects, and how successful the integration of social media and Wonder Boards were to their projects and time in the makerspace. Each interview session was video recorded.

Teacher interviews (Appendix I). I interviewed both teachers and they answered questions about how effective they found tools like Wonder Boards, Flipgrid, Google Comments, or Twitter in helping students to articulate their thinking process. They also described their experiences scaffolding student conversation with the discussion probes, teaching and practicing the AbD Thinking Routines, their impressions of students' receptiveness to recursive feedback, and their overall thoughts about the learning and activities happening in the makerspace.

Video (MP4) and audio (MP3) recordings. Every makerspace session and interview was video (MP4) and audio (MP3) recorded by a district technician with devices such as iPads and a small digital camera. I referenced these data sources to support observations, recommend changes to design feature implementation, or document the emergence of answers to the research questions. Files were transcribed and captioned as needed for the study. The video and audio files were used in order validate other data sources such as Flipgrid posts, the student focus-panel interview data, teacher interview data, project outcomes, and field notes as evidenced by footage of students in action on the videos or comparing conversations as transcribed from audio files.

Observation and field notes. As the primary observer and building administrator, I was able to enter the different makerspace sessions as my daily work schedule permitted to monitor students and teachers in action. Sometimes I would discuss observations with teachers after school or I would record field notes for future consideration. I also referenced the recorded video and audio files to log observations in a structured journal. As I noticed different interactions or happenings, I was able to make recommendations to the makerspace teachers about their instruction or modify different design features.

Data Collection Plan

Throughout the study data was collected at different points to provide a clear picture of how projects were conceived, design features implemented, or how students articulated their learning or elements of project design. Examples of these measurements are outlined in this section and Table 6.

Table 6

Data Collection Timeline

	Week #								
Data Collected	**Pre**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Post**
Engagement Survey	X								X
Video and Audio Recordings		X	X	X	X	X	X	X	X
Wonder Boards and Social Media		X	X	X	X	X	X	X	
Observations and Field Notes		X	X	X	X	X	X	X	
Emergence of Student Projects		X	X	X	X	X	X	X	
Students’ Project Evaluation									X
Participant Interviews									X

Pre and post engagement surveys (Appendix G). Pre and post engagement surveys were administered before the first makerspace session and after the last makerspace session to students in their homeroom classrooms. The survey was available on Google Forms and students accessed the form via their Chromebook and individual Gmail accounts. Data collected was automatically transferred into a Google sheet as well as class specific data charts for efficient analysis.

Video (MP4) and audio (MP3) recordings. A district technician video and audio recorded all sessions in the makerspace. With permission from my school district, I paid him to do this outside of his contracted hours. I reviewed these recordings to ensure the teachers implemented the design features with fidelity to the intent of the research study. In addition, the recordings also provided another measure to ensure outcomes of participant interviews were reported accurately.

Wonder Boards and social media. Wonder Boards and social media tools such as Flipgrid, Twitter, and Google Suite were available for students to post their thoughts, questions, or exemplars of their work each week. The teachers photographed the Wonder Boards for future documentation and reference. I reviewed the social media tools each week and recorded observations about these tools in a structured journal.

Observation and field notes. During each session, teachers jotted notes and shared them with me. I maintained a structured journal to record observations about different data collected including social media, video and audio recordings, Flipgrid posts, and Wonder Boards.

Students' projects. The Media Specialist kept track of the students' projects in her journal and lesson plans, citing the students' names and their project titles. Students also summarized details about their projects on their weekly Flipgrid posts and I reviewed those posts to monitor student progress as well.

Participant interviews. I facilitated both the student focus-panel and teacher interviews at the end of the second rotation. The student focus-panel interviews were video recorded by the district technician and the teacher interview was audio recorded for reference purposes. Data was transcribed and closed-captioned for analysis. I had intended to also interview students at the end of the first rotation, but there were too many interruptions in the school calendar including field trips, standardized testing, and student absences. By the time all participants were available for the interview in mid-June, I thought too much time had passed to obtain valid and reliable information about their experiences and did not interview students from the first rotation.

Data Analysis

Creswell and Plano-Clark (2007) recommended the following steps for data analysis: prepare the data, explore the data, analyze the data, represent the data analysis, and validate the data. There were six major data sets I had to prepare for analysis: the pre and post engagement surveys, student projects, the participant interviews, the video and audio recordings, observations and field notes, and the Flipgrid posts. Although we planned to review the Wonderboards from the first rotation, the data collected was inadequate and students did not exhibit interest in posting their ideas on the Wonder Boards. The teacher facilitators and I discontinued that feature in the second rotation. Creswell and Plano-Clark (2007) attributed the exploration phase of data as a time for researchers to familiarize themselves with the broad trends and ideas emerging from the data sets. As this study was grounded in design-based research (DBR), I developed coding protocols based on the data reviewed during this exploration phase.

In order to thoughtfully and strategically analyze the data collected, I focused on one data set at a time. Initially I worked with the quantitative results of the pre and post engagement surveys and the evaluation results of the student projects. Then I reviewed the qualitative data including the participant interviews, Flipgrid posts, the video and audio recordings, and the observations and field notes.

In order to more fully understand the possible impact of the study's design features, I detailed four student projects as case studies. Then I conducted an exhaustive analysis of the case studies with the coding protocol developed from the student focus-panel interviews. In the next sections, I briefly summarize the process of preparing the data collected, exploring the data, analyzing the data, and providing examples of data representation. Then I conclude with details about the validity of the data collected as well as the procedures of the study.

Pre and post engagement surveys. Surveys designed to measure engagement were administered online via Google Forms before the study began and then again when the study was completed. Survey prompts were based on the Reeve and Tseng (2011) Protocol (Appendix G), which specifically examined four aspects of engagement: agentic, behavioral, emotional, and cognitive. Students' responses were recorded in the Google Form and their school email account was automatically collected as part of the survey. Their responses were simultaneously transferred into Google Sheets from the original Google Form survey for future analysis. I organized data onto different pages in the Google Sheets workbook and arranged responses by grade and individual classes, and then all responses on one page.

Although four classes in total completed the surveys, when reviewing one of the second grade class's data pre-survey, I noted that some of the participant emails were omitted and prohibited the research team from validating the different data entries. The team was concerned that some of the students in that class may have responded more than once; thus, their data was excluded. From the remaining three classes, three students submitted the survey more than once. In order to keep their responses as part of the data analysis, I averaged each participant's response value and included the mean score in the final results. Five students completed the pre survey but did not complete the post survey; therefore that data set was excluded from the results. In total, 43 students' results from three classes were available for analysis.

The research team and I did not find any significant impact of the design features causing an increase in motivation and engagement from the survey data. Two-tailed paired *t*-tests used to compare students' pre and post survey data by each indicator failed to provide statistically significant differences in the pre and post survey data (Appendix R), which specifically examined four aspects of engagement: agentic, behavioral, emotional, and cognitive.

Student projects. The 67 participants worked independently or in small groups to create 39 projects with various tools including: Minecraft, cardboard, Legos, and Chromebooks with Makey Makey kits or cloud-based programs such as Google Slides and Kahoot! The teacher facilitator, Mrs. Smith, and I evaluated each project using the Maker Project Rubric (Appendix C) to measure initiative, creativity, engagement, perseverance, and collaboration.

Scoring of projects and tools used. The teacher facilitator and I reviewed and assessed each project, using the Maker Project Rubric (Appendix C), assigning scores of 3 (proficient) and 4 (exemplary) for most of the attributes including creativity, iteration, initiative, learning, and community (Appendix J). As both of us were familiar with the students and their projects, we could not blindly score the final projects, and, despite our best efforts, there always exists some possibility of researcher bias in this process. In order to reduce the risk of researcher bias, we scored the projects independently of one another, and then met a few weeks after scoring to revisit the projects and re-evaluate our initial assessments. I also reviewed extensive video footage and photographs from the study to further support the scoring outcomes.

Upon comparing the scores, both Mrs. Smith and I were completely in alignment with one another. We both understood the implications of each attribute for each category, and because both of us had extensive background with the students and the process of their work, we were keenly aware of the route that each student took to create and iterate their projects, as well as initiative they displayed in their pursuit of completing their projects. When considering the learning that transpired, both of us acknowledged that according to the rubric criteria, each child displayed at least one new skill they did not have prior to beginning their projects. Both of us agreed that the cloud-based tools allowed for the students to reach a broader audience, which influenced our decisions when scoring the community criterion for each project. We also acknowledged that there does exist some measurement bias in the community attribute as some of the tools were already digitally connected to a larger community, thus giving those projects a higher likelihood of receiving an exemplary score. All scores were recorded in Google Sheets with details including project tool, gender of participant(s) completing the project, individual scores by each project and each criterion (Appendix J).

Analysis. In Chapter 4, I fully explicate observations and analysis of the project data to support recommendations when designing elementary makerspaces and answer the original research questions. I analyzed the frequency of the tools selected and explore possible connections to gender when participants selected their materials. When presenting details about the analysis of the final projects, I embed evidence from the participant interviews, video and audio recordings, and Flipgrid posts to support various claims.

Participant interviews. As the Principal Investigator, I led two student focus- panel interviews with seven third-grade students and five second-grade students. The interviews were recorded by an independent videographer in the children's homeroom classes and focused on the participants' experiences in the makerspace. Following a script (Appendix H), I asked students about their favorite things to do in the makerspace and about the tools they preferred to use. I probed for evidence of how they perceived using the AbD Thinking Routines and if they were aware that they had applied the routines when developing their final projects. We discussed students' use of technology tools like Flipgrid and how this tool may have helped them to develop their projects. I asked the participants if they received teacher feedback, and if they did, how it impacted the development of their projects. We explored how they conceived and implemented their project ideas, and the participants provided details about their personal learning experiences.

I prepared video and audio recordings of both the student focus-panel interviews and the teacher interviews for analysis by first trimming the raw interview clips and then having them professionally transcribed. In order to support data analysis, I reviewed and edited video captioning and audio recording transcriptions, then uniformly categorized them by participant response to provide more efficient referencing. All data files were uploaded into Google Sheets and organized by grade level or teacher name to further aggregate or disaggregate data (Appendix L). Then I assigned pseudonyms to both student and teacher participants. These pseudonyms are used to reference these data sets throughout the research study.

As the teachers and I were familiar with one another, having worked together for four years, our interview took on a conversational tone and often we went off script. Rather than apply a coding protocol to the teacher interview transcripts, I decided to use this data set to support or refute student focus-panel interview responses and details from the case studies.

Codes. I grounded the codes describing the student focus-panel data sets in the research questions and the original embodied conjecture. I organized the student focus-panel interview codes into descriptive categories (Mark & Huberman, 1994) based on inferential coding of the data collected. I noticed trends emerging from the student focus-panel interviews and grouped them into cluster labels: Peer Feedback, Teacher Feedback, Making Student's Thinking Visible, Learning, and Engagement. Incorporating elements of axial coding (relating codes to one another) (Merriam, 2009), I developed codes framed around the design features to provide evidence of the emerging trends. For example, when reviewing the Peer Feedback cluster, I developed the following codes*: Peer Model, Verbal Peer Feedback,* and *Peer Flipgrid Feedback*. I fully defined the codes and then provided examples from the data to help contextualize and organize the data for analysis. Below is a screenshot (Figure 3) from the coding protocol, which is fully explicated in Chapter 4.

Coding Protocol for Data Collected During Student Focus-Panel Interviews

Code	Definition	Examples
Peer Feedback		
Peer Model (PM)	Any reference to the impact of a peer physically or verbally modeling how to use a particular tool but not verbally giving feedback to the participant about his or her project.	Hailey: I was playing on the computer and I was like, how about I start doing Makey Makey? I saw Jill doing it.
Verbal Peer Feedback (VPF)	Any reference to the impact of verbal peer feedback while working in real-time in the makerspace on the development of a project (not on the Flipgrid).	James: I was walking up and Kevin B., he's not here, he came up and he was like, "Hey James…maybe you could add this, it'll make it a lot cooler." because he was working on the computer next to me.
Peer Flipgrid Feedback (PFF)	Any reference to how a peer provided feedback on the Flipgrid regarding the project to the participant	Paige: I'm gonna add onto Sophia's. It could really help you because when you get that feedback from the other person you could think, "Oh yeah, I could really build that." And you could thank the person who gave you that feedback, and tell them that you like their feedback, or you didn't like their feedback. And you could either do their feedback, or don't do their feedback.

Figure 3. Example of codes from the coding protocol used to analyze the student focus-panel interview data.

Analysis. After reviewing and coding the data independently, I then conferred with two colleagues in my doctoral cohort and asked them to review the data and assign codes to the excerpts of text from the transcribed student focus-panel interviewee responses. In this study I refer to these excerpts as "idea units." An idea unit (IU) is a chunk of text from the transcribed student focus-panel interviews representing an idea from students' verbal responses to questions during the interview. Organizing text excerpts into idea units "aids the researcher in reducing the data into more manageable chunks that, in turn, can be presented to coders for classical content classification or coding (Carey, Morgan, & Oxtoby 1996)" (Kuraski, 2000, p. 180). I synthesized all of the coded data, along with supporting evidence from the video and audio recordings, Flipgrid posts, and teacher interviews to fully answer the research questions and create suggestions about how to develop and design the elementary makerspace-learning environment. Examples of the analysis and codebook are fully explained in Chapter 4.

Video (MP4) and audio (MP3) recordings. After video and audio recording each makerspace session, the district technician uploaded all recordings to Google Drive, creating different email accounts labeled by date and organized by grade level. He shared those accounts with me via Gmail. I could access the recordings following each session and throughout the analysis process. I reviewed all of the video recorded in each session, often renaming the individual recordings by students' names and titles of different projects. When possible, I referenced the audio files to clarify verbal exchanges from the videos. I also categorized video and audio recordings by design features or learning outcomes such as when students made their thinking visible, teachers provided scaffolds, or when students demonstrated moments of metacognition. As DBR is performed within the natural class setting, frequent check-ins with the teachers and review of the video/audio recordings encouraged simultaneous data collection and analysis (Merriam, 2009), allowing for emergent elements to be analyzed or included with the initial research questions. I referenced the video and audio recordings to support case study details, demonstrate the potential impact of the design features, support or refute student focus-panel or teacher interview idea units, and provide feedback to the teachers regarding implementation of the design features during the study.

Flipgrid posts. Flipgrid posts were stored on the password-protected Flipgrid site. After each rotation, I "froze" the weekly topics so that no one could edit, delete, or access the posts. I was also able to download and review students' video posts as MP4 files from the Flipgrid site. I regularly reviewed Flipgrid posts both during and after the study to monitor or analyze what students reported happening during each session. Then I applied my observations to support case study details, demonstrate the potential impact of the design features, support or refute student focus-panel or teacher interview idea units, and provide feedback to the teachers regarding implementation of the design features during the study.

Observation and field notes. Throughout the research study, I maintained a structured journal in which I recorded observations and next steps regarding students' behaviors in the makerspace, details about their projects, and conversations with the teacher facilitators. The teachers maintained logs about student projects and questions that came up during the study for us to review. The teachers also took photographs of the students engaged in their work and shared them with me via Google Drive. The photos helped me to track student progress and provide evidence of their work. I did reference the photos throughout my analysis of the data collected; however, I did not find the structured journal helpful in supporting my analysis. Rather, it served as documentation about procedural observations and recommendations I recorded, such as when I suggested to the teachers that students in the second rotation analyze their projects when practicing the AbD Thinking Routines rather than random objects.

Case studies. As researchers use case studies for comparison and analysis of patterns in the data (Patton, 2002, p. 447), I detailed four projects as case studies and then synthesized the details from each case study in response to the original research questions. In this next section I present the rationale for selection of the projects featured in the case studies, the analysis and sequence of the case studies, and the details regarding the exhaustive analysis of the case studies using the coding protocol from the student focus-panel interview data.

Selection rationale. After careful consideration of the 39 makerspace projects created, the research team and I selected case studies based on the following criteria: demographics, group size, and tools used. The case studies selected feature varied demographics in terms of gender and materials. Initially, only those projects completed in groups were considered. The reason for this was two-fold. First, one of the study's design features included peer feedback. As students worked in groups, they constantly had to navigate social interactions, negotiate planning and design of their projects, and synthesize information to create their projects. These partnerships and small groups provided several opportunities to evaluate the impact of peer feedback on the trajectory of students' projects. Second, the overall quantity of transcriptions and repartee allowed for increased data to analyze. However, after coding interview data and extensive review of the video footage, as well as considering the idea of peer proximity as shaping students' projects, the research team and I decided to include one case during which a student worked independently. We were curious to see if the feedback he received from peers in real time or virtually helped him to develop his project.

In some instances, projects were not completed due to student absenteeism, or projects were not necessarily as complex as students may have lost interest in a particular tool. Therefore, the projects chosen for case studies were also selected on the basis that students completed their project. In addition, when students selected their projects, they had the freedom to self-select peers with whom they would like to work. Since this study was completed as part of the students' regular instruction time in the makerspace, all students enrolled in a particular class were invited to participate in the different design features, but not all students had permission to participate in the study. Therefore, those projects including individuals without permission were excluded when selecting the case studies. This affords a more comprehensive exploration of the data collected, ultimately increasing the likelihood of valid and reliable research results. The case studies feature projects made with Minecraft, Legos, and cardboard. We included two studies from the first rotation and two from the second rotation, with a project completed by girls and boys from each rotation.

Case study sequence and analysis. After selecting the projects and participants to include in the case studies, I organized each case to demonstrate how students interacted with one another and the design features leading up to the creation of their final projects. I arranged each case study in the same sequence in order to provide a clear picture of the study and the effects on student learning. First, I present a summary of each project, specifically examining how the projects were conceived and refined by participants over each session. I begin with two case studies from the first rotation during which participants worked on their final projects during Weeks 5-7. Then I share two case studies from the second rotation of the study during which participants worked on their final projects for Weeks 1, 5, and 6.

Next, I demonstrate each of the design features' potential impact on the trajectory of each project including AbD Thinking Routines, making students' thinking visible, and teacher scaffolds. I also include details about peer proximity since this was an area of interest that emerged from analysis of the student focus-panel interview data. Then I answer each research question again by synthesizing details from each case study and conducting an exhaustive analysis of each case study utilizing the coding protocol from the student-focus panel interviews. The research team referenced the case study coded data to further verify the interview data previously analyzed and validate recommendations with regards to makerspace design.

Application of coding protocol to case studies. In order to further validate the results of the study, I conducted an exhaustive analysis of the four case studies utilizing the coding protocol that emerged from the student focus-panel interview data. Similar to the analysis process of the student focus-panel interview idea units, I created a codebook (Appendix Z) to organize my observations. This time I analyzed observable student behaviors and interactions recorded during the students' makerspace sessions and Flipgrids from Weeks 1, 5, 6, or 7. I arranged my observations of the recordings into different notations and recorded them in a codebook organized by week, participant, recording source, and the actual notation. Notations included direct quotes from participants and/or my recorded observations.

Coding process. In order to apply the protocol from the student focus-panel interview to the case study data, I reviewed the definition section of each original code. Because the first coding protocol was derived from student interview transcripts, whereas this one involved my observations of students, I changed "reference to" to "observation of," but the remainder of each definition remained the same.

As previously explained, the codes originally emerged from the research questions, the embodied conjecture, and the student focus-panel interview data. The codes were grouped into five major clusters: peer feedback, teacher feedback, making students' thinking visible, learning, and engagement. In order to ensure inter-rater reliability, the same members of the research team who coded the student focus-panel interview data also reviewed the case study data. There were several hours of video footage available to examine; however, I was unable to utilize different clips due too much background noise or too great of a distance between the speaker and the recording device. Although these factors interfered with my ability to hear what participants were saying, I was able to analyze participants' movements, activities, and interactions with peers; however, I could not always retrieve all of the necessary information to make valid assertions.

In order to maintain fidelity to the original coding protocol while coding the different case study notations, the research team and I only categorized behaviors or observations of case study participants that pertained to the original student focus-panel interview data coding protocol. In some instances the definitions of the cluster attributes did not match the data observed from various case study videos and Flipgrid posts. This is more fully explicated in Chapter 4.

Validity

In order to take advantage of the qualitative findings and to ensure validity of the study's results, I established several procedures. First, I made sure to triangulate the different data sets when answering the research questions and making suggestions for designers of elementary makerspaces. Second, I "used rich, thick descriptions to convey the findings" (Creswell, 2014, p. 202) as evidenced by the case studies, participant interview idea units, video and audio transcripts, Flipgrid posts, and students' projects. Third, as the building principal and principal investigator of the research study, I was aware that there might have been conflicts of interest leading to the potential for response bias (Creswell, 2014) as participants may have wanted to appear supportive of the school's initiative and my research. I participated in peer debriefing with members of my doctoral cohort and research team to ensure I stayed true to the research questions and that I remained ethical in following the recommendations of the Rutgers University Institutional Review Board (IRB). Throughout the study I personally encouraged all interested participants to be honest and forthright in their observations. I regularly reflected on the project through journaling and memoing to document my thoughts and concerns about the study. I also removed myself as a formal evaluator of the teachers during the study. I refrained from interacting with the students during their makerspace sessions; however, when I did converse with them I tried to follow the teacher discussion probe list. In addition, I did not respond to or make comments about the students' video posts on the Flipgrid platform.

As part of design-based research, and in consideration of qualitative research, the coding protocols were grounded in the embodied conjecture, including the Agency by Design Thinking Framework. Although I used this framework to describe learning in the makerspace, the actual research protocol I implemented was different than the original study conducted through Project Zero at Harvard University. Variations in participants' ages, duration of the study, frequency of observations, length of observations, and sample size certainly impacted my study in different ways. However, I am optimistic that the framework itself helped me to articulate the actual learning and student agency demonstrated in the makerspace-learning environment.

Finally, the sample is not very large and the demographics are not diverse so the results may not necessarily be applicable across different socioeconomic levels or geographical areas. However, by triangulating different pieces of qualitative and quantitative data, I predict that many elementary schools can generalize the findings to improve the utilization or design of elementary school makerspaces to successfully impact the emergence of student-driven learning.

In the next chapter I provided explicit details about the data collected, the analysis process, and the results from each data source. I then use the results to answer the original research questions.

CHAPTER 4: RESULTS

In this chapter I provide a comprehensive overview of the data collected and analysis of the data as it pertains to the four original research questions. As a reminder, the five questions undergirding the study are:

1. What types of makerspace projects do students create?
2. Which design features scaffold the learning trajectory of students' makerspace projects from conception to completion?
3. When describing their projects, how do students articulate the design process? Do they recognize or cite the design features as influencing their project outcomes?
4. What elements of project planning and implementation do students find motivating or engaging?

In the first section of the chapter, I begin by describing quantitative details concerning the outcomes of projects with regards to tools selected and scoring of the final projects created in order to answer the first research question. Then, in the second and third sections I answer Research Questions 2-4 in two parts. In the second section, I outline the coding protocol (Appendix M) used to analyze the qualitative data collected from the student focus-panel interviews (Appendix L), while helping the reader to contextualize the learning environment and design features in which participants created their projects. I provide supporting evidence from both the coded student focus-panel interview idea units and the teacher interview transcript (Appendix L) to support the students' responses and the analysis of the data. I reference this analysis to answer Research Questions 2-4. Then, in the third and last section, I further disaggregate projects as four case studies highlighting the most popular tools selected. I reference this analysis and detailed entries from the case studies to once again answer Research

Questions 2-4 by synthesizing observations from the case studies and the coded case study idea units to answer the original research questions and to support and validate trends across the study.

Students' Projects

The 67 participants worked independently or in small groups to create 39 projects with various tools including: Minecraft, cardboard, Legos, and Chromebooks with Makey Makey kits or cloud-based programs such as Google Slides and Kahoot! The teacher facilitator, Mrs. Smith, and I evaluated each project using the Maker Project Rubric (Appendix C) to measure initiative, creativity, engagement, perseverance, and collaboration.

Scoring of projects and tools used. The teacher facilitator and I reviewed and assessed each project with the Maker Project Rubric (Figure 4), with permission from the designers of the rubric (Appendix K), assigning scores of 3 (proficient) and 4 (exemplary) for most of the attributes (Table 6) including creativity, iteration, initiative, learning, and community. As both of us were familiar with the students and their projects, we could not blindly score the final projects, and, despite our best efforts, there always exists some possibility of researcher bias in this process. In order to reduce the risk of researcher bias, we scored the projects independently of one another, and then met a few weeks after scoring to revisit the projects and re-evaluate our initial assessments. I also reviewed extensive video footage and photographs from the study to further support the scoring outcomes.

Upon comparing the scores, Mrs. Smith and I were completely in alignment with one another. We both understood the implications of each attribute for each category, and because both of us had extensive background with the students and the process of their work, we were keenly aware of the route that each student took to create and iterate their projects, as well as initiative they displayed in their pursuit of completing their projects. When considering the learning that transpired, both of us acknowledged that according to the rubric criteria, each child displayed at least one new skill they did not have prior to beginning their projects. Both of us agreed that the cloud-based tools allowed for the students to reach a broader audience. This influenced our decisions when scoring the community criterion for each project as those cloud – based projects had a higher likelihood of receiving an exemplary score. Due to the fact that some tools were already digitally connected to a larger community, we acknowledged that some measurement bias is inherent in the community attribute. All scores were recorded in Google Sheets with details including project tool, gender of participant(s) completing the project, individual scores by each project, and each criterion (Appendix J).

MAKER PROJECT RUBRIC

	Emerging - 1	Developing - 2	Proficient - 3	Exemplary - 4
Creativity	Student follows a set of directions to complete a project, but did not explore new ways to alter the idea.	Student project is original, but mostly based off of an existing idea.	Student project is explored and expressed in a fairly original way.	Student clearly explored and expressed multiple ideas in a unique way.
Iteration	Student does not attempt to iterate or make any changes on their initial design.	Student attempts to make an iteration on the design and/ or aesthetic of their project, but is unsuccessful in any improvement.	Student undertakes 1 or more iterations of their product, improving the design and/or aesthetics.	Student completes their product, having improved the design and/ or aesthetics over time.
Initiative	Student encounters complications with frustration and does not attempt to problem-solve independently.	Student encounters complications with frustration, but briefly attempts to problem-solve independently before seeking assistance.	Student encounters complications with a positive attitude and perseveres to problem-solve independently before seeking assistance.	Student encounters complications with a positive attitude and perseveres to problem-solve independently without needing to seeking assistance.
Learning	Student did not attempt any new learning or methodology they were not already initially comfortable with.	Student attempts 1 new avenue of learning for their project, but may not have been successful in its implementation.	Student attempts 1 new avenue of learning for their project. They demonstrate a skill they did not have at the start of the project.	Student attempts multiple new avenues of learning for their project. They clearly demonstrate a synthesis of skills they did not have at the start of the project.
Community	Student does not attempt to share their learning.	Student attempts to share their learning, but without adequate explanation or reflection.	Student shares their learning informally in a peer-to-peer fashion.	Student shares their project and learning with an authentic community in a formal manner.

Figure 4. Maker Project Rubric used with permission from The Digital Harbor Foundation.

Table 7

Summary of Project Scores Using the Maker Project Rubric

Project Tools	N	%	Creativity	Iteration	Initiative	Learning	Community
Total Projects	39	100	3.62	3.59	3.54	3.72	3.03
Minecraft	12	31%	4.0	4.0	4.0	4.0	3.0
Cardboard	18	46%	3.7	3.7	3.5	3.7	3.0
Legos	5	13%	3.5	3.5	3.5	3.5	3.0
Chromebooks	4	10%	2.5	3.0	3.5	3.7	3.3

When looking at the scores by project, two things clearly stand out. First, the majority of students (77%) selected Minecraft (31%) or Cardboard (46%) as their tools of choice. Second, the teacher and I scored the Minecraft projects as exemplary outcomes—the highest score possible (4)—in the areas of creativity, iteration, initiative, and learning. All Minecraft projects were scored as exemplary (4) in the area of creativity, meaning all students completing Minecraft projects *clearly explored and expressed multiple ideas in a unique way*. Students created synthesized their own ideas and their partners' ideas to build different Minecraft artifacts including a house, a world, a garden, a doll kingdom and portals. Within each project students added their own style and choices, which led to varied aesthetics, purposes of the build, or functions of different features in the build. Two of these projects are later featured in the case study section of this chapter. All Minecraft projects received an exemplary score (4) in terms of iteration meaning all students *completed their [projects] having improved the design and/or* *aesthetics over time.* Furthermore, when evaluating initiative, Mrs. Smith and I determined that the students working with Minecraft *encountered complications with a positive attitude and persevered to problem-solve independently without needing assistance*. I reviewed video footage that supported this and during all sessions I observed students moving from computer to computer while working on Minecraft. Examples include one student pointing out a new feature to a peer, or girls with no prior experience working on Minecraft persisting in learning how to include more features to their landscape or change the colors of the characters. Finally, when assessing learning, students who completed Minecraft projects also *demonstrated their understanding of the skills they acquired from beginning of the project to the completion of the project* as evidenced in their weekly Flipgrid posts, weekly video footage, and in student focus-panel interviews when participants spoke about how they specifically improved in their Minecraft skills. I further explicate the process of design when working with Minecraft in the student focus-panel interview and case study sections featured later in this chapter.

The Chromebook activities such as Makey Makey, Slides, and Kahoot! were not evaluated in the exemplary category measuring creativity (2.5) due to the fact that the Makey Makey activities were prescriptive in nature with explicit directions given on the Makey Makey Labz website (https://labz.makeymakey.com) detailing how to create or design a particular artifact. However, Chromebook activities were assessed with higher marks on the community criterion (3.3) than their peers working with physical materials because they could also present their work to a wider audience on the Internet than just their peers in class, as was the case for the hands-on tools such as Legos and cardboard. Students working on Minecraft could have branched out via the Internet to build with other people; however, the configuration of the system at school precluded this option, thus the participants only shared their Minecraft projects with peers in their classes. Overall 59% (23) of the student groups selected hands-on tools such as cardboard and Legos and 41% (16) of the student groups chose to work with tech tools such as Minecraft and Chromebooks.

Gender. To further understand the tools selected to create the projects, I disaggregated the data by gender (Table 8). Although the differences were not statistically significant, 72% (13) of the 18 girl groups in this study chose to work with un-plugged tools, whereas 52% (11) of the 21 boy groups decided to work with digital tools. Girls completed 18 of the projects, and of these, 72% (13) were designed using physical materials of cardboard (11) or Legos (2), whereas boys completed 10 projects with either Legos (2) or cardboard (8). Boys completed a total of 21 projects, and of theirs, 53% (11) were designed with virtual tools such as Minecraft (9) and Chromebooks (2), whereas girls completed 28% (5) projects with digital tools including Minecraft (3) and Chromebook (2) projects. When comparing the actual preferences in designing the 12 Minecraft projects, boys completed 75% (9) of the projects, and girls completed 25% (3) of the projects. When analyzing the 18 cardboard projects, girls completed 61% (11) of the cardboard projects, and boys completed 39% (7) of theirs. Of the five Lego projects, boys completed 60% (3) and girls completed 40% (2). Girls and boys completed equal proportions of the four Chromebook projects.

Table 8

Summary of Projects Completed by Gender

	Total	Girls	%	Boys	%
N	39	18	46%	21	54%
Minecraft	12	3	17%	9	43%
Cardboard	18	11	61%	7	33%
Legos	5	2	11%	3	14%
Chromebooks	4	2	11%	2	10%

Summary. In answer to the first research question, "What types of makerspace projects do students create?" the students in this study chose to complete projects with hands-on tools such as cardboard and Legos more frequently than digital tools including Minecraft and Chromebooks. Designers of elementary makerspaces must consider the types of tools to include in their makerspaces, embracing both physical and digital resources, while also recognizing that the appeal of physical materials including cardboard and Legos for children may be more economically feasible for schools to garner. In addition, the Minecraft and Chromebooks projects were scored higher on the community attribute in the Makerspace Project Rubric because the projects could be shared with a wider audience than just peers in their classroom. Educators should consider how much they value the community sharing piece of project work, and if they do, how they will design their makerspaces to support digital community connections while also working within a school district's acceptable use of technology policies and tech infrastructure available in their school community.

Participant Interviews

In this section, I analyze the student focus-panel interviews (Appendix L) to answer research questions (RQ) 2-4. First, I explain the coding protocol (Appendix M) used to analyze the data sources. Then, I describe the data collected, highlighting outcomes related to the original research questions to emphasize the trajectory of a makerspace project and the possible impact of the design features on project outcomes including: AbD Thinking Routines, making students' thinking visible, and teacher scaffolds. Next, I illustrate how students articulated their thinking about the development and outcomes of their projects. Then I present participant reported evidence about makerspace experiences they found motivating or engaging. Throughout the analysis, I extract idea units from the teacher interview transcript and video footage to validate and support, or, at times, negate the participants' responses. Finally, I answer RQ2-4 by referencing the student focus-panel interview data.

Data collection. As explained in Chapter 3, as the Principal Investigator, I led the student focus- panel interviews, which were recorded by an independent videographer in the children's homeroom classes and focused on the participants' experiences in the makerspace. Following a script (Appendix H), I asked students about their favorite things to do in the makerspace and about the tools they preferred to use. I probed for evidence of how they perceived using the AbD Thinking Routines and if they were aware that they had applied the routines when developing their final projects. We discussed students' use of technology tools like Flipgrid and how this tool may have helped them to develop their projects. I asked the participants if they received teacher feedback, and if they did, how it impacted the development of their projects. We explored how they conceived and implemented their project ideas, and the participants provided details about their personal learning experiences.

In total, 12 students from the second rotation of the study participated in the focus-panel interviews (three girls and nine boys), and of those 12 participants, two students (one girl and one boy) were classified with IEPs. Two of the girls who participated in the focus-panel interviews are later featured in this chapter as one of the case studies about Minecraft and one of the boys is featured in a case study about Legos.

I also interviewed the two teachers, Mrs. Smith and Mrs. Davis, in the main office of the school and audio recorded the interview. As both the teachers and I had worked together for almost four years, the interview took on a conversational tone as we discussed the teachers' perceptions of how participants utilized the AbD Thinking Routines, the integration of technology tools such as Flipgrid, their use of teacher discussion stems, and future improvements to the makerspace. I submitted both sets of interview data to Rev for transcription, cleaned the transcriptions (Appendix L), and transferred them into a Google Sheet for coding (Appendix M).

Coding. Codes were used to organize information into descriptive categories (Mark & Huberman, 1994) based on inferential coding. When determining codes to describe the data sets, I grounded the codes in the research questions and the original embodied conjecture. For example, when seeking answers for RQ2, "Which design features scaffold the learning trajectory of students' makerspace projects from conception to completion?" I searched for data related to the three design features including the AbDTR, making thinking visible, and teacher scaffolds. In order to answer RQ3, "When describing their projects, how do students articulate the process? Do they recognize or cite the design features as influencing their project outcomes?" I again looked for details about the three design features AbDTR, making thinking visible, and teacher scaffolds as well as students' explanations of their project design process. In response to RQ4, "What elements of project planning and implementation do students find motivating or engaging?" I analyzed student answers in response to the interview question, "What was your favorite thing to do in the makerspace? Why?"

Overall I noticed trends emerging in the data collected related to peer feedback, teacher feedback, making students' thinking visible, learning, and engagement. Then I created codes specifically related to these areas (Table 8). In order to ensure validity of the responses collected and to reduce researcher-bias, I cross-referenced video footage from the makerspace sessions to further verify students' and teachers' responses. Throughout my review of the video footage, I was careful to record notes about what I actually saw or heard, not what I may have wanted to infer. At times this was challenging as I had hoped for certain results such as increased teacher feedback or more productive use of the AbDTR; however, I did not observe this in the video footage. In addition, I decided to use the teacher transcripts to support the coded idea units from the student focus-panel interviews. As stated in Chapter 3, all names used in this dissertation are pseudonyms of student and teacher participants.

Peer feedback. The first set of codes were focused on peer feedback trends based on the participants' responses related to peer modeling, verbal peer feedback, and peer Flipgrid feedback. *Peer Modeling (PM)* was defined as any student reported reference to the impact of a peer physically or verbally modeling how to use a particular tool, but not verbally giving feedback to the participant about his or her project. An example included when Hailey stated, "I was playing on the computer and I was like, how about I start doing Makey Makey? I saw Jill doing it." *Verbal Peer Feedback (VPF)* was defined as any reference to the potential impact of a participant receiving verbal peer feedback while working in real-time in the makerspace (not on the Flipgrid or other virtual tools) on the development or final outcome of a project. Examples of this type of feedback included a peer providing a suggestion, such as when James reported, "I was walking up and Kevin B., he's not here, he came up and he was like, 'Hey James…maybe you could add this, it'll make it a lot cooler' because he was working on the computer next to me." The third category of feedback, *Peer Flipgrid Feedback (PFF)*, was specified as any reference to how a peer provided feedback on the Flipgrid regarding the project to the participant. The participants may have applied or ignored the feedback when designing their projects. Below is an example of *Peer Flipgrid Feedback* as documented in an interview response from Paige:

> I'm gonna add onto Sophia's. It (Flipgrid) could really help you because when you get that feedback from the other person you could think, 'Oh yeah, I could really build that.' And you could thank the person who gave you that feedback, and tell them that you like their feedback, or you didn't like their feedback. And you could either do their feedback, or don't do their feedback.

Teacher feedback. Another area of feedback consisted of students' reported use of teacher feedback. The first code, *Teacher – Project Affirmative (TP+)*, was defined as any reference by students to interactions with a teacher during which the teacher provided students with advice or guidance about a specific aspect of making their projects. Evidence of facilitators implementing the teacher discussion stems, such as a teacher asking a student what she or he was thinking, was also coded under this label. For example, when referencing her Minecraft project, Paige reported, "So Mrs. Smith said to us, 'Do you know how to change the colors?' And she gave us feedback and said that we did good at doing that...." The second code, *Teacher – Project Negative (TP-)*, was coded as any participant's reference to the lack of feedback or interactions with a teacher when asked if the teacher provided feedback to the participant.

Making students' thinking visible. Students participating in the study had access to design features to make their thinking visible, including the Flipgrid online tool to record their thoughts about and next steps for their projects. The code *Flipgrid Self-Monitoring (FSM)* was created to categorize any reference to how the personal use of the Flipgrid helped the participant track his or her progress. An example of this included a second grade student stating, "I think the Flipgrids helped me think more. It helped me think of stuff to add onto mine, and just review what I did for the past week or so." Sometimes when describing how they self-monitored their projects using Flipgrid, students embedded examples of how they considered peer feedback. An example of this included, "The Flipgrid also helped me because, as they said the feedback, you should add onto it and make something. And it would help you, so then you could use that feedback to make your build better." Students' self-reported use of the AbD Thinking Routines as a way for them to design or enhance their projects was coded as *Application of AbD Thinking Routines (AoAbDTR).* Initially I had planned to create a code for each of the routines (*Looking Closely, Exploring Complexity,* and *Fostering Opportunity*); however, as the data set was so small, I decided to create one code encompassing all three AbDTR. An example of the AoAbDTR included a student describing the *Exploring Complexity* routine. He stated:

> My name is James, I also agree with Rob. I liked [Exploring Complexity]. Looking from different angles and giving the materials that we used. I was with Rob and Sean using ... we were on Minecraft and it was really easy like Rob said because in Minecraft you could go around the structure that you built and with the paper it made the structure even better because we looked at different angles and we could picture what it would look like in the future, the next time we go on that Minecraft book.

Learning. Students discussed two areas of formalized learning outcomes during the interviews, skill development and metacognition. The first code, *Learning – Skill (LS),* referred to any references about how participants learned to use a makerspace tool or a skill they developed while working in the makerspace, as well as an understanding of how the tools could be used to lead to further inquiry. One student stated, "I learned that LEGOs can… (be a) model and (if) it works, you could lead to different inventions in the future." The second code, *Learning – Self as Learner (LSaL)* was defined as any reference to how students viewed themselves as learners, aware of what they were doing or how they processed information to work on their projects. For example, James stated, "Then when Mrs. Smith told us about the papers that we were going to get next and I was wondering to myself, 'How am I going to do this with Flipgrid?'"

Engagement. During the interviews, both teachers and students described participant engagement in the makerspace related to preferences for certain tools and activities, as well as engagement in persevering when faced with success or setbacks. In order to categorize this information, I created two codes. The first code, *Engagement - Tools (ET),* was defined as any reference to participants describing how or why they enjoyed working with a tool or activity. One student stated, "Chromebooks is my favorite thing because I can go on multiple different kinds of websites and I can play multiple games on each website." The second code, *Engagement – Perseverance (EP),* was defined as any reference to how a participant behaved when frustrated in the makerspace. I observed one boy who became so frustrated about his Minecraft project and having to work with a partner that he started crying. Eventually he was able to collect himself to continue with his project and his partner despite his initial frustration when collaborating with a peer on this project. During the interviews, students and teachers discussed how participants handled setbacks and frustrations, as well as successes. For example, Callan, who created a project with cardboard, detailed persevering in his work, stating, “That didn't work. Kevin quit our group and then … people were joining our group and making, then destroying it (cardboard structure). Then me and Dan were like, ‘We need that someone else. So we got Kevin back.”

Table 9

Coding Protocol for Data Collected During Student Focus-Panel Interviews

Code	Definition	Examples
Peer Feedback		
Peer Model (PM)	Any reference to the impact of a peer physically or verbally modeling how to use a particular tool but not verbally giving feedback to the participant about his or her project.	Hailey: I was playing on the computer and I was like, how about I start doing Makey Makey? I saw Jill doing it.
Verbal Peer Feedback (VPF)	Any reference to the impact of verbal peer feedback while working in real-time in the makerspace on the development of a project (not on the Flipgrid).	James: I was walking up and Kevin B., he's not here, he came up and he was like, “Hey James…maybe you could add this, it'll make it a lot cooler.” because he was working on the computer next to me.
Peer Flipgrid Feedback (PFF)	Any reference to how a peer provided feedback on the Flipgrid regarding the project to the participant	Paige: I'm gonna add onto Sophia's. It could really help you because when you get that feedback from the other person you could think, "Oh yeah, I could really build that." And you could thank the person who gave you that feedback, and tell them that you like their feedback, or you didn't like their feedback. And you could either do their feedback, or don't do their feedback.

Table 9 (continued)

Code	Definition	Examples
Teacher Feedback		
Teacher – Project Affirmative (TP+)	Any reference to interactions with a teacher during which she provided students with advice or guidance about a specific aspect of making the projects.	Paige: So Mrs. Smith said to us, "Do you know how to change the colors?" And she gave us feedback and said that we did good at doing that …
Teacher – Project Negative (TP-)	Any reference to the lack of feedback or interactions with a teacher when asked if the teacher provided feedback to the participant.	PI: Anthony did Mrs. Smith give you any feedback about your Makey Makey? Anthony: No.

Table 9 (continued)

Code	Definition	Examples
Making Students' Thinking Visible		
Flipgrid Self-Monitoring (FSM)	Any reference to how the use of the Flipgrid helped the participant track his or her progress.	Sophia: I think the Flipgrids helped me think more. It helped me think of stuff to add onto mine, and just review what I did for the past week or so.
Application of AbD Thinking Routines (AoAbDTR)	Any reference the participants articulated about they used the AbD Thinking Routine to help them develop their projects or how a teacher observed students using the AbD Thinking Routines during the development of their projects.	James: I liked [Exploring Complexity]. Looking from different angles and giving the materials that we used. I was with Rob and Sean using ... we were on Minecraft and it was really easy like Rob said because in Minecraft you could go around the structure that you built and with the paper it made the structure even better because we looked at different angles and we could picture what it would look like in the future, the next time we go on that Minecraft book.

Table 9 (continued)

Code	Definition	Examples
Learning		
Learning – Skill (LS)	References to how students reported they learned to use a makerspace tool or a skill they developed	Oliver: I learned that LEGOs can… (be a) model and (if) it works, you could lead to different inventions in the future.
Learning – Self as Learner (LSaL)	Any reference to how students viewed themselves as learners, aware of what they were doing or how they processed information to work on their projects.	James: Then when Mrs. Smith told us about the papers that we were going to get next and I was wondering to myself, "How am I going to do this with Flipgrid?"
Engagement		
Engagement – Tools (ET)	Any references to preferences of tool usage.	James: Chromebooks is my favorite thing because I can go on multiple different kinds of websites and I can play multiple games on each website.
Engagement – Perseverance (EP)	Any reference to how a participant behaved when frustrated in the makerspace.	Callan: That didn't work. Kevin quit our group and then … people were joining our group and making, then destroying it (cardboard structure). Then me and Dan were like, "We need that someone else." So we got Kevin back.

Inter-rater reliability. Initially I coded my data independently; subsequently, I enlisted a member of my doctoral program cohort who is CITI certified, a professor, and has successfully defended her dissertation. I shared the coding protocol and clean idea units via Google Sheets for her to reference. We each examined the idea units and coding protocol independently. Then we coded the idea units independently and met a few days later together to discuss the coded idea units. Throughout our joint session to review the coded data, we ensured the idea units were thoroughly analyzed to fit into one coding definition, sometimes breaking an idea unit into two parts so that we could assign separate coding labels, rather than applying two codes for one idea unit. For example, when we met in person, we noted that when Anthony described his use of Flipgrid, the original idea unit could be attributed to *Flipgrid Self-Monitoring* and *Peer Flipgrid Feedback*. He stated:

> It helps you think because you can go back over to it and you can redo that video just in case you forget a little bit about it and it helps you thinks because we did the thing where other people watched our videos and they told what they thought about it.

In order to provide a more accurate analysis of the idea unit, we broke Anthony's idea unit into two parts and applied one code to each part. We coded the first part of the idea unit, "It helps you think because you can go back over to it and you can redo that video just in case you forget a little bit about it," as *Flipgrid Self-Monitoring* because Anthony described how he used the Flipgrid to help him think. We coded the second part, "…and it helps you think because we did the thing where other people watched our videos and they told us what they thought about it," as *Peer Flipgrid Feedback* because Anthony reported peers gave him feedback about his project on Flipgrid.

To ensure the validity of the coding protocol, I invited another member of my research team who is also a graduate of my doctoral program cohort, CITI certified, a professor, and a K-12 public school administrator, to review the results. He reviewed the coding protocol and applied the protocol to a clean copy of the idea units we had already coded. His analysis was 100% in alignment with our analysis for this data set.

Analysis. In total, we coded 62 "idea units" from the two student focus-panel interviews (Table 10). As previously described in Chapter 3, an idea unit (IU) is a chunk of text from the transcribed student focus-panel interviews representing students' verbal responses to questions or ideas they stated during the interview. We coded 12 instances of *Peer Feedback* with 75% (9) of the 12 students providing some response during the interviews that correlated to this code. The most commonly coded attribute under the *Peer Feedback* section was *Peer Flipgrid Feedback* (7) with 50% (6) of the students referencing Peer Flipgrid Feedback, then *Verbal Peer Feedback* coded three times with 25% (3) of the students referencing Verbal Peer Feedback, and finally *Peer Model* was coded twice with 17% (2) students referencing Peer Model. *Teacher Feedback* was coded six times by 50% (6) of the students interviewed. Seventeen percent (2) of the students referenced *Teacher-Project Affirmative*, and 33% (4) of the students referenced *Teacher-Project Negative* during the student focus-panel interviews. We coded 12 instances of *Making Students' Thinking Visible* with evidence from 83% (10) of the student focus-panel interviewees. Both *Flipgrid Self-Monitoring* and *Application of AbD Thinking Routines* were each referenced by 50% (6) of the student focus-panel participants during the interviews. *Learning* was coded twelve times with 58% (7) student references. *Learning-Skills* was coded seven times and referenced by 42% (5) of the student interviewees, and *Learning – Self as Learner* was coded five times and referenced by 25% (3) of the student interviewees. Finally, *Engagement* was coded 20 times, with 92% of student focus-panel interviewees making a reference to Engagement. *Engagement-Tools* was coded 14 times and referenced by 92% (11) of the twelve interviewees and *Engagement-Perseverance* was coded seven times and referenced by 45% (5) of the interviewees.

This coded data can be used to support answers to the research questions, particularly in the areas of *Engagement* as 92% of the students provided some information about this code and *Making Thinking Visible* as 83% of the participants gave some type of response related to this design feature as well. In the following sections, I list each research question (RQ) and bring in the coded idea units from the student focus-panel and teacher interview data to begin a discussion about how the design features of the makerspace might be used to scaffold a students' makerspace projects, how students describe the design process of their makerspace projects, how participants engaged and learned in the makerspace, and how participants made their thinking visible.

Table 10

Frequency of Coded Idea Units from Student Focus-Panel Interviews

Codes	Frequency of Code	# of Students	% of Students
Peer Feedback	**12**	**9**	**75%**
Peer Model (PM)	2	2	17%
Verbal Peer Feedback (VPF)	3	3	25%
Peer Flipgrid Feedback (PFF)	7	6	50%
Teacher Feedback	**6**	**6**	**50%**
Teacher – Project Affirmative (TP+)	2	2	17%
Teacher – Project Negative (TP-)	4	4	33%
Making Students' Thinking Visible	**12**	**10**	**83%**
Flipgrid Self-Monitoring (FSM)	6	6	50%
Application of AbD Thinking Routines (AoAbDTR)	6	6	50%
Learning	**12**	**7**	**58%**
Learning – Skill (LS)	7	5	42%
Learning – Self as Learner (LSaL)	5	3	25%
Engagement	**20**	**11**	**92%**
Engagement – Tools (ET)	14	11	92%
Engagement - Perseverance (EP)	6	5	42%
Total Idea Units	62		

RQ2: Which design features scaffold the learning trajectory of a student's makerspace project from conception to completion? I originally proposed that the three design features might help students scaffold the learning trajectory of their makerspace projects from conception to completion. In this section I examine teacher and student interview idea units to document how AbD Thinking Routines, making students' thinking visible, and teacher scaffolds supported the students in designing and implementing their projects.

AbD Thinking Routines. For three consecutive weeks during the first rotation of the study, teachers provided explicit instruction with the AbD Thinking Routines (AbDTR) including*: Looking Closely, Exploring Complexity,* and *Fostering Opportunity*. Each week, the teachers asked students to examine a self-selected item from home or one available in school. The teachers modeled how to go through each process and used supporting record sheets to help students organize their thoughts and observations (Appendices O, P, & Q). Each recording sheet included prompts related to specific AbDTR, along with areas for students to write and sketch. Upon careful review of the first rotation projects, and as this is a design-based research study, the teacher facilitators and I thought it would be more helpful if the students actually used the AbDTR to analyze the projects they created during Week 1. We hypothesized that this would be more efficient and practical, ideally leading to multiple iterations of their projects. Therefore, in the second rotation of the study, students had the option to personally select objects, including the projects they started in Week 1. In addition, it should be noted that due to school scheduling conflicts, the students in the second rotation only completed the *Looking Closely* and *Exploring Complexity* routines. The teachers did not explicitly teach the *Fostering Opportunity* routine to participants in the second rotation.

During the teacher interviews, both facilitators noted that students initially had difficulty answering questions on the recording sheets; however, they did well with the sketching elements such as drawing their artifacts from different perspectives or designing renditions of their artifacts for future iteration. With scaffolding from the teachers in explaining vocabulary more fully (e.g. complexity, relationship, etc.), the students were able to answer most of the questions. Mrs. Smith reported that she observed students sketching and labeling objects efficiently when identifying parts and purposes of an object in the *Looking Closely* routine, yet when asked to explain the relationship between parts and purposes, students required additional support from the teachers to help guide their thinking and to further elaborate their responses. Mrs. Smith stated that she asked the students to detail the complexities, specifically the relationship between parts and purposes. She cited this example about a keychain, “If it (keychain) was made out of another material, or if it didn't have this little link to hold the keys...” as one way to prompt participants to transfer observations about an object’s parts and synthesize those observations to inference the relationship between an object’s parts and purposes.

In many cases, when initially asked about the AbDTR, students said they did not remember using them. However, when I prompted them with reminders about how they used the worksheets to record their thinking about their personal objects, they immediately recalled what they had drawn and reported some of those experiences. For example, Sophia described that when she looked closely at the parts of a broken iPad that she thought about how people could make the iPad work by simply pressing a button. Paige added that she found the routines helpful because she could think about an object from different angles, which she later applied when working on a character in her Minecraft project. This example will be explained more fully in the case study section of this chapter.

Other students indicated that they enjoyed the sketching components of the AbDTR;

specifically citing that drawing an object from multiple perspectives or angles was a way to plan or refine their work. Sean, a boy who completed a Minecraft world reported, “I thought it (AbD Routines) was really cool because … when we draw the pictures, it can help us plan out what we want to do next. And like, oh, we should take out this or maybe we should add this or we should reconfigure this.” His partner, James, added:

> Looking from different angles and giving the materials that we used… on Minecraft and it was really easy …because in Minecraft you could go around the structure that you built and with the paper it made the structure even better because we looked at different angles and we could picture what it would look like in the future…

Anthony, who was interviewed in a different focus-panel than Paige, also stated that the AbDTR helped him to create his Makey Makey game controller. He explained that when he looked at the controller from different physical perspectives it helped him to figure out which way to turn the paper when positioning the different alligator clips extending from the Chromebook to the paper. Callan said he used the AbDTR to help break down the different pieces in his cardboard structure. Oliver acknowledged using the AbDTR to help him sketch out his Lego Beyblades model. Oliver’s experience will be detailed more fully in the case study section of this chapter.

From the data collected, the sketching elements and looking at objects from multiple perspectives through the explicit teaching and practice of the AbDTR seemed to be the most helpful to participants. When I observed the teachers explicitly instructing the students (both in real time and on the video recordings) about how to complete the *Exploring Complexity* routine, I noticed that the students took their time and focused when sketching their objects, demonstrating interest in analyzing their objects from multiple physical views. When considering the design of the makerspace learning environment, the integration of the AbDTR could be helpful for students to learn how to sketch out their ideas or look at objects from multiple perspectives as they move through the design process.

Making students' thinking visible. Teachers provided ways for students to make their thinking visible on classroom Wonderboards and social media. Students could place post-its with their ideas, sketches, or questions on the Wonderboards positioned around the room. They also had the opportunity to use Google Drive and Flipgrid to explain their thinking, summarize their efforts, ask questions, and provide peer feedback. This next section describes how the physical and digital platforms served as vehicles to make students' thinking visible.

Although the teachers modeled how to post ideas, sketches, or questions on the Wonderboards, the teachers reported that students did not self-select this tool to post evidence of their thinking. The teachers said they noticed the participants ignored the boards for the first rotation of the study and, with my permission, did not utilize the Wonderboards in the second rotation. During the teacher interview, Mrs. Smith commented that she thought the Wonderboards did not give the students immediate feedback, nor was the process as visually appealing and engaging in comparison to the Flipgrid social media tool. The students interviewed were in the second rotation of the study so they did not have experience with the Wonderboards.

During the study, students also had access to the commenting feature on Google Drive and the video posting function on the Flipgrid website. Only one student chose to use a Google Drive app, Google Slides, for her final project, and she did not use the commenting feature during her project. Thus, the Google Drive commenting feature is not included in the data reported. It should be noted the commenting feature was not novel to the participants as they often used it during writing assignments or project work during their homeroom classes.

Each week the teachers posted different prompts (Appendix N) on the Flipgrid site related to the projects created during each session or the AbDTR utilized. For example, the Week 1 prompt stated, “Please describe what you made in [the makerspace] today, (date). You have 90 seconds to respond. You can show your actual product, pictures, sketches, or anything that you would like. If you have questions about your project, you can ask them on the video too!” Participants used Flipgrid to make their thinking visible by answering teacher prompts, showing the actual artifacts they created for their projects or analyzed for the AbDTR, and sharing realizations about the process of creating projects. They accessed the Flipgrid site on their Chromebooks to create and post their videos. In total, 426 responses were collected and each response lasted from 30 – 90 seconds, a time restriction of the digital platform. Of these 426 responses, some were duplicates of the same topic, as students may have needed more time than the 90-second duration allocated for each video clip. In addition, some of the students were off topic or being silly when responding and had to redo their clips.

Students had had very little exposure to Flipgrid prior to the study beginning. While some participants in the second rotation had used Flipgrid in their homeroom classrooms and third grade participants had used Flipgrid once or twice during previous makerspace sessions, Flipgrid was new to the entire school for this particular school year. The teachers reported that they thought the students were engaged by Flipgrid because it was novel to them, the feedback was immediate, the children enjoyed recording themselves talking about their work, and they liked playing with the “fun” features of the platform where they could take a selfie and add digital stickers to their portraits. The weekly videos created by each participant provided several pieces of informative data about each student's project and, in some cases, evidence of how the design features of the study impacted their design process. Examples are included in the case studies later in this chapter.

During the first few weeks of the study, students answered the questions posted by the teachers on Flipgrid and read through their responses on the videos they posted. By the end of the study, when posting their video responses on Flipgrid, students took turns prompting one another or spoke freely, often pointing to their projects and physically moving around the larger projects to help the viewer notice something interesting or to show how they actually changed their thinking from the beginning of the project to the end. Specific examples are embedded in the case studies featured later in this chapter. During the student focus-panel interview, Sophia stated, "I think the Flipgrids helped me think more. It helped me think of stuff to add onto mine, and just review what I did for the past week or so."

During Week 4 of the second rotation, the teachers and I randomly assigned students to give feedback to their peers on Flipgrid. The teachers explicitly demonstrated how to use the feedback feature available on Flipgrid. During Week 5, students had to review the feedback and could decide if they wanted to include the feedback to help them develop their ideas or projects. During the focus-panel interviews with students, seven participants expressed that they received peer feedback on Flipgrid. A group of third-grade boys reported that by looking at the Flipgrid videos posted by their peers, they could consider other participants' projects to develop ideas for their own projects, particularly when working on Minecraft. In reference to the feedback received on Flipgrid James stated, "…I got really good feedback that we should maybe add more doors and add more entrances and we were thinking about maybe adding a drawbridge." Sophia, a second-grade student, noted that the Flipgrid allowed her to check in on her progress, meaning she could look back at what she had done the week before in order to move forward in the current week's project session.

Although students cited Flipgrid as a way of garnering feedback about their projects, they also reported that at times they found posting a video on Flipgrid interfered with their project work. For example, James said, "Sometimes I didn't like Flipgrid, some days I didn't because I was really into it and when we got to Flipgrid we had to stop working on our project and if we didn't have Flipgrid we could make more progress on our project."

The teacher facilitators also stated that they sometimes noticed that the features offered on the Flipgrid dashboard distracted students. For example, once students finished posting the video, they could add digital emoji or costume stickers, as well as phrases like "Cool!" or "Awesome!" to their Flipgrid posts. The teachers reported that some of the students were more focused on in adding the "fun" features rather than on the actual quality of their Flipgrid responses, and my observations of videos posted on Flipgrid provided evidence of this assertion.

In addition, during their interview, the teachers reported that when students were told to give feedback to peers on the Flipgrid, they sometimes commented on the actual technical components of the video (e.g. sound, clarity, visuals, etc.) rather than the summary about the individual projects. I reviewed 23 Week 4 Flipgrid posts in which students were directed to provide feedback to peers. Of the 23 posts available, 14 of the Flipgrid posts focused on giving project feedback such as adding more color to a doghouse or including "fancier" features in Minecraft such as "quartz flooring." Nine of the videos available from Week 4 included students giving feedback about the actual Flipgrid post recorded. For example, students suggested their peers speak louder, move to a quieter spot when recording their Flipgrids, include more details when speaking about their projects rather than just pointing to the projects, and refrain from asking questions of the viewer "because you only have 90 seconds to record your Flipgrid and you need the time." In order to leverage this tool more fully, teachers should plan to address the technical components of how to create valuable Flipgrid posts so that the viewer can see, hear, and understand the project work, ideally leading to more meaningful feedback.

Students in third-grade also reported that although they liked receiving feedback from their peers on Flipgrid, it was often their proximity to other participants that allowed them to receive and give feedback. They noted that it was more convenient to just walk up to someone standing near them to ask questions and that when someone was working next to them, they could (for example) look at their screens on Minecraft to see new ideas or features they could add to their own Minecraft worlds. My review of the video footage supported this claim as I saw students observing one another working with tools and then transferring that observation to their own projects. Examples include cutting cardboard, screwing in a screw, unpacking their Makey Makey kits, or working on a coding game.

In order to make thinking visible, schools can leverage Flipgrid to cultivate a community of learning with students enrolled in their schools, as well as in the wider global community. For this research project, data collected can be referenced as evidence for the potential future use of Flipgrid as a vehicle for students to monitor their work and provide feedback to peers. However, schools need to consider peer proximity as a student-reported preferred tool for feedback as well.

Teacher scaffolds. Throughout the study, the teachers monitored students as they worked in the makerspace. In order to extend or scaffold students' thinking, the teachers used discussion probes from the AbDTR as appropriate to further query students' application of knowledge and synthesis of ideas. Probes included: *What are its parts? What are its various pieces or components? What are its purposes? What are the purposes for each of these parts? In what* *ways could it be made to be more effective? In what ways could it be made to be more efficient? In what ways could it be made to be more beautiful?*

The teachers reported that they found it difficult to implement the discussion probes and that often they had to remind themselves to follow the script. They also said that it was challenging as educators to guide students to discover their own solutions rather than telling the student the correct way to do something. Mrs. Smith said she would have to walk away from a student after telling them, "Think about it. Take a look. Take a look and try different things, and I'll come back." Mrs. Davis said that when one student with special needs, Anthony, was working on his Makey Makey project, she noticed he did not have the wires connected properly and that he asked her what he should do. She stated that he should go back to the circuit building inherent in Makey Makey kits and asked the child, “Well, which one aren't [you holding], don't you need to hold one? Or which one is supposed to touch you?" She said that eventually Anthony did figure it out but that it was really challenging not to solve the problem for the student in this instance. Even when I was present to observe the sessions, I found it difficult to refrain from offering suggestions to students. In one instance, Oliver, a student focus-panel interviewee, was trying to balance his Beyblade spinner made of Legos. He needed to balance the weight and I wanted to tell him how to do it, but instead I stood off to the side and observed him. Eventually he did figure out how to distribute the blocks and successfully made his Beyblade spin. This example is explained in more detail in the case studies featured later in this chapter.

When asked if teachers provided feedback to students, third-grade students said that the teachers did not give them feedback about their projects that often the feedback came from their peers. However, most of the second-grade students agreed that Mrs. Smith and Mrs. Davis showed them how to provide feedback to their peers, and that they received some feedback from the teachers. Paige commented, “When Mrs. Smith came over to us she did say, ‘How did you build this? How did you get the idea to do this?’ and she gave us feedback to help us do more stuff.” Overall students did not express awareness that the teachers had utilized the scripted discussion probes

Although the third-graders said the teachers did not provide them with feedback, my review of the video footage from all four classes does provide evidence of teachers modeling how to use tools, suggesting to students that they use certain materials, and questioning students with some of the discussion prompts. From my review of the video footage, I noted that student-initiated interactions with the teachers had to do with how to use a tool, where to find a tool, or how to acquire more supplies. Although second-graders reported interactions with teachers as providing feedback, when I reviewed the videos for the whole class sessions and the fourth case studies, I found most of the interactions were oriented around classroom management directives such as cleaning up or recording Flipgrids.

The teachers expressed that they found it difficult to implement so many different learning experiences, making it challenging to manage the materials, the children, and the design features of the research study. In order to provide more effective teacher scaffolding, designers of makerspaces may want to consider how to support teacher practices related to effective questioning, wait time, and classroom management through ongoing coaching, professional development, and in class support.

RQ3: When describing their projects, how do students articulate the design process? Do they recognize or cite the design features as influencing their project outcomes? When describing the design process of their projects, students reported that peer feedback, peer proximity, and perseverance impacted their work. In this next section I triangulate the coded data, teacher interview transcripts, and my observations of the video recording to further support their statements. I also include a summary about how the students' perceived the design features' possible impact to their design process and project outcomes.

Peer feedback. Both teachers and students interviewed reported that peer feedback offered the participants time to expand, reflect, or revise their ideas and skills from the beginning of the project to the end of the project, both virtually via Flipgrid and in real time during class through modeling or verbal feedback. A group of third grade boys discussed ways in which verbal peer feedback and peer modeling impacted their work, particularly learning new skills on Minecraft. James stated:

> At first I was in the beginning of the Minecraft. Then when I joined I was terrible at Minecraft. I didn't know any of the controls. A few times Sean and Rob kept up with me and now I actually know what to do and I actually can make stuff. I'm not as good as them but I am okay.

Another group member, Sean, noted the he served in a leadership capacity and that his prior knowledge and modeling of Minecraft impacted the work in the group. He stated:

> I was in Rob and James' group. We were making the castle because I gave Rob the castle idea and the river. Because I use to play Minecraft all the time on my iPad and I used to build castles on top of hills and stuff, and I never built one in the water, I was like, "Why don't we try to build a castle?" I really like building castles in Minecraft.

At the beginning of the study, James had planned to create something on Flipgrid independently of the required weekly posts. As he worked on his own, he also observed his peers working on computers nearby, and he demonstrated metacognitive awareness of his own learning by acknowledging, “I noticed Sean and Rob were working on a really cool Minecraft world and that week I asked them if I could join them because I didn't know how I was going to do that with Flipgrid.” Initially he did not know how to create something in Minecraft, and by initiating a working partnership with Sean and Rob, he learned new skills and was able to change the Minecraft snowballs “into fire charges which are like fireballs” on his final Minecraft project.

After reviewing the video footage of each makerspace session, I observed that peer feedback generated during the study was student-driven and occurred spontaneously for many student groups such as when a participant observed a peer model or received verbal peer feedback; however, the teachers and I thought it would be helpful for students to provide specific feedback to one another about their work to ensure all students received some type of peer feedback. Each week all students posted video updates on Flipgrid about their projects or things they had done in the makerspace that week. During Week 4 of the second rotation, the teachers directed students to give feedback to their peers virtually on the Flipgrid. Students were randomly assigned two classmates and reviewed their Flipgrid posts. Then they posted a video response to give advice or recommendations about a person’s video post. Sean commented, “I got a really good feedback that we should maybe add more doors and add more entrances and we were thinking about maybe adding a drawbridge (to his Minecraft project).” In contrast, Anthony, an interviewee with special needs, reported that he did not appreciate the feedback he received as he thought his peers did not tell him enough about how to improve his Makey Makey game controller and focused too much on the quality of his Flipgrid video post.

Peer feedback through verbal peer feedback, peer modeling, and virtually on tools like Flipgrid has the potential to help students conceptualize their project ideas and make decisions while engaged in their work. When designing elementary makerspaces, the integration of peer feedback can be fostered through the physical design of the space to allow for frequent movement, as well as different tool options and activities to promote collaboration. Furthermore, the mindset of the teacher and school can also promote peer feedback through the design of instruction to encourage partnerships, as well as scaffolding ongoing formative assessments to drive instruction and support for students' work. Participants in this research project expressed the ability to critique the feedback received from their peers, and the facilitators provided a learning environment in which the participants had autonomy when deciding whether or not to include the advice or suggestions of their peers.

Peer proximity. After examining idea units coded under the heading *Peer Feedback* and reviewing extensive video footage recorded during each session, I started to realize that peer proximity, both virtual and physical, could also have impacted students' design process. Hailey, a third grader with special needs, explained that she decided to select Makey Makey as her final project because she saw a peer near her working on a Makey Makey kit. I coded this example as *Peer Model*; however, it was also due to Hailey's proximity to her peer that she decided to create the Makey Makey project. Students and teachers reported that sometimes as a peer worked next to another peer he or she would mention something that would make the project "cooler." Review of video footage recorded during each makerspace session further supported interviewees' responses regarding peer proximity impacting the trajectory of a project as I observed students checking in on one another or giving advice throughout the sessions. For example, Lara and Anna, third-grade girls, worked next to one another during the first week of the study, Lara focused on cardboard while Anna played with a Makey Makey Kit. Lara gave Anna specific advice about how to close her circuit by switching the wires and making sure she made contact with the alligator clips and the conductive object. Based on this feedback, Anna successfully created a Makey Makey game controller during that week's session.

Connor and Declan, third-grade boys, worked near each other on Flappy Bird to code a new game. They had their Chromebooks set up directly in front of each other as they sat together and were able to work on both of the devices. Initially Declan said, "Look!" and showed Connor his game. Connor replied, "How did you do that?" They laughed and then Declan modeled how to login to Flappy Bird and create the game with the coding blocks. Declan instructed Connor to develop his game by adding more coding blocks. Connor realized that by adding coding blocks he could have the bird complete different functions. Connor showed his work to Declan and Declan responded, "I can set an obstacle, make gravity random, make it faster. Best game ever!" Connor and Declan successfully completed Flappy Bird games during that makerspace session.

Peer proximity, both virtual and physical, can also promote opportunities for peer feedback to cultivate a learning environment that helps students conceptualize and design projects. From the interview data and video footage reviewed I can clearly provide evidence that when students had the opportunity to work near a peer, they effectively engaged in the design thinking process to create, refine, and iterate their projects. With regards to projects, simply being near a peer in the classroom provided increased chances for students to verbally engage with one another or observe one another to help develop a project. Educators can also establish virtual spaces, such as Flipgrid, where students can have a digital proximity to help facilitate peer feedback to impact the trajectory of a makerspace project.

Perseverance. When working in the makerspace, students demonstrated perseverance, which was defined as how a participant behaved when frustrated in the makerspace. Hailey and Anthony, two students with IEPs in Grade 3, both selected Makey Makey kits as their final projects. They both found focusing and reading difficult so it was very challenging for them to figure out how to read the directions from the Makey Makey website and problem solve when the circuits did not immediately work. During my review of the video recordings from their makerspace sessions, I observed Anthony asking the teachers how to start assembling the Makey Makey kit. They re-directed him to Google or a peer to figure things out. He eventually persevered to create his Makey Makey game controller, and during the student focus-panel interview, Anthony explained that he made his game controller user-friendly by designing larger buttons to allow for easier circuit building and conductivity.

Mrs. Davis reported that she also saw students persevering in the face of frustration, noting that at first working on the Makey Makey was extremely challenging for Hailey. Mrs. Davis stated that as she observed Hailey, she noticed Hailey did not position her paper correctly to complete the circuit. Mrs. Davis described how Hailey spent time closely examining her paper and tried different positions. Mrs. Davis said, "She figured out that her arrow was going the wrong way, and so she erased it and fixed her arrow, and then really fitted it (the alligator clip) in. So, she did problem solve … (on her own)."

Students' abilities to persevere with a project, even when faced with difficulty, were impacted by the teachers allowing the students to problem solve on their own. Reaching a successful outcome took time, spanning two makerspace sessions for both Hailey and Anthony. When designing makerspaces, educators should allow time for students to think and engage in multiple iterations of their work. This can be done through scheduling of the makerspace session, providing ongoing access to materials by keeping them securely stored from session to session, and allowing for open-ended outcomes that value the process as well as the product created. In addition, teachers must also be given permission from administrators to let children work independently and scaffold learning for students as needed through explicit feedback, re-direction, direct instruction, or access to the tools and activities provided.

Design features. We coded some evidence from the interview data in which students articulated, recognized, or cited the design features as influencing their project outcomes. As previously detailed, students identified Flipgrid as helpful in revising or enhancing their project design. For example, Sophia stated, “I think the Flipgrids helped me think more. It helped me think of stuff to add onto mine, and just review what I did for the past week or so.” A few students mentioned applying the AbDTR when working on Minecraft as a way to help analyze their structures from different views. James reported that by thinking of all the possible views and perspectives of an object (*Exploring Complexity* routine), “…you could go around the structure that you built and with the paper it made the structure even better because we looked at different angles and we could picture what it would look like in the future, the next time we go on …Minecraft.” His partner, Sean, agreed with him, “When we draw the pictures, it can help us plan out what we want to do next. And like, oh, we should take out this or maybe we should add this or we should reconfigure this.”

Students’ prior thinking about their projects also appeared to scaffold their design process. For example, Oliver explained how he began thinking about doing work with Legos earlier in the school year and how he could use the Legos to design and improved a Beyblade spinner. He stated:

> A long time ago, back in December ... me, Alex, and Kyle made Beyblades. Once we started [this research study] we wanted to do Legos because they were already taken apart. I said to myself, “I want to recreate what we did and make it even better than before.”

Oliver worked on his Beyblade tops throughout the study and spent a great deal of time figuring out how to balance the Beyblades so that they would spin and not immediately topple over (Figure 5).

Figure 5. Oliver testing his Lego Beyblade to see if it would spin.

Perhaps with more explicit instruction by the teachers or with repeated exposure, students would have overtly attributed the design features as shaping their project work. The students did mention Flipgrid as a way to monitor their work, and this is more fully explored in the case studies featured later in this chapter. Both Flipgrid and AbDTR were appealing to participants as they designed their projects and should be considered by designers of makerspaces as a way to help scaffold and support student project work.

RQ4: What elements of project planning and implementation do students find motivating or engaging? When reviewing the interview data to determine which elements of project planning and implementation students found motivating or engaging, we coded preferences of tools as well as evidence of learning. In this section, I examine how students' choice of and use of tools both motivated and engaged them through their time in the makerspace. In addition, I examine how student-reported learning, both skill-based and metacognitive, served as catalysts for motivation and engagement in the makerspace-learning environment.

Tools. During the focus-panel interviews, students were explicitly asked to describe their favorite things to do in the makerspace setting. Students stated their preferences for different tools like Chromebooks, Legos, Makey Makey, Minecraft, and cardboard. When asked to explain why they liked a particular tool, they said that they enjoyed working with their friends, the opportunity to direct their own learning, or the variety of experiences possible with a particular tool (Table 11). For example, when I evaluated the five idea units in which students reported Chromebooks were among their favorite tools to use, all of the students stated the variety of choices as the reason for this tool selection. They described playing games or playing with friends as additional reasons for choosing Chromebooks as their favorite tools. Students also reported having the ability to be autonomous in how they used the tools as another motive for selecting Minecraft, Makey Makey, and Chromebooks as their favorite tools in the makerspace.

While coding the data, the research team and I realized students had expressed definite preferences for selecting tools or engaging with the design features stemming from different emotions. As stated above, students reported they enjoyed playing with their friends, having autonomy to choose from a variety of tools, and even expressed some tools were just fun to work with like the cardboard. Oliver said that his time in the makerspace was "my favorite thing to do all year!" Teachers reported that although all students completed the Flipgrid with regularity each week, sometimes students expressed annoyance or frustration when interrupted to stop project work in order to complete a Flipgrid to document their thinking. Sean agreed: "…sometimes I really want to work on my project a little more but then we have to do the Flipgrid and stop doing what we're doing." In order to mitigate this frustration, the teachers provided transition warnings so that students could prepare to clean up materials or add finishing touches to their work and then prepare to post on the Flipgrid.

Table 11

Examples of Students' Tool Preferences and Rationale for their Tool Choices

Idea Unit	Tools*	Reason*
James: My favorite thing is to play on the Chromebooks, play on Minecraft and play with the Legos. Chromebooks is my favorite thing because I can go on multiple of different kinds of websites and I can play multiple games on each website.	Minecraft Legos Chromebooks	 Variety of choices Playing games
Sean: The reason I like using the Chromebooks is because I like to play different games on the Chromebooks. It's simpler.	Chromebooks	Variety of choices Playing games User interface
Anthony: My favorite thing to do is play games on the Chromebooks… because you can go play a lot of things on the Symbaloo, which is the thing I really like.	Chromebooks	Variety of choices Playing games
Kevin: Everything is to play with my friends. Playing Minecraft with them, and playing on the Chromebooks with them. I liked Chromebooks because it has Scratch and Scratch is a really fun website. Basically, you get to see other people's projects and I played other people's projects with my friends and also I can make my own project, which is really cool.	Minecraft Chromebooks	Play with friends Play with friends Variety of choices Peer feedback Autonomy Fun factor

* References to preferences of tools are color coded in blue and references to reasons for tool preferences are color coded in green.

Table 11 (continued)

Idea Unit	Tools*	Reason*
Oliver: My favorite thing to do…is use the Chromebooks and play with the Legos to make Beyblades. My favorite thing to do on Chromebooks is go on to ABCya! onto Blue because there is a variety of different games that I can play and play with my friends.	Legos Chromebooks	Make Variety of choices Play with friends
Nathan: I like the cardboard challenge because it's fun to cut it and then build with it.	Cardboard	Fun factor
David: I like the Legos because you can make whatever you want.	Legos	Autonomy
Sophia: I like Makey-Makey because you can really let your imagination run wild and make whatever you want.	Makey Makey	Autonomy Imagination
Paige: I really like Minecraft because you can be creative.	Minecraft	Creativity
Mark: I like motorized Legos because you get to make it move.	Legos	Function

* References to preferences of tools are color coded in blue and references to reasons for tool preferences are color coded in green.

Overall students reported Chromebooks as their preferred tool because of the variety of choices available when utilizing the Chromebooks and the ability to play with friends and play games (Figure 6). Many public schools offer each student their own Chromebook, sometimes referred to as "1:1 Chromebooks," to support standardized testing mandates and provide access to cloud-based applications via Google Suite. Makerspace designers can leverage the availability of Chromebooks as a means to provide a variety of engaging learning opportunities in the elementary makerspace setting.

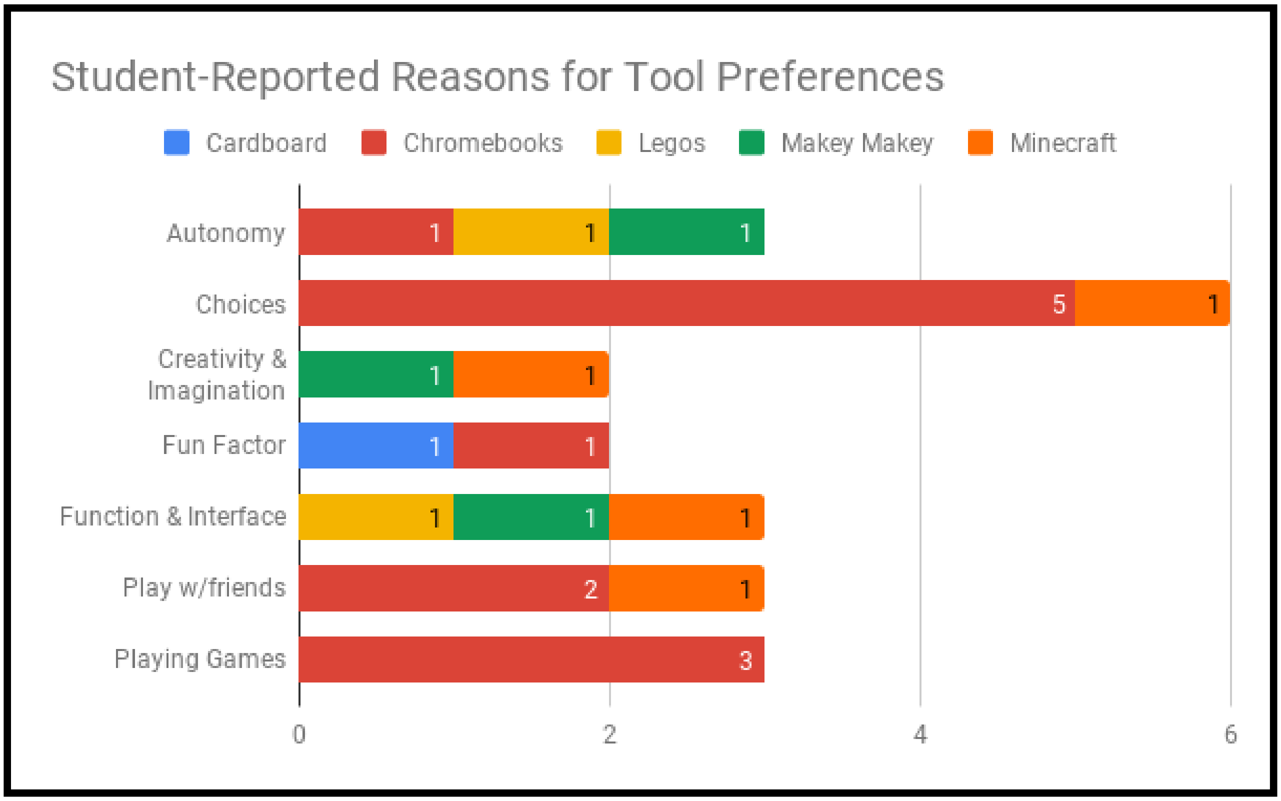

Figure 6. Chart detailing student-reported reasons for tool preferences.

Learning. When asked what they actually learned in the makerspace setting, students reported that they improved in certain skills like building in Minecraft. James stated, "…When I joined I was terrible at Minecraft. I didn't know any of the controls. A few times Sean and Rob kept up with me and now I actually know what to do and I actually can make stuff. I'm not as good as them but I am okay." They also learned that they could use materials to represent their ideas such as when Oliver realized, "I learned that Legos can ... [be] a model and it works you could lead to different inventions in the future." Anthony understood that "unplugged" tools could be combined with tech tools as demonstrated when he created his Makey Makey game controller and completed his circuit with paper and wires connected to the computer.

Outcomes related to self-regulation and self-confidence also emerged. Sophia stated that through her experiences in the makerspace experimenting with new tools, she could do anything and that she learned to control the tools more effectively. Paige acknowledged that working with her partner on Minecraft helped her "to cooperate with other people, because sometimes I take over a project, I just become the boss of it. The makerspace helped me learn how to cooperate with other people, like a partner or in a group." I reviewed video footage to confirm this assertion, and I observed Paige interacting with several peers working nearby to learn more about Minecraft features and then sharing that information with her partner, Sophia.

Surveys on engagement. Although coded interview data demonstrated some evidence of engagement and motivation in the makerspace setting, surveys designed to measure engagement did not show any significant impact of the design features causing an increase in motivation and engagement. Surveys were administered online via Google Forms before the study began and then again when the study was completed (Appendix G). Two-tailed paired *t*-tests used to compare students' pre and post survey data by each indicator failed to yield statistically significant differences between the pre and post survey data (Appendix O), which specifically examined four aspects of engagement: agentic, behavioral, emotional, and cognitive.

Students demonstrated agency as they worked within the makerspace to select tools, project ideas, and partners. When asked about their experiences in the makerspace, student reported that they liked having choices with regards to how they used the different tools and opportunities to play with friends. In order to support motivation and engagement in the elementary makerspace, designers should consider integrating opportunities for students to have agency when designing their projects and selecting tools, experiences to work with their peers, access to many choices, and the "fun factor" inherent in children's process of learning and innate sense of curiosity. In an age when mindfulness initiatives are sweeping across the globe to help students develop self-regulation, consideration of how makerspaces can provide these skills should also be addressed in order to enhance the potential for social-emotional learning.

Summary. When triangulated, the coded interview data, teacher interview transcripts, and review of video recordings serve as evidence for possible planning ideas when implementing and designing elementary makerspaces. Peer feedback, both physical and digital, is an element that all students and teachers agreed impacted the trajectory of makerspace projects. Further extending that feedback to include the idea of peer proximity necessitates that designers create spaces with opportunities for students to interact with each other in real time and virtually. Access to tools that encourage student choice, multiple outcomes, time with friends, playing, and the "fun factor" are helpful in order to build motivation and engagement. The use of the Flipgrid platform successfully made students' thinking visible and encouraged peer feedback to help shape final project outcomes. Additional suggestions for makerspace designs are included following the case studies.

Case Studies

In this next section I present case studies of four student projects. Because case studies can be used for comparison and analysis of patterns in the data (Patton, 2002, p. 447), individual cases will be detailed and then synthesized in response to the original research questions. As explained in Chapter 3, I initially selected case studies based on project scores, tools used, and those projects created by student partnerships. Later, the research team and I decided to include a project made by one individual student to determine if the findings from the partnership projects could be transferred to students who worked independently.

First, I present two case studies from the first rotation during which participants worked on their final projects during Weeks 5-7. Then I present two case studies from the second rotation of the study during which participants worked on their final projects for Weeks 1, 5, and 6. As I describe each case, I follow the same sequence. To begin each case study I summarize details about each project, specifically examining how the projects were conceived and refined by participants over each session. Next, I analyze each of the design features' potential impact on the design process of each project including AbDTR, making students' thinking visible, and teacher scaffolds. I also include details about peer proximity because this was a factor that emerged from analysis of the student focus-panel interview data. Then I summarize the analysis of each case study, including key takeaways. After discussing the case studies, I present an exhaustive analysis of the case studies utilizing the coding protocol from the student focus-panel interviews. Finally, at the end of this section, I answer RQ2-4 again by synthesizing details from each case study and coded case study data to further verify the interview data previously analyzed and validate recommendations with regards to makerspace design.

Case study #1: Bridge to design thinking. Anna and Sarah, two third-grade girls, created a bridge made out of cardboard during Weeks 6 and 7 of the first study rotation. Initially, during Week 5, Anna worked with another student on a Google slideshow about Greece while Sarah worked with cardboard independently. After reviewing video recorded during the study, I noted that Sarah learned how to cut the cardboard and work with the Makedo screws as she observed Mrs. Smith demonstrating the tools to a group of boys working nearby. In addition, throughout this session, Sarah quietly observed the group of boys as they worked, and she interacted with them once to discuss who was using which piece of cardboard for their projects. Although Anna and her partner worked together to create a shared Google slideshow in Week 5, Anna abandoned the slideshow in Week 6 and asked Sarah if she could join her in building with cardboard instead. They smiled at one another and immediately set to work with cardboard.

As Anna and Sarah worked together to create their bridge (Figures 7 & 8), they had access to a variety of cardboard pieces of different shapes and sizes, Makedo screws and cutters, tape, and scissors. While it is not clear from the video and audio footage which one of the girls suggested the idea of the bridge, the girls did collaborate to select different pieces of cardboard to make the bridge. Anna told Sarah to grab one more cardboard tube to support the bridge, and Sarah suggested to Anna that an empty box would make for a good bridge. Both girls were amenable to each other's suggestions. The girls spent time cutting the box and demonstrating to one another how they could use the flaps as the actual drawbridge. During Week 6, Mrs. Smith gave feedback to the girls in the form of granting them permission to use the different tools around the room and reminding them to keep the tools organized. At one point Mrs. Smith suggested that as the girls emptied extra papers from one of the boxes, that they put the papers in the recycling can.

During Weeks 6 and 7, students responded to prompts on Flipgrid about their time in the makerspace. The Flipgrid prompt for Week 6 stated, "You now have the opportunity to choose your own projects and we are so interested to learn more details about your work. Use this Flipgrid to talk about your project, ask questions, or explain next steps." In their Flipgrid, Sarah and Anna described how they planned to design their bridge, naming specific *parts and the* *purposes* of each piece. They described where they would put the screws to allow the drawbridge to open. Anna said they planned to make a model of a boat and then demonstrated how the bridge would open as the boat passed through. She explained how they would put tubes on each corner to lift the bridge and one in the middle for extra support. Sarah further elaborated how they would put up walls “so the cars just don't fall into the ocean.”

Figure 7. Anna and Sarah work on their project.

Figure 8. Anna and Sarah show their finished bridge.

Teachers provided students with the same Flipgrid prompt during Week 7. However, this time Sarah and Anna reported on the *design process of their project*, as opposed to pointing out parts of their project and the purposes of the parts from as they did the previous week. Citing examples of multiple iterations, Sarah and Anna mentioned that their bridge project took them a very long time and that they made changes to their project in order for the bridge to remain stable and for the drawbridge to work correctly. They described how they attempted to stabilize the bridge with more tape and supporting structures like cardboard tubes.

Sarah: It took us a long time, a very long time. You see all of this tape. It kept just breaking.

Anna: Yeah, it hasn't always been secure. So every time it broke, we had to put on more cardboard. We had to put a couple more layers on top of it.

Sarah: First we thought of coloring the tape brown but it didn't really work. See look over here. We put this bar over here to kind of make it a little ramp.

Case study #1 analysis. In this section, I document how the design features of the study may have helped to shape the trajectory of the girls' project work. Inherent to the process of design-based research, unexpected outcomes or *ontological innovations* "provide new lenses for making sense of what is happening in the … instructional setting in which a design study is situated" (DiSessa & Cobb, 2009, p. 99). Researchers can then use these findings to make pedagogical or instructional recommendations. Therefore, based on extensive review of the individual case studies, interview data, and video footage, I introduce unexpected ontological innovations impacting the trajectory of the girls' work in the makerspace including peer proximity and students' articulation of the design process.

AbD Thinking Routines (AbDTR). As previously explained, all students in the study learned about the AbDTR during Weeks 2 – 4 (Appendices P-R) and had time to practice the routines on objects of their choosing, not necessarily their final projects. The girls may have applied the routines (Appendices S & T) to their project work, possibly impacting the final project outcomes. For example, on the Week 6 Flipgrid post, the girls discussed changes they would make to their project, as well as difficulties they experienced. Anna considered aesthetics and areas for improvement, similar to the *Fostering Opportunity* routine, when she described how she would try to blend the tape in more or make the bubble wrap blue to have it resemble water. Akin to the *Exploring Complexity* routine, she addressed the different perspectives of the user, as well as the bridge itself, as she showed the viewer how vehicles could cross the bridge. Finally, she may have incorporated elements of parts and purpose analysis from the *Looking Closely* routine when she talked about how she would make the bridge more stable by adding tape or the way she connected the cardboard with tape. Although the girls did not sketch their bridge, its parts, and aesthetic features, as they would have formally been asked to do when practicing the AbDTR, the girls explicitly described form, function, and aesthetics of their bridge. Nevertheless, this does not necessarily mean they incorporated, applied, or internalized the AbDTR as the girls' language was general, and they did not explicitly attribute the process of describing their projects to the AbDTR.

Making students' thinking visible. The girls' use of the Flipgrid design feature may have impacted their ability to talk about their project and the design process. In the Week 6 prompt, they explained what they would do the next time they met, and in the Week 7 video entry, the girls showed how they followed through on their recommendations from Week 6 to create their final project. The girls also acknowledged the multiple iterations required to build their bridge, specifically when attempting to stabilize the base in order to have the drawbridge move up and down. While the girls demonstrated what they built, they never explicitly discussed what they had learned during the research study or examples of metacognitive awareness.

Teacher scaffolds. While reviewing video footage, I did not detect many interactions between the girls and the teacher facilitators. As previously noted, Sarah did observe Mrs. Smith demonstrating to a group of boys how to cut with cardboard. In addition, Mrs. Smith did offer the girls some directions about gathering materials such as pointing to different locations around the room or suggesting they recycle different items. It does not appear that the teacher scaffolds had significant impact on the girls' final project design.

Peer proximity. Peer proximity may also have impacted the girls' project in two different ways. When Anna decided to abandon her Google slideshow in Week 6, she looked around the room and saw that Sarah was working alone and nearby. She had not yet worked with Sarah during the previous weeks and the girls did not typically work or play together during other parts of their school day or recess time. Throughout their time together, both of the girls appeared engaged with each other as evidenced by their close proximity and laughter, and they also appeared engaged with the tools provided as they returned to find more items to add to their bridge. During Week 5, as Sarah worked independently, her proximity to a group of three boys allowed her to observe their cardboard cutting techniques and then apply similar techniques when she cut the cardboard in subsequent weeks. She was also able to show her partner, Anna, how to cut the cardboard during Week 6 as evidenced by the video footage recorded.

Case study #1 summary. In first case study, *Bridge to design thinking*, Sarah and Anna created a bridge from cardboard and described multiple iterations to their work. The trajectory of their project began with Sarah working independently with cardboard. Then, Anna abandoned her first project, and due to her proximity to Sarah, as well as having the agency to self-select a partner, Anna worked with Sarah to design and complete the bridge. There is evidence from this case study that indicates that both girls were engaged throughout their project work, and that they relied on each other, as well as their peers, to complete their project through peer modeling and verbal peer feedback. Throughout the study, the girls engaged in verbal peer feedback with each other to make decisions regarding material choices and how to build their bridge. Utilizing the Flipgrid platform the girls were able to make their thinking visible by identifying the parts and purposes of their drawbridge and explaining their design process.

Case study #2: Minecraft: Building connected learning with sewers, pipes, and bridges. Connor and Jordan, third-grade boys in the general education setting, both showed interest in working with technology tools throughout the study and they collaborated to create a Minecraft house and landscape for their final project. During Week 1, Connor chose to work with Flappy Bird while Jordan worked with another peer to create an arcade game with Makey Makey and cardboard. During Week 5, both boys started to work on separate Minecraft projects. Initially Connor worked independently, and Jordan partnered with his classmate from Week 1. Jordan’s partner refused to share the controllers with Jordan, and Jordan eventually lost interest in working with him. I reviewed video footage from Week 6 in which Jordan walked away from his partner and then observed other students working on Minecraft (Figure 9). Connor asked Jordan to look at his screen, and then the boys started working together during Weeks 6 and 7.

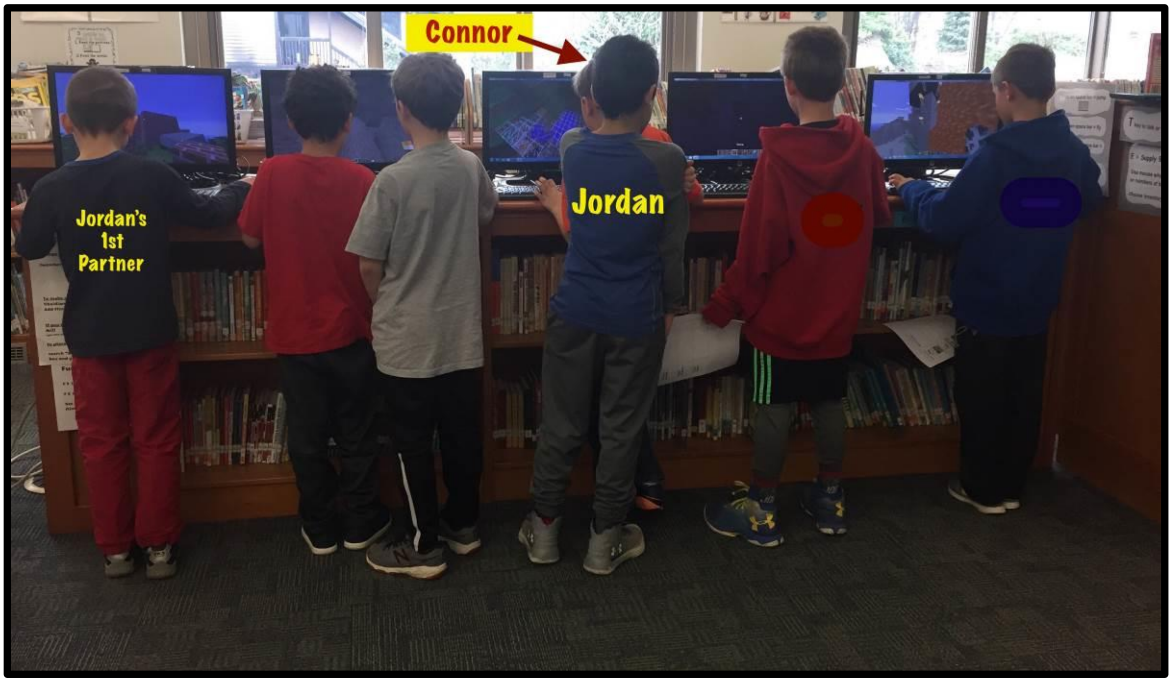

Figure 9. Jordan observing classmates working on Minecraft.

For their final project, Jordan and Connor designed a virtual house on Minecraft and the infrastructure leading to and from the house including roads, a drawbridge, and sewer lines. During their Week 6 Flipgrid video, the boys said that sewer lines ran under the house; levers were included to open and close the roof of the house; and a trap door was placed on the roof of the house (Figure 10) with pistons to move the door to block unwanted intruders or allow someone in the house.

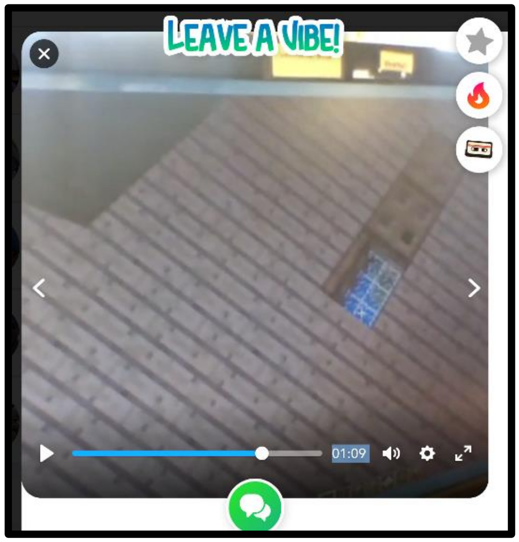

Figure 10. Screenshot of the Minecraft house trapdoor.

As the boys recorded their Flipgrid video posts describing their projects, they were sitting adjacent to one another. After reviewing the boys' Flipgrid posts, I noticed that as Connor recorded his Week 6 video post, he paused and listened to Jordan's response, and then he added similar details to his response. For example, Connor said he made a project with Minecraft, and at the same time, Jordan said he made his project with Minecraft.edu. Connor then added to his post "edu" as well. As Jordan reported that he made pistons, Connor then reported the same thing. Finally, as Jordan described the levers, Connor paused and then added some comments about the levers to his post a few seconds later.

In their Week 7 Flipgrid post, the boys created two videos to highlight their final outcomes, each video lasting one minute and thirty seconds. In these posts they both spoke on the video as they explained their project. As the boys navigated the computer screen to show their Minecraft house and infrastructure, Jordan took the viewer through the interior of the house to identify a couch they had made and then tried to exit the house through the trapdoor roof. He commented, "It's really hard to get out of here." Connor stated, "Yeah it is. It makes it very safe though so nobody can get in." The boys were excited to show the viewer the drawbridge they made with levers to control the movement of the drawbridge. They did not state the purpose of the drawbridge.

***Case study #2 analysis*.** In this next section, I explain how the boys' use of the design features may have shaped final project outcomes. Although the participants in this case study did not describe the design process or what types of changes they would make to their Minecraft build, it was evident that they had both worked on the project together while taking turns narrating the landscape and structures in their Minecraft build in their Week 7 Flipgrid.

AbD Thinking Routines. During weeks 2-4, both boys worked with the teacher to apply the AbDTR to objects they brought in from home or found in the classroom (Appendices V & W). The boys may have applied AbD Thinking Routine behaviors such as *Exploring Complexity* as they took the viewer through the *different parts* of their sewer system, house, and bridge. They also made sure they showed the items from different physical *perspectives* as they used the computer mouse to spin the Minecraft build (including their house and landscape scenes), or hover over or underneath a structure. The boys showed *Looking Closely* behaviors as they described the functions and purposes of their levers, trap door, and drawbridge. They noted that making it difficult to exit the house made for a safer environment. However, there is no concrete evidence that the boys knowingly applied the AbDTR, or that they expressed awareness of internalizing and transferring the routines to their project work.

Making students' thinking visible. The boys posted video responses on Flipgrid during Weeks 6 and 7 to document the artifact they created on Minecraft. They described the structure they built together, citing specific details with regards to the different elements of design including pistons, levers, furniture, and safety; however, they did not demonstrate utilization of the Flipgrid as a tool to showcase changes over time or iterations to their design process. Rather, they used the Flipgrid to summarize the week's activity. Connor did rely on Jordan for verbal prompts and cues as demonstrated by his repetition of Jordan's comments in his own Flipgrid posts.

Teacher scaffolds. I did not observe any significant interactions with the teacher facilitators while the boys designed their project. After careful review of the video footage, I noted that Mrs. Smith's interactions with the boys were part of general classroom directives such as prompting students to begin working on their Flipgrids or to start cleaning up materials. In addition, I did observe the teacher checking in with each group individually to make sure they were on task and engaged with one of the makerspace tools.

Peer proximity. Similar to the first case study, the boys did not actually begin working together in Week 5. Although they both decided to create a project in Minecraft, Connor initially worked independently, and Jordan elected to work with his partner from Week 1. I carefully reviewed the video footage collected and noted that Jordan's partner did not want to share control of the screen and the keyboard. Jordan eventually lost interest in working with this person, and during Week 6 he walked behind a group of boys lined up in front of the desktops on which they built virtual artifacts on Minecraft (Figure 9). Connor asked Jordan to look at something on his screen, and then Jordan started showing Connor how to add different building options in Minecraft. In the video footage, I observed both boys sharing the keyboard controls. I could not decipher specific quotes from the audio and video footage; however, the boys' non-verbal behaviors indicated they were interested in what each other had to say and contribute. For example they took turns adding items to their virtual build with the keyboard controls, they stood closely to one another, and they remained engaged in their project work for 20 minutes without stepping away from the computer monitor. In this case, the boys' proximity to one another and interactions that ensued when working on this project did impact final project outcomes.

Case study #2 summary. In the second case study, *Minecraft: Building connected learning with sewers, pipes, and bridges,* Connor and Jordan collaborated to design a house and landscape in Minecraft with various features including trapdoors, sewers, pipes, and bridges. The trajectory of their project began with Connor working independently on Minecraft during Week 5, while Jordan worked on Minecraft with his original partner from Week 1. Jordan lost interest in working with his partner during Week 6, and began looking at his peers' Minecraft projects on their computer monitors. Due to his proximity to Connor, Connor invited Jordan to look at his project on Minecraft. At that point Jordan engaged with Connor in verbal peer feedback, and he gave Connor advice about the design of his Minecraft build. There is evidence from this case study that indicates that both boys were engaged throughout their project work, and that they relied on each other to complete their project through peer modeling and verbal peer feedback. Utilizing the Flipgrid platform, the boys were able to make their thinking visible by identifying the parts and purposes of their Minecraft house and landscape and summarizing their weekly builds. In addition, when recording his Flipgrid post, Connor leveraged his proximity to Jordan as a model for recording his own Flipgrid post.

Case study #3: Minecraft: It takes a village. Sophia and Paige, second-grade girls, collaborated on Minecraft to create a virtual village. These girls participated in the second rotation of the study, which ran for six consecutive weeks, and they also participated in the student focus-panel interviews. Although I have already discussed several of their interview idea units, I include specific quotes or information to support or refute information when describing and analyzing the case study. This case differs from the first two case studies as during the first week of the study, Sophia and Paige selected to work together on Minecraft to design a house with a yard and garden, and they continued to iterate their Week 1 project throughout Weeks 5 and 6. During their Week 1 Flipgrid, the girls took the viewer on a tour of the inside of the house (Figure 11). They pointed out the bed, desk, window, and Jeff – a blue Minecraft character. Paige directed Sophia to show the viewers the garden and pigpen outside. Sophia explained they planted trees and water. Paige corrected Sophia and said, “There’s no such thing as planting water. You know that.” Sophia laughed and said she meant the plants.

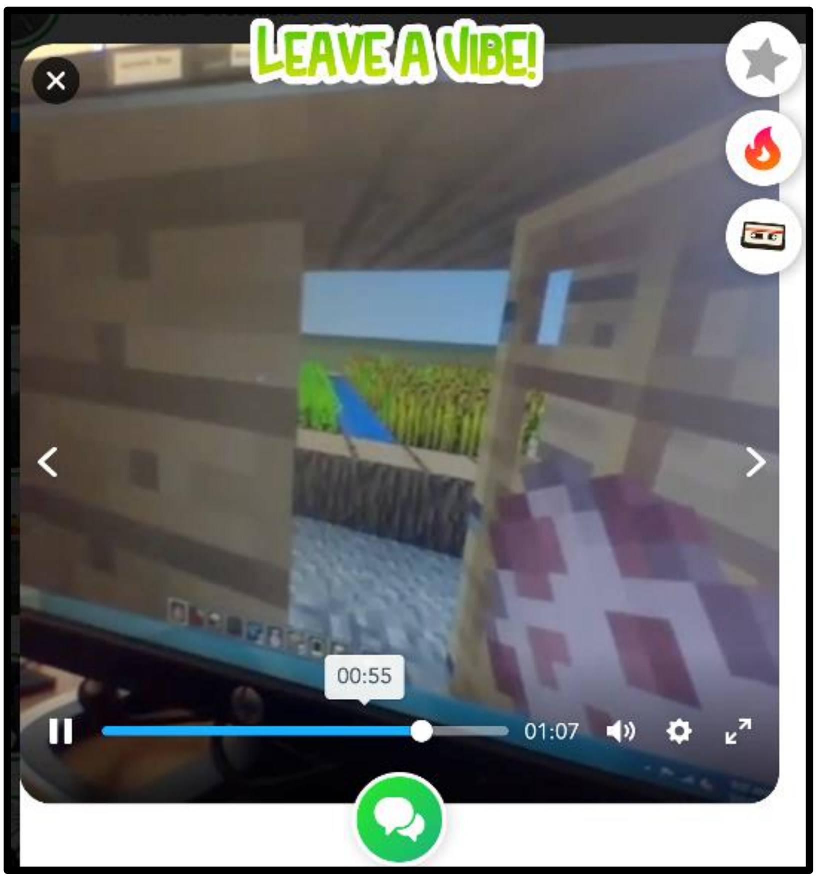

Figure 11. Sophia and Paige’s Week 1 Flipgrid showing the Minecraft garden when exiting the Minecraft house.

For the last two weeks of the study, Sophia and Paige continued to collaborate on their Minecraft village. On the Week 5 Flipgrid, they showed the viewer the new features in their design, which included a swimming pool with a beacon in the middle of it. Sophia stated, “We are thinking about adding some lava and some portals. It's all in a village in Flat World - Jeff has changed. He is now King Jeff with a crown and he is now red.” In the final Week 6 Flipgrid, Paige said, “We also made a unicorn that wears a top hat - surrounded the pool with lava to make it safe. We put a beacon in the middle of the pool.” The girls explained that they asked their peers for feedback about how to design a beacon in Minecraft, and that one of the boys helped them. I reviewed video footage to confirm their assertion and was able to identify the specific boy who assisted them. Throughout their final Flipgrid, they stated that they could not finish their project as they ran out of time; however, they did state their desire to make the walls higher.

Case study #3 analysis. In this next section, I discuss how the girls’ use of the design features may have shaped their final project outcomes. Similar to the first case study, I also explore evidence of how the girls explained their design process, specifically noting their need to confer with peers regarding improvements they made or wanted to make to their original project design.

AbD Thinking Routines. During Week 2, the girls completed the *Looking Closely* and *Exploring Complexity* AbDTR independently, specifically analyzing tech devices including an iPad, a Kindle, and their project on Minecraft (Appendices W & X). During Week 4, due to time constraints involving school assemblies and field trips, rather than completing the *Fostering Opportunity* routine, the teacher facilitators assigned students to give peer feedback on Flipgrid to randomly assigned classmates. Sophia commented on two of her classmates’ posts, one of whom worked with Legos and the other with cardboard, specifically giving them advice about how to improve the quality of their videos not their projects. On the other hand, Paige was assigned to two students who worked near her on Minecraft, and she gave them specific feedback about how to improve their builds by "decreasing the amount of water" or streamlining the number of objects in the build as the "shapes were confusing." The students who provided feedback to Sophia and Paige via the Flipgrid did not have permission to participate in the study; therefore, those data are excluded.

The girls may have applied the AbDTR to their final project as evidenced in the girls' Week 5 and 6 Flipgrids. For example, they may have demonstrated *Looking Closely* behaviors when they described the different items they had created and their functions, such as the purpose of the lava feature around the pool to provide safety. They did not elaborate on how the hot lava would be considered safe. As explained earlier in the chapter, Paige stated that she used the *Exploring Complexity* routine to look at an object from different perspectives. Upon review of her worksheet (Figure 12), I noted that she had actually chosen to analyze Jeff, the character she created in Minecraft. She identified Minecraft as the object she was analyzing and drew a picture of Jeff's face with his name on the title page. When answering the question, "In what ways could it (the object) be made to be more beautiful?" Paige made a list to add more houses to her village. Although she did not explicitly state or write that she used the *Exploring Complexity* routine to change Jeff's appearance from blue to red, she self-selected to use her project as part of the AbD Thinking Routine exercises. As stated earlier, during the second rotation of the study, the teachers and I encouraged students to select an object of their choice or their projects to analyze when completing the AbDTR.

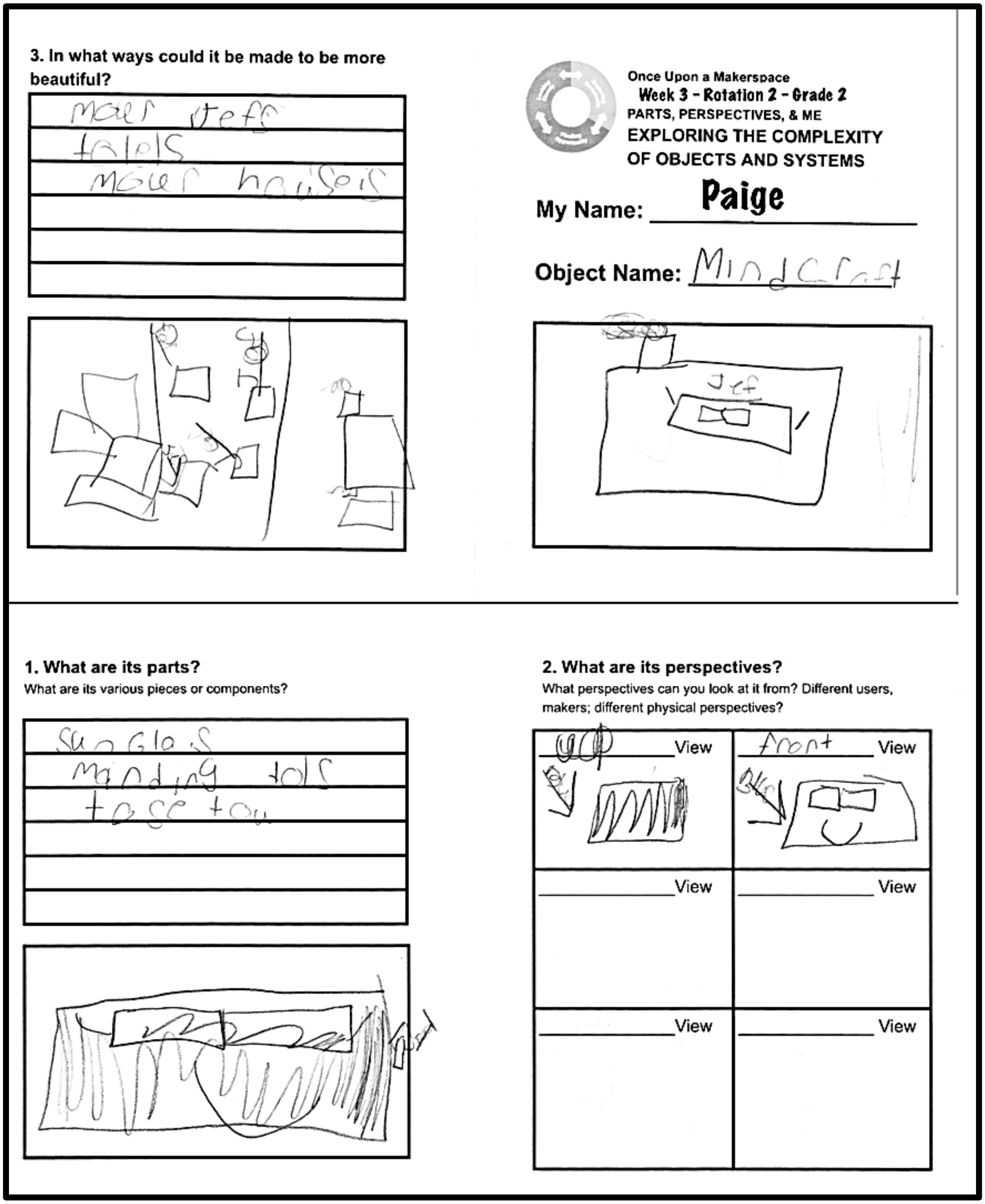

Figure 12. Paige's worksheet documenting her analysis of Minecraft for the *Exploring Complexity* AbD Thinking Routine.

Although the teachers did not explicitly teach the *Fostering Opportunity* routine during the second rotation of the study, the girls may have demonstrated *Fostering Opportunity* behaviors when explaining the changes made to Jeff as their comments specifically related to the aesthetics of Jeff's appearance changing from blue to red. As stated in the previous case studies, the participants' language was rather general and one cannot surmise that the girls internalized and transferred the AbDTR. Furthermore, in consideration of the fact that the teachers had not explicitly taught the *Fostering Opportunity* routine to the participants in this rotation, the potential lack of validity and reliability when considering the possibility of the AbD Routines impacting the outcomes of the projects needs to be explored. I will expand up on this idea further in the "Limitations" section of Chapter 5.

Making students' thinking visible. Both Sophia and Paige enjoyed being the center of attention on their posted Flipgrid videos as evidenced by maintaining eye contact with the viewer, smiling at the viewer, and prosody/inflection when speaking on the videos. As stated earlier, throughout the different Flipgrid posts, both Sophia and Paige described changes to their design process, summarized each session, and explained possible ideas for future iteration. For example, during the Week 5 Flipgrid post they talked about how they added new features like the beacon, and how they planned to include more portals. In the Week 6 Flipgrid post, the girls used the Flipgrid to explicitly request their peers give them feedback about "how to dye beacons" (change the color), demonstrating their awareness that they could potentially use Flipgrid as part of a feedback loop with their peers.

Teacher scaffolds. During the student focus-panel interviews, Sophia and Paige reported that Mrs. Smith provided feedback and support to the girls while they worked on their Minecraft project. I reviewed footage from both Weeks 5 and 6, and noted that Mrs. Smith stayed near the girls for about 12 minutes as they worked on the Minecraft project. I could not decipher everything that was said; however, Mrs. Smith did nod in affirmation as the girls demonstrated the addition of new features to their design

Peer proximity. As in the other cases, I noted peer proximity as an ontological innovation inherent in the actual set up of the study and the class. As previously described, the teachers placed the computers and monitors for Minecraft on top of a bookcase, and students could stand in front of them to build on Minecraft. Throughout Weeks 5 and 6, I observed video footage of Paige working with Sophia to design the Minecraft village. Sophia had her hands on the keyboard and controller at all times. Paige pointed to her classmates' adjacent monitors, Sophia would look, and then they added similar elements to their own build including the beacon and portals. Paige leveraged the physical proximity of both her peers and their monitors to develop her own Minecraft project as she shared information with her partner, Sophia. The two girls also utilized virtual peer proximity inherent in the Flipgrid to seek information as evidenced by their request for feedback regarding how to change the color of the beacon.

Case study #3 summary. In the third case study, *Minecraft: It takes a village,* Sophia and Paige collaborated to design a village in Minecraft with various features including house, garden, and swimming pool. In contrast to the first two case studies, Paige and Sophia began working together during Week 1 on their Minecraft village, and they sustained interest in the project, as well as collaboratively working together, throughout the entire study. There is evidence from this case study that indicates that both girls were engaged throughout their project work, and that they relied on each other and their peers to complete their project through peer modeling and verbal peer feedback. Utilizing the Flipgrid platform, the girls were able to make their thinking visible by identifying the parts and purposes of their Minecraft village, summarizing their weekly builds, describing how they asked peers for advice during the makerspace sessions, and using their Flipgrid post to seek advice from peers. In addition, this case also provides evidence of the teacher providing affirmation of the girls' choices for revisions to their project work, as well as possible impact to Paige's participation design process when she utilized the AbDTR.

Case study #4: Beyblades: Seeking balance and power with Legos. In this last case study, I report details about how Oliver, a third-grade student, created motorized Beyblades from Legos. Beyblades are spinning top toys, which feature removable parts so that the user can customize the design. Children have been playing with Beyblades since the late 1990s; the popularity of the toy grew as the syndicated television series by the same name became popular with children. Children can play games with one another, sometimes using the Beyblades to strike another Beyblade or just to spin the Beyblades. Oliver created his own Beyblades model from Lego bricks, a Lego motor, a Lego battery pack, and different gears and axles. As previously described in the analysis of the student focus-panel interview data, Oliver stated that he had had an interest in creating the Beyblades Lego models earlier in the school year, prior to the study beginning.

After analyzing the interview data, the research team and I identified the potential impact of peer proximity and peer feedback on the development of several projects. Despite working independently on his project, Oliver talked to himself aloud about his project, sought peer feedback on Flipgrid, and discussed his project with the teacher facilitators. He was also able to move about the makerspace to check in with his peers and show them his progress. Therefore, I decided to include Oliver as an independent participant to further support the potential impact of the study's design features on the creation of individual student projects.

Oliver participated in the second rotation of the study, which ran for six consecutive weeks, and he also participated in the student focus-panel interviews. This case differs from the first two case studies because during the first week of the study, Oliver immediately set to work to create his motorized Beyblades. He continued with his project during Weeks 5 and 6. I present details about the iterative nature of Oliver's project as evidenced in the Flipgrids he posted during Weeks 1, 3, 5, and 6, as well as the potential impact of the design features and peer proximity on his final project outcome.

During Week 1, Oliver created two Beyblades from Legos. In his Flipgrid post for Week 1, he showed the viewer his Beyblades, explaining the purpose as, "They are tops that battle." He continued to explain how he used two motors and a battery box to make the Beyblades move, and he also showed the viewer how he could spin them himself. In this Flipgrid post, he sought feedback from the viewer of this Flipgrid asking if he should add anything else to his Beyblades. He described the features specific to each of the Beyblades he created, highlighting how the first spinner moved up and down on the axle which would allow him to "obliterate" the other spinner. He presented his second Beyblade, comparing it to the first, and showed the viewer how the two Beyblades differed in size and build (Figure 13).

Figure 13. Screenshot of Oliver's Week 1 Flipgrid post as he presented his original Beyblades models.

Oliver practiced the AbDTR during Weeks 2 and 3. He decided to analyze his Beyblades for both the Looking Closely and Exploring Complexity routines (Appendix Y). He wrote that the purpose of the Beyblades was to "battle each another," and he both listed and sketched several components of the Beyblades including axe, sword, axle, and tips. On the Exploring Complexity routine worksheet, he sketched the Beyblades from different perspectives and identified ways to improve his Beyblades. He wrote, "I made Beyblade number 2 better by making the sides even. I need to make the motor cords not tangle." Then he posted a Flipgrid detailing the changes he had made to his Beyblades from Week 1 to Week 3. He explained how he took apart each of the Beyblades and made the sides even on one of the Beyblades, and how he added a Lego piece as a weight and increased the size of the spinner base (Figure 14). "It works very well especially because I added this weight and much wider base. It spins and stays up for a little while. Not just two seconds until it falls down." Then he proceeded to ask the viewer for feedback, "One thing I would like to ask you is how do you think other Lego pieces could make these better, and how do you think could I make these motor cords not get tangled? Just say it. Talk to me."

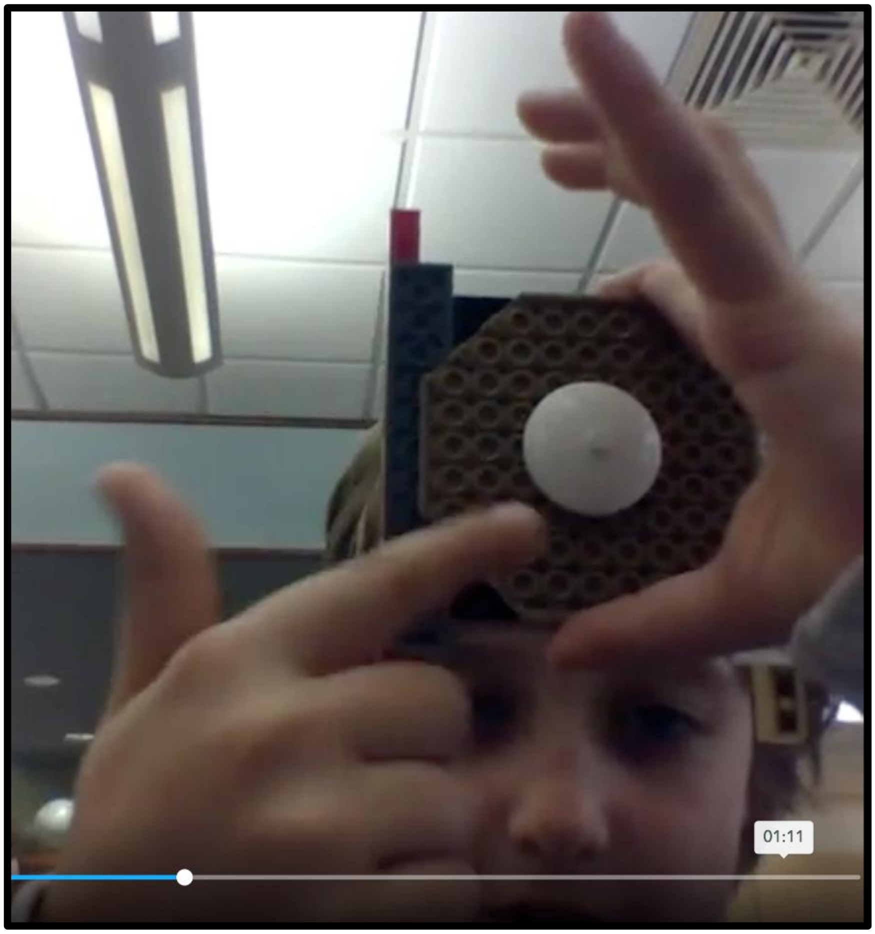

Figure 14. Screenshot of Oliver's Week 3 Flipgrid post as he showed the viewer the wider base and the added weight on one of his Beyblades.

Mrs. Smith randomly assigned two classmates to give Oliver feedback via Flipgrid during Week 4, and in his Week 5 Flipgrid post Oliver reflected on his classmates' feedback. He rejected his first classmate's advice about improving his video recording techniques specifically related to his camera angles. He explained that he did not find the feedback about his video recording techniques helpful, and that he did not have time to record a new post. While he considered his second classmate's suggestion about making the Beyblades smaller, he decided to maintain the Beyblades' current sizes. Oliver explained that if he did make the Beyblades smaller, people would not be able to see the Beyblades easily, making it less entertaining to play with them or view them.

In the second part of his Week 5 Flipgrid post, Oliver explained that the teacher facilitators gave him more parts to improve his Beyblades. I reviewed the video footage from Week 5 and observed Oliver self-talking about how he needed another battery pack, predicting that it was going to be difficult to make both Beyblades move with just one battery pack. Oliver was holding both the Beyblades and could not turn on the battery pack. Mrs. Davis was nearby and asked him if he wanted her to turn on the battery pack. He nodded yes, and they tested the power of one battery pack's capacity to move both Beyblades. The Beyblades spun into one another, and the wires connecting the Beyblades to the battery packs became tangled. Oliver asked Mrs. Davis to turn off the battery pack and said he needed another battery pack. Mrs. Davis offered to bring one to him and gathered the materials. Oliver connected the individual battery packs to the Lego motor attached to each Beyblade. He and Mrs. Davis tested the Beyblades again; however, this time each of them held one of the battery packs and both Beyblades spun independently of one another. As Oliver and Mrs. Davis moved closer together, the Beyblades collided with one another. Mrs. Davis asked Oliver if that was supposed to happen and he explained that the purpose of the Beyblades game was to battle one another, and that when one of the Beyblades broke, the person whose Beyblade broke the other person's Beyblade won.

They turned off the battery packs and Oliver observed that one Beyblade continued to spin. Mrs. Davis commented that she thought it was interesting that one of the Beyblades continued to spin even though the battery had been turned off. Oliver explained to her that the spinning piece was round and could continue to move for a little bit even when the power source was off. The conversation abruptly ended as Mrs. Smith made a whole class announcement to begin cleaning up.

For the last session of the study, Oliver created a new project in addition to his Beyblades project. He had found a Spiderman Lego car and said he wanted to make it move. He attached two battery packs to the two motors connected to the rear axle of the car, and he was able to make the car move. He noted that both battery packs had to be turned on at the same time or the wheel that started moving first would cause the car to turn and not move in a straight line. He manually synchronized the "on" function and the car was propelled right off the table (Figures 15 & 16).

After this experience, Oliver told the videographer that he wanted to test the car to see if it would move across the rug. The batteries fell off the car as it moved due to the friction of the carpet. He said he would think about some solutions. In his Week 6 Flipgrid post, he told the viewer that he had conferred with Mrs. Smith about the problem, and he thought they should create some type of pulley system to have the batteries move with the car.

Figure 15. Oliver demonstrating how the battery packs connected to the Lego motors and the motors to the car.

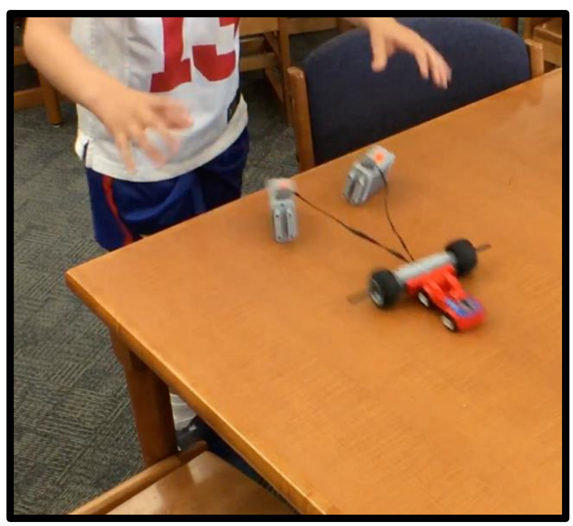

Figure 16. Oliver releasing the Spiderman car as it moved across the table.

Oliver put the Spiderman car away, and then demonstrated how his final Beyblades model worked, explaining that he wanted to make the battery packs stand up so that they didn't get in the way of the spinning Beyblades (Figure 17). When he tried to stand the battery packs on the table and turned them on, they fell over. He held the Lego motors in the air, suspending the Beyblades and batteries in the air as well. (Figure18). As the Beyblades continued to spin, the propeller blades fell off. Oliver noted that he thought they were was too long and said, "I have to do something about that." Since this was the last session and almost the end of the school year, he did not revisit these projects.

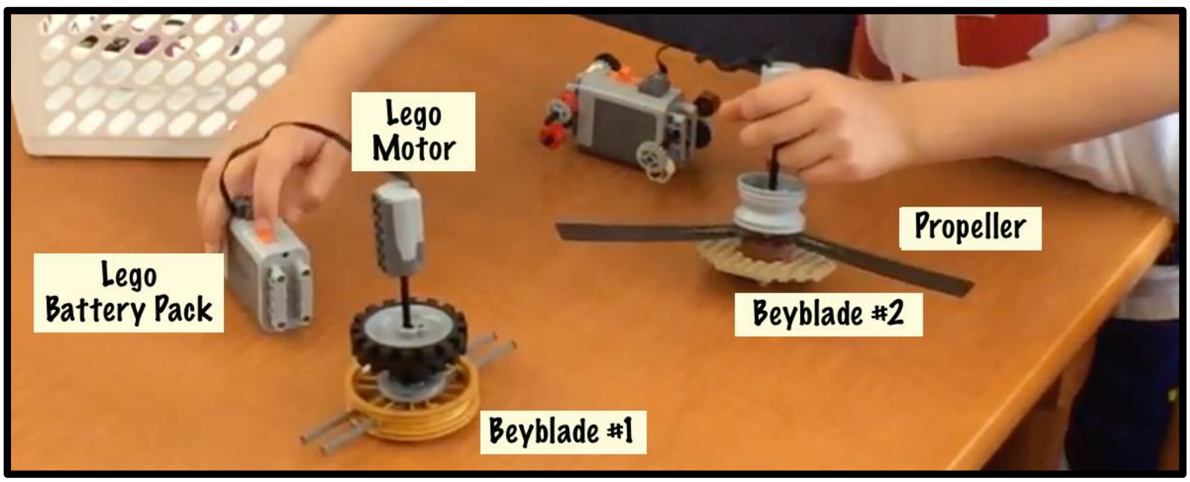

Figure 17. Oliver's demonstration of how the Beyblades move with Lego battery packs and Lego motors.

Figure 18. Oliver holding the Lego motors.

Case study #4 analysis. In this next section, I analyze how Oliver's use of the different design features may have shaped his final project outcomes. Throughout the study, Oliver consistently sought feedback on the Flipgrid platform and he made multiple iterations to his design to improve function and form.

AbD Thinking Routines. Oliver chose to utilize his project when he practiced the *Looking Closely* and *Exploring Complexity* routines. He successfully identified ways to improve his Beyblades explaining on his *Exploring Complexity* worksheet (Appendix Y) that he made the sides even on Beyblade #2 and he stated his desire to find a solution for the tangled motor cords. Oliver clearly organized his thoughts and ideas about his project within the structure of the AbDTR as evidenced by his worksheets and multiple iterations to his project. However, it is not clear if his use of the routines actually changed his project. He previously stated he had been thinking about designing the Beyblades for several months, so perhaps his project outcomes were due to his prior thinking rather than the AbDTR.

Making students' thinking visible. Oliver leveraged the Flipgrid platform to thoughtfully speak about his project and explain the iterative nature of his design process. He also sought peer feedback and encouraged people to respond to his video posts. He used Flipgrid to explain his thoughts about his peers' feedback, and provided clear rationale as to why he rejected their feedback. Throughout the study, Oliver self-talked and noticed when he needed to find solutions to different problems such as when the propeller blades fell off one of the Beyblades. He demonstrated metacognitive awareness when he anticipated and stated that it would be difficult to turn on both of the battery packs at the same time during Week 5.

Teacher scaffolds. During the student focus-panel interview, Oliver did not recall receiving any teacher feedback about his project. However, after careful review of the video footage and his Flipgrids, I observed him interacting with the teacher facilitators and his project, such as when Mrs. Davis assisted him with turning on the battery packs or when she brought him more Lego battery packs and motors. He also stated on his Week 6 Flipgrid that he had conferred with Mrs. Smith about how to attach the battery packs to the Spiderman car, possibly with a pulley.

Peer proximity. As explained earlier in this chapter, peer proximity emerged as an ontological innovation of the study. Although Oliver worked independently, he did utilize the Flipgrid platform to interact with his peers by requesting advice and also giving feedback. In the makerspace environment, I observed him visiting his friends throughout the study to show them his project. Sometimes students would walk by to look at what Oliver had made, and at one point, a classmate grabbed one of the Beyblades, accidentally breaking it. Oliver quickly gathered the pieces and re-assembled his Beyblade. Although Oliver did not regularly seek out peer feedback in the actual makerspace setting, he did seek out advice from peers via the Flipgrid posts, a form of digital peer proximity as discussed earlier in the chapter.

Case study #4 summary. In the fourth case study, *Beyblades: Seeking balance and power with Legos,* Oliver created a motorized model of Beyblades with Legos and Lego accessories. In contrast to the first two case studies, Oliver knew from Week 1 that he intended to make models of Beyblades with Legos and Lego accessories, sustaining interest in his project throughout the entire study. There is evidence from this case study that indicates that Oliver persevered to problem solve challenges with his build, conferred with the teachers, and interacted with his peers. Utilizing the Flipgrid platform, Oliver was able to make his thinking visible by identifying the parts and purposes of his Beyblades, summarizing his weekly iterations, and seeking advice from peers. In addition, this case also provides evidence of the teachers actively questioning Oliver about his project and Oliver asking his teachers for feedback about his project. Oliver also used the AbDTR to analyze his Beyblades and there is evidence that as he practiced the AbDTR, he transferred the routines to his project work.

Application of coding protocol to case studies. In order to further validate the results of the study, I conducted an exhaustive analysis of the four case studies utilizing the coding protocol (Table 8) that emerged from the student focus-panel interview data. Similar to the analysis process of the student focus-panel interview idea units, I created a codebook (Appendix Z) to organize my observations. This time I analyzed observable student behaviors and interactions recorded during the students' makerspace sessions and Flipgrids from Weeks 1, 5, 6, or 7. I arranged my observations of the recordings into different notations and recorded them in a codebook organized by week, participant, recording source, and the actual notation. Notations included direct quotes from participants and/or my recorded observations. As a reminder to the reader, I have placed the coding protocol on the next page (Table 12)

Table 12

Coding Protocol Applied to the Case Studies

Code	Definition
Peer Feedback	
Peer Model (PM)	Any observation of the impact of a peer physically or verbally modeling how to use a particular tool but not verbally giving feedback to the participant about his or her project.
Peer Verbal Feedback (PVF)	Any observation of the impact verbal peer feedback while working in real-time in the makerspace on the development of a project (not on the Flipgrid).
Peer Flipgrid Feedback (PFF)	Any observation of how a peer provided feedback on the Flipgrid regarding the project to the participant.
Teacher Feedback	
Teacher – Project Affirmative (TP+)	Any observation of interactions with a teacher during which she provided students with advice or guidance about a specific aspect of making the projects.
Teacher – Project Negative (TP-)	Any observation of the lack of feedback or interactions with a teacher when asked if the teacher provided feedback to the participant.
Making Students' Thinking Visible	
Flipgrid Self-Monitoring (FSM)	Any observation of how the use of the Flipgrid helped the participant track his or her progress.
Application of AbD Thinking Routines (AoAbDTR)	Any observation of the participants articulating how they used the AbD Thinking Routine to help them develop their projects or how a teacher observed students using the AbDTR during the development of their projects.

Table 12 (continued)

Learning	
Learning – Skill (LS)	Any observation of how students reported they learned to use a makerspace tool or a skill they developed
Learning – Self as Learner (LSaL)	Any observation of how students viewed themselves as learners, aware of what they were doing or how they processed information to work on their projects.
Engagement	
Engagement – Tools (ET)	Any student reference to preferences of tool usage.
Engagement -Perseverance (EP)	Any observation of how a participant behaved when frustrated in the makerspace.

Coding process. As explained in Chapter 3, in order to apply the protocol from the student focus-panel interview to the case study data, I reviewed the definition section of each original code. Because the first coding protocol was derived from student interview transcripts, whereas this one involved my observations of students, I changed "reference to" to "observation of," but the remainder of each definition remained the same. Although Oliver, Sophia, and Paige were also student interviewees, in this section I analyzed only observable data from the case study participants' videos and Flipgrid posts, not the student focus-panel interviews.

In order to maintain fidelity to the original coding protocol, the research team and I were very strict with our selection of notations to code, only categorizing behaviors or observations of case study participants that pertained to the original student focus-panel interview data coding protocol. In some instances the definitions of the cluster attributes did not match the data observed from various case study videos and Flipgrid posts. For example, students definitely learned new skills throughout their time in the makerspace; however, the definition for *Learning – Skills (LS)* is, "Observations of how *students reported* they learned to use a makerspace tool or a skill they developed." In the case studies, students did not necessarily report learning a new skill or tool, yet it was obvious to the research team that in fact students did learn to use new tools as demonstrated by Sarah learning how to cut cardboard or Paige and Sophia learning how to incorporate different features in Minecraft. When possible we attributed those examples to other attributes such as *Peer Model* when Sarah observed students working with cardboard. Another example of attribute definition and evidence mismatch included the *Application of Agency by Design Thinking Routines (AoAbDTR)*, which is defined as, "Any observation of the participants articulating how they used the AbD Thinking Routine to help them develop their projects or how a teacher observed students using the AbDTR during the development of their projects." In the case studies, students did not articulate how they may have used the AbDTR; however, it does not mean they did not use the routines. As previously described in case studies #3 and #4, the participants did apply the AbDTR as they developed their final projects as evidenced by their AbDTR worksheets.

In the next section I detail the frequency of each cluster and corresponding attributes. Then I disaggregate the coded case study data along with vignettes from the different video recordings to provide specific examples in response to the research questions (Table 13).

Analysis. In total the research team and I analyzed 49 notations from the video footage and Flipgrid posts featuring participants from the different case studies. The frequency of coding *Peer Feedback* included 20 references from the case studies, with the most commonly coded attribute being *Verbal Peer Feedback* (VPF) with 12 instances, then *Peer Model (PM)* coded five times, and finally *Peer Flipgrid Feedback (PFF)* coded three times. The frequency of *Teacher Feedback* coding included two notations, with both of the notations considered *Teacher-Project Affirmative* from Oliver's case study. The frequency of *Making Students' Thinking Visible* included 12 notations, and they were equally distributed amongst the case studies (3 per case study) as *Flipgrid Self-Monitoring*. The research team determined the evidence analyzed did not meet the code's definition for *Application of the AbD Thinking Routines*. The coding frequency of *Learning* included six notations, with all of the notations considered *Learning – Self as Learner*, and zero coded notations labeled as *Learning-Skills*. Oliver's case study had the most references to the *Learning-Self as Learner* (4). Finally, the frequency of coding *Engagement* included nine notations with *Engagement-Tools* coded five times and *Engagement-Perseverance* coded four times.

Table 13

Frequency of Coded Case Study Notations

Codes	**Frequency**				
	N	**CS1**	**CS2**	**CS3**	**CS4**
Peer Feedback	**20**	**6**	**7**	**3**	**4**
Peer Model (PM)	5	2	2	1	0
Verbal Peer Feedback (VPF)	12	4	5	2	1
Peer Flipgrid Feedback (PFF)	3	0	0	0	3
Teacher Feedback	**2**	**0**	**0**	**0**	**2**
Teacher – Project Affirmative (TP+)	2	0	0	0	2
Teacher – Project Negative (TP-)	0	0	0	0	0
Making Students' Thinking Visible	**12**	**3**	**3**	**3**	**3**
Flipgrid Self-Monitoring (FSM)	12	3	3	3	3
Application of AbD Thinking Routines (AoAbDTR)	0	0	0	0	0
Learning	**6**	**1**	**0**	**1**	**4**
Learning – Skill (LS)	0	0	0	0	0
Learning – Self as Learner (LSaL)	6	1	0	1	4
Engagement	**9**	**3**	**0**	**0**	**6**
Engagement – Tools (ET)	5	3	0	0	2
Engagement - Perseverance (EP)	4	0	0	0	4
Total Notations	**49**	**13**	**10**	**7**	**19**

In the next section, I list each research question (RQ) and use the coded case study notations along with evidence from each case study to discuss how the design features of the makerspace might be used to describe the trajectory of participants' makerspace projects, their engagement, evidence of their learning, and how they made their thinking visible. My ultimate goal is to demonstrate how the design features of the study and the participants' use of these features influenced students' projects and experiences in the elementary makerspace setting.

RQ2: Which design features scaffold the learning trajectory of a student's makerspace project from conception to completion? I originally proposed that the three design features might help to scaffold the learning trajectory of their makerspace projects from conception to completion. In this section I examine coded data from the video footage and Flipgrid posts, and supporting evidence from the case studies to show how the AbD Thinking Routines, making students' thinking visible, and teacher scaffolds supported the students in designing and implementing their projects.

AbD Thinking Routines (AbDTR). While the research team and I did not code any notations as demonstrating the application of the AbDTR, there is strong evidence from the case studies in which Oliver and Paige utilized the AbDTR to describe and enhance their projects. As already presented, Paige decided to examine her Minecraft village during the *Exploring Complexity* routine activity (Appendix X). Paige did not explicitly state that the routine helped her to develop her project; however, there is evidence on her worksheet documenting her thinking about different project elements including adding more houses to her village and sketching Jeff, a character from her Minecraft village. Although she did not attribute the *Exploring Complexity* routine to the addition of houses or Jeff's change in appearance from blue to red, she self-selected to use her project as part of the AbDTR exercises which may have led to some of the features in her final project. Oliver also referenced his project when he practiced the *Looking Closely* and *Exploring Complexity* routines. He successfully identified ways to improve his Beyblades by making the sides even on Beyblade #2 and he stated his desire to find a solution for the tangled motor cords. As previously stated it is not clear if his use of the routines actually impacted his project. During the student focus-panel interview he stated that he had been thinking about designing the Beyblades for several months, so perhaps his project outcomes were due to his prior thinking not the AbDTR.

Data gathered from the first two case studies featuring Anna, Sarah, Connor, and Jordan was not sufficient for the research team to determine if the students' use of the AbDTR impacted their final projects. While Anna and Sarah explicitly described form, function, and aesthetics of their bridge, it did not necessarily mean they incorporated, applied, or internalized the AbDTR as the girls' language was general and they did not explicitly attribute the process of describing their projects to the AbDTR. Jordan and Connor described their Minecraft build on Flipgrid, making sure to showcase the different physical perspectives and identify the different parts and purposes of their build. As was the situation in the first case study, there is no concrete evidence that the boys knowingly applied the AbDTR or that they expressed awareness of internalizing and transferring the routines to their project work.

It is possible for educators to use the AbDTR to scaffold conversations around design thinking. The routines are derived from Harvard's Project Zero and have been utilized make thinking visible and to develop a *Maker Mindset*, which empowers students to tinker, invent, and create. Recommendations for improvement to the use of the routines in the elementary makerspace setting will be described in more detail in Chapter 5; however, initial suggestions for designers of makerspaces include teachers directing students to practice the routines by analyzing their own projects rather than random objects. In the first rotation the students picked a new object each week and practiced the AbDTR skills; however, we did not observe formal application of the AbDTR to their projects. The teacher facilitators and I encouraged students in the second rotation to practice the routines for the purpose of refining or developing their projects. To further improve the likelihood of students internalizing the AbDTR, teachers should frequently model the AbDTR language during class and they should hold students accountable to speak in the language of the AbDTR. Although this may feel forced initially, modeling domain-specific vocabulary – the language around how one speaks when working in a particular subject area – is common practice in many elementary school settings. In the case of the AbDTR, teachers and students would practice saying and writing phrases or terms specific to each routine in the context of designing, creating, iterating, and refining their projects

Making students' thinking visible. Students featured in the case studies made their thinking visible through sketches, Flipgrid posts, and conversations with peers and adults. Paige sketched out her Minecraft ideas to demonstrate she wanted to add more houses to her Minecraft village while Oliver drew and outlined his ideas to improve his Beyblades. Case study participants used the Flipgrid platform each week to summarize what they had done or learned in a particular session, describe their projects, or ask for feedback. Sarah and Anna made their thinking visible when they talked about the process of designing their bridge, specifically citing features they found challenging or how they improved the functionality of the bridge. For example, Anna described how she and Sarah planned to put tubes on each corner to lift the bridge and one in the middle for extra support. Sarah described how they planned to create walls "so the cars just don't fall into the ocean." Connor and Jordan said the doorway they created was designed for security so that nobody (in the virtual realm) could break into their Minecraft house.

Paige and Sophia explained their desire to create beacons in their Minecraft village and how they sought peer assistance in order to design the beacons in Minecraft. Oliver continuously used Flipgrid to summarize his work, explain refinements to his Beyblades, and to ask for advice regarding challenges he experienced.

In order to make thinking visible, schools can leverage tools like Flipgrid to cultivate a community of learning with students enrolled in their schools, as well as the wider global community. Furthermore, while speaking on his Flipgrid, I observed Connor listening to Jordan record his response nearby, and Connor started add to his response based on what Jordan was saying. Data collected during this research study can be referenced as evidence for the potential future use of Flipgrid as a vehicle for students to monitor their work, explain their thinking process, model domain and content specific language, and provide feedback to peers.

Teacher scaffolds. In addition to conversing with students utilizing the teacher discussion stems, teachers also interacted with students to give directives, teach the AbDTR, or collaborate to solve project challenges. From the coded case study data, there are three instances when Mrs. Smith and Mrs. Davis interacted with Oliver. At different times they helped Oliver to actively problem-solve challenges such as the Lego motor cords tangling with the Beyblades and the battery packs not propelling the Spiderman car forward. They also provided advice regarding tool usage such as when Mrs. Smith told Oliver it was not a good idea to let the cords tangle or in Week 1 when she showed Anna how to cut cardboard, "You cut it like that and go back and forth." The teachers interacted with the students in the case studies to remind them to put away materials or to begin recording their Flipgrid posts. I did not observe the teachers using the discussion stems with the case study students.

Similar to the student interview data set, the case study data was inconclusive in demonstrating the impact of teacher scaffolds on student project outcomes. Teachers interacted with the students in the case studies; however, the majority of the interactions had to do with giving directives or explicitly teaching the AbDTR. Although Oliver collaborated with the teachers, the other students did not engage with the teachers in ways that produced significant outcomes for their project work. As designers of elementary makerspaces consider teacher facilitator involvement, they would need to develop clear expectations and guidelines to support teacher practices related to effective questioning and classroom management through ongoing coaching, professional development, and in class support.

RQ3: When describing their projects, how do students articulate the design process? Do they recognize or cite the design features as influencing their project outcomes? In order to answer this question, I reference coded notations and vignettes from the case studies to show how students design process was attributed to peer feedback, peer proximity, and perseverance. Although the case study participants did not explicitly cite the design features as influencing their project outcomes, I include details about how I connected the design features to project outcomes with supporting evidence from the case study vignettes and coded notations.

Peer feedback. In the case studies, peers provided feedback to give specific advice regarding how to use a tool, model a particular skill or technique, communicate approval of a classmate's project, or follow teacher directives to post feedback on Flipgrid. Participants acted as a *Peer Model (PM)* when they overtly demonstrated how to do something with a makerspace tool such as when Ryan said to Jordan, "Just do it like this," as he modeled how to cut the board for the Makey Makey game screen they created in Week 1; or when Connor asked Declan to help him logon to Flappy Bird. In other instances, participants quietly studied peer models as they worked with the different tools. The peer models were unaware that other students were observing them as they worked with different tools. For example, Sarah observed a group of three boys working on their cardboard objects. She noticed how they cut the cardboard and then used the same tools as the boys to cut the cardboard in subsequent weeks. Another example included how Paige observed two classmates working on the computer monitors next to her in Minecraft and then how she shared those observations with her partner to include some of the same features in their final project.

Throughout the case studies, there was evidence of *Verbal Peer Feedback (VPF)* such as when Paige suggested to Sophia that they include the features she just saw her peers implement in Minecraft and when Sarah suggested to Anna that they could use a box to help build the bridge. While Connor and Jordan worked together on the same monitor to build in Minecraft, Jordan told Connor he could make a piston and "I have a plan!" At one point, Paige and Sophia explained that they asked their peers for feedback about how to design a beacon in Minecraft and that one of the boys helped them. The final projects from the first three case studies were visibly impacted by the verbal peer feedback received.

Prior to the teachers explicitly instructing students to provide *Peer Flipgrid Feedback* to their randomly assigned peers during Week 4 of the second rotation, Oliver sought peer Flipgrid feedback starting in Week 1. As he worked independently on his project, Oliver made an effort to request advice about his Beyblades such as when he stated, “Do you think I need to add anything else? Tell me. ” During his Week 3 Flipgrid post he said, “One thing I would like to ask you is how do you think other Lego pieces could make these better and how do you think could I make these motor cords not get tangled? Just say it. Talk to me.” Even though he never received the desired peer Flipgrid feedback regarding possible solutions to some of his challenges, such as the motor cords tangling, he still requested peer Flipgrid feedback in subsequent weeks. Paige and Sophia also sought peer Flipgrid feedback about their Minecraft village during the last week of the study, recognizing that Flipgrid could be used to facilitate a feedback loop. They explicitly requested their peers give them feedback about "how to dye beacons" (change the color).

When Oliver received teacher assigned peer Flipgrid feedback from two classmates, he refused to implement their suggestions. He initially appeared irritated about the advice he received from one peer on the Week 5 Flipgrid as evidenced by his tone and non-verbal cues. He explained that he could not go back and redo his video as the first peer had suggested. He thoughtfully explained why he rejected the second peer's advice to make his Beyblades smaller, claiming they would not be as entertaining for the person playing with the Beyblades. Paige and Sophia did receive peer Flipgrid feedback; however the peers who gave peer Flipgrid feedback did not have permission to be in the study so the data was not used.

Oliver was responsive to verbal peer feedback as evidenced in this coded excerpt:

> James stops in to see what Oliver is doing. Oliver shows him the Beyblades and James tells Oliver, "Cool!" Then Oliver asks James to hold a Beyblade to test them out. They laugh and James shows his approval by smiling and engaging with Oliver and the Beyblades.

Oliver used the verbal peer feedback he received from James as a form of affirmation for his work. This is an interesting area for future exploration to determine how peer approval could sustain or impede the trajectory of project work.

From this second data group, I confirmed the findings stemming from the student focus-panel interview data set from which the research team and I identified peer feedback as a possible impact to form and support the trajectory of a makerspace project. Designers of elementary makerspaces must consider both virtual and physical feedback loops to help sustain the trajectory of student work. In the case studies, students utilized peer feedback to design their projects, learn new skills, or affirm their project work. When working independently, students should be given opportunities to have peers provide feedback. Oliver sought peer Flipgrid feedback beginning in Week 1 and never received advice regarding a solution to his challenges in designing his project. Although teachers explicitly showed students how to provide feedback on Flipgrid, one of his peers commented on the quality of his video post and not his project. Teachers working in makerspaces should increase modeling and practice experiences for students to provide peer Flipgrid feedback, as well training and practice time to record comprehensive videos that are easy for the viewer to understand and watch. Ideally students would then comment on the actual projects rather than video recording techniques, ultimately creating more meaningful and valuable feedback loops.

Peer proximity. Peer proximity was an ontological innovation that emerged from this study. As previously discussed, when analyzing the student focus-panel interview data, the research team and I realized that peer proximity, both virtual and physical, could also have impacted the trajectory of students' projects. In addition to being close enough to a peer to observe him or her in action, just being near someone also led to students working together on their final projects. For example, Connor and Logan happened to end up working together in Week 6 simply because Connor was near Logan working on Minecraft. As Logan became disinterested in working with his partner on Minecraft, he roamed around the Minecraft monitors and Connor called Logan over to show him something on his monitor. From that point on, Logan and Connor collaborated to design a Minecraft artifact. Similarly, in Week 6 when Anna no longer wanted to work with Skylar on the Chromebook, she looked around the room and saw Sarah working independently with cardboard nearby. She walked over to Sarah and then the two girls worked together with cardboard, eventually designing their bridge. Paige's ability to walk away from her partner to observe others building in Minecraft gave her opportunities to learn new skills and apply these skills to her final project.

Oliver's case does not appear to be impacted by peer proximity. He worked independently throughout all of the sessions. Although one peer stopped by to touch the Beyblades and another helped Oliver test the Beyblades, his peers did not give him specific advice or suggestions about his project. Oliver was the only one in his class who worked with Legos so he did not have a peer model resource or someone who shared his interest in working with Legos during the research study.

When designing makerspaces, schools should consider classroom management styles and school philosophy with regards to students' independence in selecting partners with whom to work or in moving about the learning environment. Students with partners in the case studies demonstrated that having close physical proximity to peers and the autonomy to move about the room led to successful project outcomes through the design process to create, iterate, and refine their work. Establishing digital proximity through virtual spaces like Flipgrid could further facilitate meaningful and productive feedback loops for students working independently, in partnerships, or in groups. In addition, digital proximity could be expanded to include students or experts around the globe allowing students working independently to seek out peer models or experts to help them with their project work. Digital proximity would need to be strategically implemented in compliance with schools' acceptable use (of technology) policies and codes of student conduct.

Perseverance. As previously defined, perseverance was considered, "Any observation of how a participant behaved when frustrated in the makerspace." Although case study participants faced some challenges in the makerspace setting such as Jordan dealing with an uncooperative partner, Sophia and Paige learning new skills on Minecraft, or Sarah and Anna refining the functionality of their drawbridge, none of them appeared frustrated. They worked on their projects for two or more consecutive weeks and they followed directives from the teachers to continue working on their projects. They appeared happy and engaged. They also refined their work through multiple iterations; however they did not appear frustrated; rather, they appeared proud of their projects and described how they made their projects.

Oliver exemplified the idea of perseverance as evidenced by his explanations on Flipgrid detailing his work, multiple iterations, and efforts to refine his Beyblades. Despite being frustrated by the tangled motor cords, he continued to persevere in his determination to create Beyblades from Legos. Oliver reported that by adding more pieces to his Beyblades, “I made them a lot better."

Throughout the study Oliver sought advice about how to prevent the Lego motor cords from tangling. During video footage from Week 6, Oliver presented a possible solution to prevent the motor cords from tangling. He explained that he wanted to make the Lego battery packs (to which the motor cords were connected) stand up so that they didn’t get in the way of the spinning Beyblades. He made stands for the battery packs but they could not withstand the force of the moving Beyblades; eventually the battery packs toppled over on the table and then the motor cords became tangled. Even though this was the last session, Oliver said he would continue to think about some solutions to this problem.

During this same session, Oliver also demonstrated how his Beyblades with large propeller blades could spin. As the Beyblades continued to spin, the propeller blades fell off. Oliver noted that he thought they were too long and said, “I have to do something about that.”

Despite some difficulty in determining how to utilize the Lego battery packs to maneuver his Spiderman car, Oliver eventually realized that if he manually synchronized turning the Lego battery packs on at the same time his Spiderman car would move forward. Upon testing his hypothesis, the car did in fact propel itself right off the table.

Oliver consistently articulated when he needed to improve an artifact or solve a problem in the face of a challenge. In order to determine the source of Oliver's perseverance, many other areas would need to be considered including personality, confidence, ability to socialize, and self-esteem. Oliver's ability to persevere may have been innate and not necessarily a result of the makerspace setting. However, since the teachers encouraged students in the second session to refine their projects over the entire six weeks, perhaps this scaffold facilitated increased engagement and motivation for Oliver, allowing him to persevere. Oliver was also the only case study in which one person worked independently. Perhaps his perseverance was a result of having to be self-reliant; however, conversely, maybe his self-reliance was in fact the source of his perseverance and thus why he was able to sustain a project independently during the six-week rotation. Regardless of the source of Oliver's perseverance, a practical suggestion for designers of makerspaces would be to encourage teachers and schools to allow students multiple opportunities to work on a project, spanning several class sessions.

Design features. Students in the case studies leveraged the Flipgrid platform to self-monitor their progress, often detailing how they refined or enhanced their projects. I reference the case study vignettes and case study notations coded as *Flipgrid - Self-Monitoring (FSM)* to demonstrate how students' self-monitoring helped them to articulate the process of design. For example, in their Week 5 Flipgrid post, Sophia described what she and Paige planned for the week ahead, "We are thinking about adding some lava and some portals. It's all in a village in

Flat World - Jeff has changed. He is now King Jeff with a crown and he is now red." In their Week 6 Flipgrid, Paige and Sophia described their experiences, detailing how they included more features in Minecraft and sought peer advice about their beacon.

Connor and Jordan each created a Flipgrid in Week 6 and summarized what they had built; describing the levers, pistons, doors, and other features they created in their Minecraft world. They did not provide the rationale for their decisions except for the door being safe so intruders could not enter the house. As Oliver talked about the progression of his Beyblades in the Week 6 Flipgrid, he recognized that he needed to find solutions to different problems, such as when the propeller blades fell off one of the Beyblades, and provided rationale for some of his decisions. Sarah and Anna also provided rationale for their design process as they described future enhancements to their drawbridge. For example, on their Week 6 Flipgrid post, they planned to strategically place the Makedo screws to allow the drawbridge to open. Anna also said they would make a model of a boat and then demonstrated how the bridge would open as the boat passed through. She described how they would put tubes on each corner to lift the bridge and one in the middle for extra support. Sarah described how they would put up walls "so the cars just don't fall into the ocean."

In their Week 7 Flipgrid, Sarah and Anna engaged in conversation to analyze the process of designing their bridge citing how they layered additional cardboard to make the bridge stable.

Sarah: It took us a long time, a very long time. You see all of this tape.
It kept just breaking.

Anna: Yeah, it hasn't always been secure. So every time it broke, we had to put on more cardboard. We had to put a couple more layers on top of it.

Sarah: First we thought of coloring the tape brown but it didn't really work. See look over here. We put this bar over here to kind of make it a little ramp.

They also discussed what they would do differently, including adding more tape to make the bridge stable and in, reference to the bubble wrap under their bridge, Anna suggested, “Maybe if we had colored the bubble wrap blue then it would look like the ocean.”

Although the case study participants did not cite the design features as influencing their project outcomes it was evident that the Flipgrid design feature was helpful in developing their projects, summarizing their progress, and making their thinking visible. When designing makerspaces, educators should consider adopting and explicating a design thinking process so that students could better understand and articulate the process of how they created, iterated, or refined their work. The Flipgrid platform could serve as a management tool for teachers to assess how students are progressing in describing their work and understanding the design thinking process.

RQ4: What elements of project planning and implementation do students find motivating or engaging? When reviewing the case study data to determine which elements of project planning and implementation students found motivating or engaging, the research team and I coded preferences of tools and evidence of learning. In this section I examine how tools and learning outcomes, both skill based and metacognitive, encouraged students’ motivation and engagement.

Tools. While working the makerspace, students had access to a variety of tools including Chromebooks, Minecraft, cardboard, Makey Makey kits, and assorted Lego bricks, motors, battery packs, gears, and axles. Students had agency to select any tool they wished to use and they could change their decisions about which tools they wanted to use for their final projects. Oliver worked with Legos starting in Week 1 and had previously stated that he had been thinking about designing his Beyblades project throughout the school year. His engagement may have been due to a previous interest possibly helping him to sustain his project work. Sophia and Paige partnered together in Week 1 to begin their Minecraft project and video footage showed them working together during Weeks 1, 5, and 6 on the same Minecraft village. The girls had never worked in Minecraft prior to the study and frequently observed peers or asked for advice to help improve their skills. Perhaps their interest in learning something new or perhaps their ability to confer with other peers about Minecraft fueled their engagement.

Conversely, students from the first two case studies did not begin their project work in Week 1, nor did they remain with the same partners. Anna and Jordan left their original partners to work with Sarah and Connor. Both Connor and Jordan had an interest in building with technology from Week 1 as demonstrated by Connor's interest in Flappy Bird and Jordan's work with a Makey Makey kit. Sarah and Anna also chose to work with building materials such as Makey Makey and cardboard for Anna, and Legos for Sarah. Perhaps this common interest in tools related to building ultimately led to their final partnerships and projects. Connor and Jordan built a digital world in Minecraft while Sarah and Anna built a physical model of a drawbridge.

Coded data from the case studies included examples of students self-selecting materials for practical or functionality purposes such as when Anna knew that she needed both cardboard and a computer to work on her Makey Makey game controller in Week 1 and then announced her decision to gather those materials. In Oliver's Week 1 Flipgrid he described the features specific to each of the Beyblades he created, highlighting how the first spinner moved up and down on the axle which would allow him to "obliterate" the other spinner.

In other instances, I observed participants in the case studies showing emotional responses to their work. For example, Sarah's cardboard was stored on the makerspace stage, along with several other students' cardboard creations. As she looked for her cardboard during Week 6, she appeared worried when she couldn't find it but then looked relieved when she saw it. Perhaps one could interpret her expression of worry as demonstrating some engagement or connection to her cardboard work in progress. In his Week 1 Flipgrid, Oliver expressed his enthusiasm for Beyblades when introducing them to the viewer, "These are Beyblades...they are tops that battle, Tops that battle are fun, right?"

In order to engage students in the makerspace setting, designers of makerspaces should ensure students have a variety of tools and the agency to self-select the tools as well as their partners. Prior to implementing an elementary makerspace, school administrators and faculty should clearly articulate their vision and expectations for the makerspace so that classroom management and pedagogical practices scaffold the vision and expectations. In addition, teachers should be vigilant in leveraging emotional responses to students' project work and tools offered to sustain an environment of engagement.

Learning. Students in the case studies were not explicitly asked what they had learned during their makerspace sessions. However, I did code data about how students viewed themselves as learners. The code *Learning – Self as Learner (LSaL)* was defined as, "Any observation of how students viewed themselves as learners, aware of what they were doing or how they processed information to work on their projects." Students in the case studies expressed their learning in response to practical needs when working with tools. For example, as Anna prepared to cut cardboard for her Makey Makey game controller in Week 1, she asked a peer with whom she was working, "Can I draw a line so I know where to cut it?" Anna anticipated that she would need to scaffold her cutting skills with the line so she could successfully create her Makey Makey game controller.

Sometimes, students in the case studies talked about their learning in terms of future planning. For example, after working in Minecraft in Week 5, Sophia stated on her Flipgrid, “We are thinking about adding some lava and some portals. It's all in a village in Flat World - Jeff has changed. He is now King Jeff with a crown and he is now red.” Sophia recognized that she wanted to make changes to her Minecraft world, and later she articulated her desire for help. Both video footage and Flipgrids provided evidence of Sophia and Paige being self-aware that they needed to seek assistance in order to learn how to add the portal and beacons by asking for advice or learning a new skill from peers.

Oliver often talked to himself in response to self-determined modifications to his projects or his need to acquire additional supplies to complete his project. While working on his Beyblades project, Oliver self-talked about how he needed another battery pack, predicting that it was going to be difficult to make both Beyblades move with just one battery pack, "I'm going to need another pack." When showing the viewer of his Week 1 Flipgrid how his Beyblades worked, Oliver demonstrated self-awareness about how he made the Beyblades move stating, "I used these two motors and the battery box to make them spin. I can hold them myself or I can at least try to. They can come in and smash into each other.” He continued to search for solutions to his tangled motor cords, and in his Week 6 Flipgrid he stated, “… You know what else I have in mind? The bases so the battery boxes could be held up and not get tangled in the motors.” Oliver was self-aware when talking about his Beyblades project to the videographer in Week 6. He was trying to make the Spiderman Lego car move in a straight line. He noted when adding Lego battery packs to his Spiderman Lego car that both battery packs had to be turned on at the same time or the wheel that started moving first would cause car to turn and not move in a straight line. He manually synchronized the “on” function and the car was propelled right off the table.

Learning opportunities are available throughout the makerspace setting to engage students as they develop skills and awareness of themselves as learners. As students plan for their projects and iterations, teachers working in the makerspace-learning environment can monitor student progress through tools like Flipgrid or anecdotal records from class. Understanding that students will learn for practical purposes, such as needing a new skill to complete a project or planning modifications to a project, can help teachers to proactively consider the types of tools available for the students to use, how to provide access to those tools, and ways to support students' abilities to articulate their plans about using the tools. To further develop metacognitive awareness, teachers can model or demonstrate self-awareness of their own thinking as they use tools in the makerspace-learning environment or they can identify peer models as they self-talk or summarize their activities each week on Flipgrid.

Summary

The case studies detailed provide some evidence of the design features' impact on students' project work, articulation of their learning, and engagement. In this last section I discuss my findings regarding the design features and provide suggestions for elementary makerspace designers with regards to Flipgrid, AbDTR, tools, learning outcomes, and engagement.

Design features. Making students' thinking visible through Flipgrid ultimately led to participants engaging in metacognitive awareness, project planning, and independently seeking feedback. Although the teacher scaffolds did not appear to have a significant impact on the students' project trajectories, learning, or engagement, the teachers did create and facilitate an environment of student agency and student-driven learning which allowed for the students' projects to emerge over time. After conducting a more in-depth analysis of the case studies, I noted that students did exhibit some AbDTR behaviors; however, the research team and I could not conclusively prove causality between the AbDTR and students' project work. In the future, teachers could leverage the AbDTR to help students develop their projects through continued modeling, instructing students to select their projects as the objects to analyze when practicing the routines, and creating opportunities for the students to use the language of the AbDTR when posting videos on Flipgrid.

Tools. When talking about their favorite tools to use in the makerspace, students reported a variety of choices including the ability to play with friends, to play games, to be creative, to have autonomy, and to experience the "fun factor" as reasons for tool preferences. At times, students selected tools for practical purposes such as modeling work or refining their projects, and they also demonstrated emotional investment in their tools and projects. Designers of makerspaces should provide opportunities for students to utilize a variety of tools and respect the emotional connections students may develop when working with a particular tool or project.

Learning outcomes. Students demonstrated how they learned new skills or developed new interests throughout the study. Having opportunities to self-talk about their work on Flipgrid or access peer models scaffolded their learning and sustained engagement and motivation for their project work. As students demonstrated awareness of themselves as learners and planned to find solutions to different challenges they encountered or ways to utilize the tools to successfully impact their project design, they remained engaged in their project work and evolved in their skillsets. Educators working in makerspaces need to be mindful of helping students learn to be more self-aware of their thinking and planning so that they can successfully continue to engage with their project work, or even know when it might be time to abandon a project if engagement and motivation are waning.

Engagement. Throughout the study I observed video recordings in which most students exhibited joy and cooperation when working with peers, thus helping to sustain their interest in different projects. Others were able to sustain engagement and motivation in the makerspace by having the autonomy to leave a partnership to find a new partner, or to work independently. Participants also provided feedback to one another through affirmation of project choices or design, which encouraged students to continue with their work. Students engaged with one another simply because of their proximity to a peer to observe a peer model, or engage in verbal feedback loops. As educators decide how to structure their makerspace-learning environment, they must consider how to facilitate peer relationships in the classroom so that the students remain engaged and motivated. Certainly giving students autonomy in choosing with whom they would like to work is a starting point.

In this chapter I have provided practical suggestions for schools and elementary makerspace designers based on the research study's results. In the next chapter, I ground the findings in theoretical frameworks and topics from the literature review to more fully document and articulate the potential impact of this body of research.

CHAPTER 5: DISCUSSION AND REFLECTION

This chapter is divided into three sections to summarize the study's findings and propose theoretical implications, describe limitations of the study, and discuss opportunities for further investigation. In the first section I summarize the study's findings framed within the original research questions to fully articulate the theoretical implications of the research findings for researchers, educators, and designers of learning environments. In the second section, I outline limitations of the study including sample size, demographics, timelines, project tools, and design features. Then, in the third section, I suggest topics worthy of further exploration to sustain feedback, develop projects, and personalize learning for elementary students.

Research Findings & Implications

To date, there has been very little empirically based research to demonstrate effectual tools to support the implementation of an elementary school makerspace, specifically focusing on fostering informal learning outcomes such as student agency. Therefore, I had proposed that the physical design features, instructional strategies, and learning scaffolds in the elementary makerspace setting would foster an environment that cultivated opportunities for students to pursue areas of personal interest to give them ownership over their learning as they worked in the elementary makerspace setting. Educators can reference the study's outcomes as they design the physical space and develop curricula for the makerspace-learning environment.

As I will discuss in this chapter, the theoretical contributions of this study include advancing our understanding of how making thinking visible and peer feedback support students' design thinking in the elementary makerspace-learning environment. I have identified Flipgrid and peer proximity as two such elements that have not yet been emphasized in the literature and have explicated in more detail how the availability of makerspace tools and peer feedback support the design process of elementary students' makerspace projects. In addition, I have built upon the research regarding how to maintain situational interest and foster engagement.

Practical implications. As already discussed in Chapter 4, there are many practical suggestions which educators can leverage to both design the physical makerspace-learning environment and create curricula for teachers to implement in the makerspace-learning environment. As a reminder to the reader, I have summarized the findings by each original research question and provided practical suggestions for educators to examine types of projects created, the impact of the design features, the design process, and how students were engaged throughout their time in the makerspace (Table 14).

Projects. With the first research question I sought to understand what types of projects students created in the elementary makerspace setting. Students in this study chose to complete projects with hands-on tools such as cardboard and Legos more frequently than digital tools including Minecraft and Chromebooks. As educators garner resources for their makerspace-learning environments, they can embrace both physical and digital tools, while also recognizing that the appeal of physical materials, including cardboard and Legos, may be more economically feasible for schools to acquire. Based on the Maker Project Rubric, digital projects were scored as more readily connected to a larger community. Educators can support digital community connections while also working within a school district's acceptable use of technology policies and tech infrastructure available in their school community.

Design features. In response to the second research question, I sought to understand how the design features of the study impacted students' project outcomes. Students made their thinking visible on Flipgrid as they summarized and monitored their project work, served as peer models, and provided feedback to peers. Educators design instruction that supports students' access to

Flipgrid and explicitly teach students how to give feedback to peers and evaluate feedback received. Students also reported that they enjoyed the sketching components of the AbDTR; specifically citing that drawing an object from multiple perspectives or angles was a way to plan or refine their work. By frequently modeling the language of the AbDTR, educators can help students to elaborate their ideas and look at their projects from multiple perspectives as they move through the design process.

Design process. With the third research question I sought to understand how students articulated their design process and if they cited the design features of the study as impacting their work. Students reported that they utilized peer feedback to design their projects, learn new skills, or affirm their project work. Peer feedback through verbal peer feedback, peer modeling, and virtually on tools like Flipgrid has the potential to help students conceptualize their project ideas and make decisions while engaged in their work. Educators can support peer feedback by designing the physical makerspace to allow for frequent movement, as well as offering different tool options and activities to promote student collaboration. Participants in this research project demonstrated the ability to critique the feedback received from their peers, and the facilitators provided a learning environment in which the participants had autonomy when deciding whether or not to include the advice or suggestions of their peers. In order to enhance reciprocity in feedback loops, educators can teach students how to provide and critically evaluate peer feedback. When students had the opportunity to work near a peer, virtually or in real time, they effectively engaged in the design thinking process to create, refine, and iterate their projects. Educators can establish virtual spaces, such as Flipgrid, where students can have a digital proximity to help facilitate peer feedback to impact the trajectory of a makerspace project; and a physical environment that support social interactions, frequent movement, and agency.

Student engagement. With the final research question, I sought to understand what types of experiences students found engaging. Students who participated in the student focus-panel interviews reported Chromebooks as their preferred tool because of the variety of choices available when utilizing the Chromebooks and the ability to play with friends and play games. Educators can leverage the availability of Chromebooks as a means to provide a variety of engaging learning opportunities in the elementary makerspace setting. Students demonstrated agency as they worked within the makerspace to select tools, project ideas, and partners. Educators may consider integrating opportunities for students to have agency when designing their projects and selecting tools, experiences to work with their peers, access to many choices, and the “fun factor” inherent in children’s process of learning and innate sense of curiosity. Outcomes related to self-regulation and self-confidence also emerged. As mindfulness and social-emotional learning initiatives are in demand for many school districts, educators can explore how makerspaces can enhance the potential for social-emotional learning through cooperative activities and self-awareness.

Table 14

Summary of Research Findings and Practical Implications for Educators

RQ1.What types of makerspace projects do students create?		
Focus	**Research Findings**	**Practical Implications for Educators**
Making	Students in this study chose to complete projects with hands-on tools such as cardboard and Legos more frequently than digital tools including Minecraft and Chromebooks.	Embrace both physical and digital resources, while also recognizing that the appeal of physical materials including cardboard and Legos for children may be more economically feasible for schools to garner.
Virtual Community	Based on the Maker Project Rubric, digital projects were scored as more readily connected to a larger community.	Support digital community connections while also working within a school district's acceptable use of technology policies and tech infrastructure available in their school community.
RQ2.**Which design features scaffold the learning trajectory of students' makerspace projects from conception to completion?**		
Focus	**Research Findings**	**Practical Implications**
Flipgrid	Students summarized and monitored their project work, served as peer models, and provided feedback to peers on Flipgrid.	Provide student access to Flipgrid and explicitly teach students how to give feedback to peers and evaluate feedback received.
AbDTR	Students indicated that they enjoyed the sketching components of the AbDTR; specifically citing that drawing an object from multiple perspectives or angles was a way to plan or refine their work.	Use the AbDTR to help students to sketch out their ideas or look at their projects from multiple perspectives as they move through the design process. Teachers need to frequently model the AbDTR language.

Table 14 (cont.)

RQ3. When describing their projects, how do students articulate the design process? Do they recognize or cite the design features as influencing their project outcomes?		
Focus	**Research Findings**	**Practical Implications**
Peer Feedback	Students utilized peer feedback to design their projects, learn new skills, or affirm their project work.	Design the physical makerspace to allow for frequent movement, as well as different tool options and activities to promote student collaboration.
	Peer feedback through verbal peer feedback, peer modeling, and virtually on tools like Flipgrid has the potential to help students conceptualize their project ideas and make decisions while engaged in their work.	Help teachers to develop a mindset that promotes peer feedback through the design of instruction to encourage partnerships, as well as scaffolding ongoing formative assessments to drive instruction and support for students' work.
	Participants in this research project expressed the ability to critique the feedback received from their peers, and the facilitators provided a learning environment in which the participants had autonomy when deciding whether or not to include the advice or suggestions of their peers.	Teach students how to provide and critically evaluate peer feedback.
Peer Proximity	When students had the opportunity to work near a peer, virtually or in real time, they effectively engaged in the design thinking process to create, refine, and iterate their projects.	Establish virtual spaces, such as Flipgrid, where students can have a digital proximity to help facilitate peer feedback to impact the trajectory of a makerspace project. Develop routines and a learning environment for students that support social interactions, frequent movement, and agency.

Table 14 (cont.)

RQ3. When describing their projects, how do students articulate the design process? Do they recognize or cite the design features as influencing their project outcomes?		
Focus	**Research Findings**	**Practical Implications**
Perseverance	Students' abilities to persevere with a project, even when faced with difficulty, were impacted by the teachers allowing the students to problem solve on their own.	Provide ongoing access to materials by keeping them securely stored from session to session, and allowing for open-ended outcomes that value the process as well as the product created. Let children work independently and scaffold learning for students as needed through explicit feedback, re-direction, direct instruction, or access to the tools and activities provided. Encourage teachers and schools to allow students multiple opportunities to work on a project, spanning several class sessions.
Design Features	Students articulated, recognized, or cited Flipgrid and AbDTR as influencing their project outcomes.	Consider Flipgrid and AbDTR as ways to help scaffold and support student project work.
	Students' prior thinking about their projects appeared to scaffold their design process.	Value and acknowledge students' interests to engage and motivate them in the makerspace.

Table 14 (cont.)

RQ4. What elements of project planning and implementation do students find motivating or engaging?		
Focus	**Research Findings**	**Practical Implications**
Chromebooks	Overall students reported Chromebooks as their preferred tool because of the variety of choices available when utilizing the Chromebooks and the ability to play with friends and play games.	Leverage the availability of Chromebooks as a means to provide a variety of engaging learning opportunities in the elementary makerspace setting.
Agency	Students demonstrated agency as they worked within the makerspace to select tools, project ideas, and partners.	Consider integrating opportunities for students to have agency when designing their projects and selecting tools, experiences to work with their peers, access to many choices, and the "fun factor" inherent in children's process of learning and innate sense of curiosity.
Social-Emotional	Outcomes related to self-regulation and self-confidence also emerged.	Explore how makerspaces can enhance the potential for social-emotional learning through cooperative activities and self-awareness.

Theoretical implications. In this next section I begin by discussing how the research findings are broadly consistent with the current literature with regards to makerspace projects, the impact of the study's design features, students' articulation of their design process, and student engagement. Then I describe powerful findings about makerspace tools, making the thinking and creative process visible, and the impact of peer proximity that are not currently discussed in the literature.

Student projects. The first research question was referenced to determine what types of projects students created in the elementary makerspace setting. Fifty-nine percent (23) of the student groups created projects with hands-on tools such as cardboard and Legos, and 41% (16) of the student groups chose to produce digital artifacts with tech tools such as Minecraft and Chromebooks. This research study was framed within the theoretical frameworks of Constructionism and Constructivism. While working in the elementary makerspace, students created projects (artifacts) based on their interests (Constructionism), and they actively engaged in areas of personal interest and sustained inquiry as they developed their projects over multiple iterations (Constructivism).

When designing their projects, students exhibited Maker Literacy (Chu et al., 2017) as they applied maker *skills*, created *mental models*, and engaged in *practices* in order to represent different concepts. Having been immersed in the makerspace for two years when the study began, students already had background knowledge about how to use different tools, and, in some cases, leveraged their prior skillsets with coding, Minecraft, Legos, cardboard, Makey Makey, and other items to make their projects. Students without prior knowledge of how to use their makerspace tools were able to create mental models or sketches of what they wanted to build, and sought advice from peers to enhance their projects.

Gourlet and Decortis (2017) described *designerly learning* as the ways in which students use tools in the makerspace, identifying *instrumental genesis*, the process by which makerspace tools are transformed by the maker into a vehicle to design solutions based on personal schema (experience) or connections, as part of makerspace-learning environments. The research team and I observed instrumental genesis as students made their artifacts with various tools, and then collaborated with their peers to enhance or refine their projects, such as those who had little experience with Minecraft or when Oliver explored ways to resolve the issue of his cords tangling.

Agency is a critical component of both designerly learning (Gourlet and Decortis, 2017) and the Maker Mindset (Dougherty, 2016). In this study, students demonstrated agency as they self-selected their partners, designed their projects focus, and chose their tools. When asked to explain why they liked a particular tool, they said that they enjoyed working with their friends, the opportunity to direct their own learning, or the variety of experiences possible with a particular tool.

Some of the makerspace tools and ultimately the projects could readily be shared with a wide community, as was the case for the Minecraft and Chromebook projects. Students leveraged the Minecraft application to design and create artifacts in real time with their peers, while also remaining connected to the larger digital platform of Minecraft: Education Edition. As students developed their Minecraft projects, they demonstrated sensitivity to design (Clapp et al., 2016) when they created features or refined aesthetics in their Minecraft builds (e.g. beacons, portals, color changes, etc.). Although students designed projects on Minecraft, they could only present their projects to their peers due to the school's acceptable technology use policy. Had the students been able to communicate with a wider community than just their peers, they may have been able to demonstrate collective cognitive responsibility (Zhang et al., 2002) to iterate or enhance their artifacts.

Regardless of materials available in makerspaces, Sheridan et al. (2014) proposed that all makers were involved in meaningful and iterative work, often valuing the process involved in making different artifacts. Clearly, as students in this study made their projects and selected their tools based on personal interests, they fully immersed themselves in the process of making their projects. The video recordings and the Flipgrids collected in this study serve as documentation of the students' engagement and interest while working on their projects, further supporting the work by Sheridan et al (2014).

Design features. In response to the second research question, I sought to understand how the three design features (Agency by Design Thinking Routines, making thinking visible, and teacher scaffolds) impacted the students' projects. In this next section, I connect each of the design features to existing research as either a support or an extension of current findings.

Agency by Design Thinking Routines. While the research team and I could not prove that the Agency by Design Thinking Routines (AbDTR) impacted students' project work, there is some evidence that the students used and liked components of the AbDTR such as sketching their projects or looking at their projects from multiple perspectives. Research by Kangas, Seitamaa-Hakkarainen, and Hakkarainen (2011) indicated that students could externalize their plan for a project through sketches and drawings. Perhaps if our students had shared their AbDTR sketches or drawings with peers or others in the school, we may have found them to be more applicable to the project design process.

Making thinking visible. Flipgrid emerged as the most referenced and the most impactful design feature. Students described how they used Flipgrid to document their work, plan for future steps, and provide/receive feedback about student projects. I will discuss the students' use of Flipgrid later in this chapter as one of the major findings of the study.

Teacher scaffolds. Data gathered about the impact of teacher scaffolds was inconclusive.

Although we did not find evidence of the teacher scaffolds impacting the students' projects, the research team and I observed teachers conversing with students while utilizing the teacher discussion stems, interacting with students to give directives, teaching the AbDTR, or collaborating with students to solve project challenges. In order to maintain situational interest in their project work, Vongullusksn et al. (2018) reported that teachers should provide students with scaffolding and support.

Students' articulation of their design process. With the third research question I sought to understand how students articulated their project design process and if they attributed the design features of this study to their design process. In this next section I discuss student-provided responses as to how peer feedback, peer proximity, perseverance, and the design features of the study impacted their project design process.

Peer feedback. Students cited peer feedback as shaping their design process. Both verbal peer feedback and peer modeling had immediate impacts on students being inspired to start a project, refine their projects, learn how to use a tool to complete their projects, or to have their design choices affirmed. Clapp et al. (2016) reported that in the makerspace setting students could co-critique projects in order to refine the project or solve problems.

Bers, Strawhacker, and Vizner (2017) referenced the importance of "feedback in practice" as students worked in the makerspace setting. Throughout this study students participated in feedback loops simply by speaking with one another or communicating on Flipgrid. Although some students reported that they readily welcomed and applied peer feedback received on Flipgrid, others said they rejected the peer Flipgrid feedback as they did not find it helpful or applicable to their projects. When using Flipgrid, students exhibited behaviors aligned to the Tinkering for Learning Dimension Framework (Bevan et al., 2015) including actively seeking out feedback or inspiration from materials or environment, demonstrating innovating approaches in response to feedback from peers or teacher, and/or disagreeing with each other's strategies, solutions, or rationales.

Peer proximity. While peer feedback was a factor in students' design process, peer proximity was identified as an ontological innovation of the study. Simply being near a peer allowed students to engage in verbal peer feedback or peer modeling. I will explore this topic in more detail later in the chapter.

Perseverance. There was some evidence in the study of students persevering to problem solve when designing their projects such as when Oliver tried to distribute the weight of his Beyblades so they would spin or when he continuously tried to resolve the issue with the Lego motor cords tangling. Oliver had expressed prior personal interest in designing his project, which Vongkulluksn, Matewos, Sinatra, and Marsh (2018) contended impacted students' abilities to maintain situational interest in their makerspace work. Students featured in the case studies demonstrated their ability to persevere when solving problems related to their project designs (e.g. stabilizing the bridge or addressing the tangled Lego motor cords). Their behaviors were also consistent with Bevan et al. (2015) who reported that when participants persisted toward their goals in the face of setbacks or frustration, and persisted to optimize strategies or solutions as two behaviors demonstrating perseverance in the TLDF.

Design features. As I have already described the outcomes related to the design features, I will summarize the student reported impact of the design features on their project work. Students stated that the AbDTR behaviors such as sketching elements and looking at objects from multiple perspectives helped them to develop and refine their projects. Students said Flipgrid impacted their project outcomes as it provided a documentation tool for them to summarize their work, plan for future makerspace sessions, and seek feedback. At times students reported that teachers engaged with them to collaborate on design challenges, to explain how to use a tool, or to provide directives regarding activities available in the makerspace.

Student engagement. With the fourth question, I sought to answer which elements of the makerspace students found engaging. As previously discussed, students expressed enjoyment and preferences when working with different tools, and they also described how they enjoyed learning new skills or working with friends. Students in this study were able to act with agency, which further enhanced their engagement (Reeve & Tseng, 2011). Providing opportunities for students to design projects based on their personal interests and experiences engaged them throughout their time in the makerspace as well (Dougherty, 2016; Järvelä & Renninger, 2014).

Ontological innovations. While most of the findings from this study are aligned to the current research surrounding elementary makerspaces, I am proposing three ontological innovations, which emerged from the study as being important for educators to consider when developing curricula for the elementary makerspace-learning environment. First, I present students' preference for cardboard when designing their projects. Then I explore Flipgrid as way to document students' creative thinking process. Finally, I conclude by explaining the impact of peer proximity on students' design thinking and project outcomes.

Cardboard. As the reader will recall, there were many different tools and activities available to students in the study's makerspace setting including Makey Makey kits, Chromebooks, Minecraft, cardboard, Legos and accessories, a greenhouse, carpentry tools, Makedo screws, and more. Forty-eight percent of the projects completed were made from cardboard. When discussing tools used in makerspaces, many researchers examined how different technologies (Bers et al., 2018; Chu et al., 2015; Chu et al., 2017) were being used in the makerspace setting. Martinez and Stager (2013) acknowledged the availability of high-tech materials in makerspaces, but also the increased interest in "low-tech" materials like cardboard and recycled materials as being appealing to makers and referred to cardboard as "the hot new material" (p. 87).

The You Tube sensation "Caine's Arcade," an11-minute documentary by Nirvan Mullick (https://www.youtube.com/watch?v=faIFNkdq96U), revealed how a nine-year old boy created an arcade with leftover cardboard pieces from his father's auto parts store and inspired a wave of "Global Cardboard Challenges" where communities gather in schools or other public spaces to build with recycled cardboard. The Imagination Foundation designed the "Global Cardboard Challenge" events as a way to both inspire people to play and build, but also to drive conversation around the need for play in educational settings. The Imagination Foundation recommended using cardboard as an entry point for children to start making and playing; ultimately expecting that children will move onto more complex tools, integrating technology like circuits or Makey Makey kits into the cardboard play scenarios (Peppler, Halverson, & Kafai, 2016, p. 123). Certainly cardboard is an easily accessible resource for most communities and should be leveraged as a tool for makerspaces. "Simple materials can be perfect to let one's imagination take over – something that some of the most expensive toys fail to do," (Dougherty, 2016, p. 125).

The appeal of cardboard in this study may have been due to demographics of the students who have access to technology both at home and at school, and perhaps they found the novelty factor of working cardboard appealing. Perhaps the sensory implications of touching the cardboard or the motion students experienced when cutting cardboard were the reasons for the popularity of this tool. Regardless, researchers and designers of elementary makerspaces should consider the appeal and wide availability of cardboard to use as a tool for students to use in the makerspace setting.

Flipgrid. The use of Flipgrid to document students' thinking emerged as a critical component to the students design thinking process. Each week teachers prompted students to post evidence of what they had worked on that week. Students were taught that they could use Flipgrid to seek and provide feedback as well. Students reported using Flipgrid to summarize their weekly progress, plan for future iterations, and also seek feedback.

The use of documentation tools encourage students to extend and enrich their learning over time (Krechevsky et. al, 2013; Wurm, 2005), and certainly Flipgrid could be added to the plethora of documentation options for students. Flipgrid is grounded in the theoretical framework of Connectivism (Boitshwarelo, 2011) because it is a digital tool that provides a repository for ideas to be shared across multiple platforms and communities. The sociocultural implications of Flipgrid support the idea of a participatory culture of learning (Bevan et al., 2015; Jenkins et al., 2010) in which participants integrate technology to share ideas, conduct research, ask questions, or create solutions.

When designing his Beyblades, Oliver used Flipgrid to seek feedback, demonstrate solutions, and explain his thinking. Through his weekly Flipgrids, he preserved the design thinking process of his Beyblades project, creating a story of his makerspace project. In his book, ***Free to Make***, Dougherty (2016) defined creation as, "act(ing) on an idea, turn(ing) it into something real, and shar(ing) it" (p. 143). As Oliver and other students made their thinking visible, they also made their creative design process visible as they summarized their weekly progress, made plans for future iterations, or sought feedback.

When searching for research about Flipgrid as a tool for documenting the creative design process, I found many posts on social media about how Flipgrid can be used for formative assessment, discussion forums, digital portfolios, and social-emotional learning. I have found some research that explored how Flipgrid was used in higher education as a collaborative learning tool (Saçak & Kavun, 2020), and as a way to build student engagement (Craig, 2020). Although I contacted the Flipgrid organization for their white papers or possible research resources, they told me none were currently available. As Flipgrid has gained popularity with all age groups across different school settings, it is time to consider its potential as a vehicle to document students' creative design process.

Peer Proximity. While peer feedback impacted students' projects, simply being near another student impacted project outcomes. Studies focusing on the design of makerspaces such as The Studio Framework (Halverson & Sheridan, 2014) included recommendations that makers work with a variety of materials and in different groupings. In this study, participants working in the makerspace setting had access to varied materials and groupings. They were able to move around the space freely and act with agency when working on their projects. As they walked by a peer, observed a peer, or spontaneously engaged with a peer, they conceived project ideas such as when Hailey observed a peer working on Makey Makey, or they learned new skills such as when Sarah observed boys cutting cardboard.

While findings from this study involving peer feedback are consistent with the literature (Demirbilek, 2015; Vongkulluksn et al., 2018), I have not found anything in the literature about peer proximity in the elementary makerspace setting. Further research about the impact of students' proximity to one another while working in the elementary makerspace setting could be helpful when educating teachers or determining school philosophy with regards to the importance of students' freedom to move about the learning environment.

Limitations

The sample size and demographics limit the outcomes of this study. The study only looked at four classes in a homogenous and affluent suburban school district. In addition, the participants came to school with extensive opportunities afforded to them from home and some prior knowledge of the makerspace tools. These factors may have impacted their choices for tools and their ability to sustain a project over a period of time. Although I would like to attribute the design elements as having an impact on students' final project outcomes, it may have in fact been due to students' familiarity with the tools and, of course, their personal experiences outside of the makerspace-learning environment.

Further limiting the results of this study is the timeline of the study. The reality of the school environment and the master schedule dictated the amount of time and the timeslots during which students worked on their projects. Perhaps if the participants had worked on projects for consecutive days rather than consecutive weeks, the outcomes would have differed. In addition, if the participants had been allowed to work on their projects in conjunction with general education classroom topics or even at home, they may have created more authentic and meaningful work.

While analyzing the impact of the Agency by Design Thinking Routines on students' project work, I expected that the use of the AbDTR would have significantly shaped the students' work. However, I could prove that students internalized and transferred the routines to their project work. The language the students used when describing their projects was very general and, as previously discussed, students may have benefitted from increased exposure to the language of the routines, as well as increased practice opportunities with the routines. When analyzing the student application of the AbDTR I noted that although Paige and Sophia had not been taught the *Fostering Opportunity* routine, they exhibited some of the behaviors such as imagining and implementing ways to improve their Minecraft village. This observation made me question the validity of my previous AbDTR analysis, and I started to think that perhaps none of the students actually transferred or internalized anything from the AbDTR. Further complicating my analysis was the release of new Agency by Design documents to support learning in the makerspace after the study had already launched. Their new framework is ensconced within the idea of Maker Empowerment – "A sensitivity to the designed dimension of objects and systems, along with the inclination and capacity to shape one's world through building, tinkering, re/designing, or hacking" (Retrieved on August 20, 2019 from http://www.agencybydesign.org/explore-the-framework) and they published several new tools for educators to use in their makerspaces. If I were to do this study again, I would want to explore the new materials to help design and scaffold student learning in the makerspace.

Opportunities for Further Investigation

In addition to the implementation of the new AbD Framework described above, there are other opportunities for further exploration of the design features. In this last section, I will propose ideas for further investigation including the use of Flipgrid to develop domain specific language, gendered tool domains, and how makerspaces can be places for personalized learning.

Flipgrid. The use of Flipgrid in classrooms can potentially afford educators increased access to formative assessments in order to drive instruction and understand each learner in their classes. This free tool provides engagement and multiple points of entry for all learners who have access to tech tools and Wi-Fi. As Connor and Jordan worked together to film their Flipgrids, Connor would listen to Jordan and then add similar vocabulary in his Flipgrid post. It would be interesting to explore the use of Flipgrids for students with special needs or English Language Learners (ELLs) to determine how this tool could help them to develop relationships with peers and domain or content specific language related to their makerspace project work.

Gendered tool domains. While studying over 30 makerspaces in Sweden, and as part of a large-scale national testbed, Erikkson, Heath, Ljungstrand, and Parnes (2018) examined the potential for makerspaces to serve as learning environments which can create equal opportunities for students to pursue personal interests and have access to materials across gender, including those items which encourage digital fabrication. "To maintain motivation and increase children's ability to construct mental models with previous knowledge and experience, it is important to involve children's own interests in educational activities" (Eriksson, Heath, Ljungstrand, & Parnes, 2018, p. 14). Research emerging on tools provided in makerspaces (Searle, Fields, and Kafai, 2016) documented gendered domains such as textiles and sewing being considered more feminine and technology and coding more masculine. In their study, "Is Sewing a Girl's Sport?" the researchers found that the students changed their preconceived notions of gendered domains and were able to experiment with the different tools provided including textiles, sewing, and coding, ultimately developing new interests and skills. Our makerspace recently acquired digital sewing machines, and I would be interested in exploring the emergence of how this hybrid tool fosters increased opportunities to combine both hands-on and technology explorations across gender. In addition, it would be worth combining the cardboard or Legos with Makey Makey kits and other tech tools to leverage the participants' interests in either tool to create more hybrid outcomes featuring both plugged-in and unplugged learning opportunities.

Personalized learning. When interviewing participants or observing them, all of them appeared engaged as they created things of personal interest or worked with peers. Throughout the study students expressed that they loved going to the makerspace as they could pick their own tools and work on whatever they wanted. According to (Reeve & Tseng, 2011, p. 258), in the schools where educators do embrace agentic engagement, students can personalize their learning and act with intentionality in determining the content and rationale of what is being learned. This made me think as a principal how I could leverage this interest and model for teachers how to incorporate more personalized learning opportunities. Many schools incorporate Genius Hour, which is modeled after Google's company philosophy, encouraging employees to pursue personal interests for 20% of the time (Retrieved 12/8/2018 from: https://geniushour.com/what-is-genius-hour/). It would be interesting to combine this approach in both the makerspace and general education settings to give students more opportunities to develop agency in and ownership of their learning.

Conclusion

This study intended to provide evidence about how the makerspace-learning environment in the elementary school setting could foster and sustain opportunities for the emergence of student agency. The quantitative and qualitative data collected in this study may be used to improve makerspace-learning environments and to guide educators about the design process of students' project work, how students can make their thinking visible, and how students can develop engagement through student-driven learning experiences. The emergence of cardboard as a popular tool, Flipgrid as a way to document the creative process, and the simple realization of students just being near one another as impacting the design process of students' projects are important findings for educators as they design elementary makerspaces.

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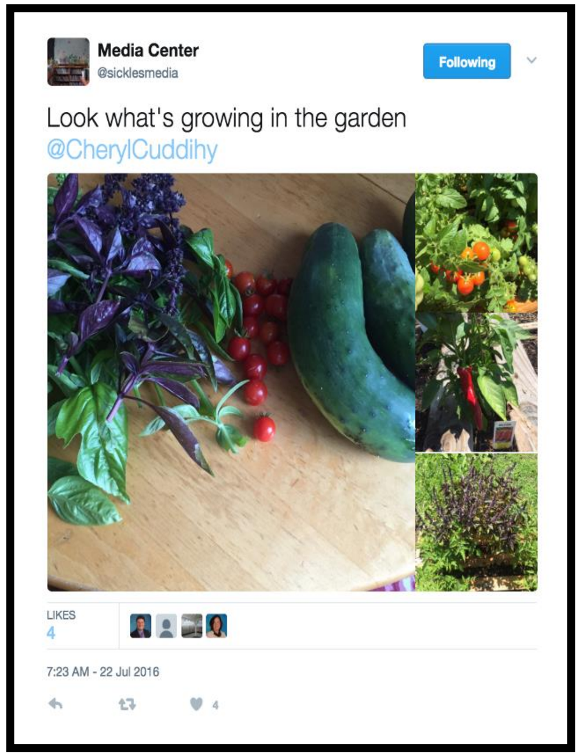
Appendix A: Tweets from the Makerspace

Figures 1 & 2. Students building with Bricks 4 Kidz Lego Kits.



Figures 3 & 4. Produce from the summer 2016 Sickles Garden.

Figure 5. Monmouth University students explain to Kindergarten students how a bee pollinates a flower.

Appendix B: Agency by Design Thinking Routines

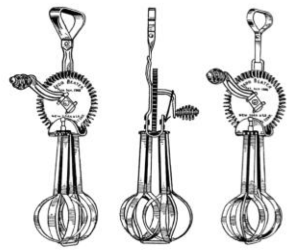
Students will use the *Agency by Design (Agency by Design) Thinking Routines* to help bring awareness to the complexities of objects and systems. In order to integrate the Agency by Design Thinking Routines, the teacher will provide time in class for students to look carefully at objects and systems in order to notice their intricacies, nuances, and details. Students can collaborate with a peer partner or in small peer groups --- no more than 4 --- to actively use the Agency by Design Thinking Routines. This means they will converse with one another as they use the Agency by Design Thinking Routines to guide their discussions and record their observations. They will explore simple objects and complex systems such as Legos, Lego machines, Tinkering Area tools, Makey Makey Boards and projects, garden & greenhouse, etc. Agency by Design Thinking Routines are hyperlinked in the table below and attached in the following appendices.
Table 1
Hyperlinks to Agency by Design (Agency by Design) Thinking Routines

Routine 1 **Looking Closely**	**Routine 2** **Exploring Complexity**	**Routine 3** **Fostering Opportunity**
Parts, Purpose, Complexity	**Parts, People, Interactions** **Parts, People, Perspective** **Think, Feel, Care**	**Imagine If…**

The teachers will **explicitly model** how to look closely during a whole class direct mini-lesson (10 minutes). Then they will provide time for students to select an object and practice the looking closely routines using the "Parts, Purpose, Complexity" activity hyperlinked above. This strategy will continue with the Exploring Complexity and Fostering Opportunity routines. The teachers will model through **a "think-aloud,"** meaning them self-talk as they make observations and detail how they represented her thinking – photos, drawings, and journal entries. Eventually students will self-select routines to help develop their own thinking as they participate in design challenges or pursue self-directed projects throughout the study.

PARTS, PURPOSES, COMPLEXITIES

LOOKING CLOSELY



Choose an object or system and ask:

What are its **parts**?
What are its various pieces or components?

What are its **purposes**?
What are the purposes for each of these parts?

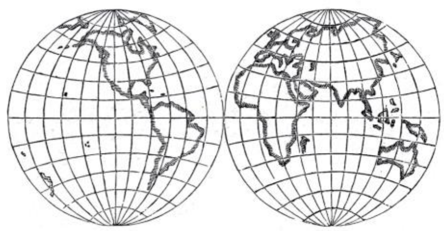
What are its **complexities**?
How is it complicated in its parts and purposes, the relationship between the two, or in other ways?

Agency *by* Design | www.agencybydesign.org
Project Zero | Harvard Graduate School of Education!

!

PARTS, PEOPLE, INTERACTIONS

EXPLORING COMPLEXITY



Identify a system and ask:

What are the **parts** of the system?

Who are the **people** connected to the system?

How do the people in the system **interact** with each other and with the parts of the system?

How does a change in one element of the system **affect** the various parts and people connected to the system?

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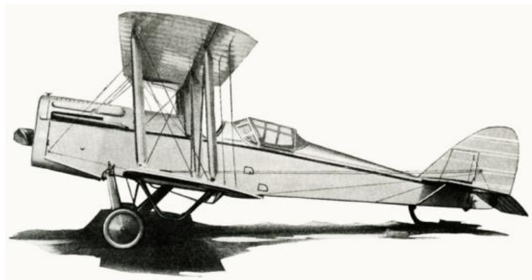
!

PARTS, PERSPECTIVES & ME

A ROUTINE FOR EXPLORING THE COMPLEXITY OF OBJECTS AND SYSTEMS



Choose an object or system and ask:

What are its **parts**?
What are its various pieces or components?

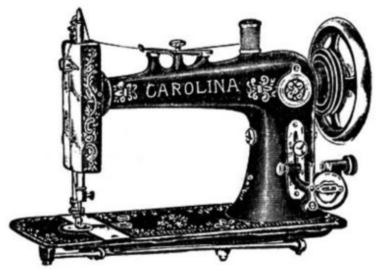
What **perspectives** can you look at it from?
Different users, makers; different physical perspectives.

How are ***you*** involved?
What connections do you have? What assumptions, interests or personal circumstances shape the way you see it?

From the Exploring Complexity Project Materials Developed by:
Flossie Chua, Karin Morrison, David Perkins, Shari Tishman
Project Zero | Harvard Graduate School of Education

THINK, FEEL, CARE

EXPLORING COMPLEXITY



Step inside a system:

Choose a variety of people within a system and then step inside each person's point of view. As you think about what you know about the system, consider what each person might think, feel, and care about:

Think: How does this person understand this system and their role within it?

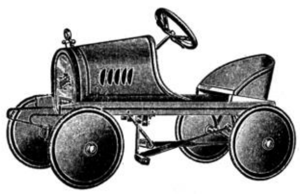
Feel: What is this person's emotional response to the system and to their position within it?

Care: What are this person's values, priorities, or motivations with regard to the system? What is important to this person?!

!

IMAGINE IF…

FINDING OPPORTUNITY



Choose an object or system:

Consider the parts, purposes, and people who interact with your object or system, and then ask:

In what ways could it be made to be more **effective**?

In what ways could it be made to be more **efficient**?

In what ways could it be made to be more **ethical**?

In what ways could it be made to be more **beautiful**?

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!

Appendix C: Maker Project Rubric

Final projects were evaluated by the Principal Investigator and Media Specialist with rubric below.

MAKER PROJECT RUBRIC

	Emerging - 1	Developing - 2	Proficient - 3	Exemplary - 4
Creativity	Student follows a set of directions to complete a project, but did not explore new ways to alter the idea.	Student project is original, but mostly based off of an existing idea.	Student project is explored and expressed in a fairly original way.	Student clearly explored and expressed multiple ideas in a unique way.
Iteration	Student does not attempt to iterate or make any changes on their initial design.	Student attempts to make an iteration on the design and/ or aesthetic of their project, but is unsuccessful in any improvement.	Student undertakes 1 or more iterations of their product, improving the design and/or aesthetics.	Student completes their product, having improved the design and/ or aesthetics over time.
Initiative	Student encounters complications with frustration and does not attempt to problem-solve independently.	Student encounters complications with frustration, but briefly attempts to problem-solve independently before seeking assistance.	Student encounters complications with a positive attitude and perseveres to problem-solve independently before seeking assistance.	Student encounters complications with a positive attitude and perseveres to problem-solve independently without needing to seeking assistance.
Learning	Student did not attempt any new learning or methodology they were not already initially comfortable with.	Student attempts 1 new avenue of learning for their project, but may not have been successful in its implementation.	Student attempts 1 new avenue of learning for their project. They demonstrate a skill they did not have at the start of the project.	Student attempts multiple new avenues of learning for their project. They clearly demonstrate a synthesis of skills they did not have at the start of the project.
Community	Student does not attempt to share their learning.	Student attempts to share their learning, but without adequate explanation or reflection.	Student shares their learning informally in a peer-to-peer fashion.	Student shares their project and learning with an authentic community in a formal manner.

Appendix D: Alignment of Makerspace to the User Center Design Framework

As my staff and I continue to refine and enhance the materials and learning activities in our makerspace, we have evaluated our makerspace through the User Center Design (UCD) Framework. We examined each UCD criterion to monitor our progress and define areas in need of improvement. Outcomes are outlined and aligned to each of the UCD components below.

Understanding the targeted learners. Students in grades K-3 work weekly in the makerspace and their developmental readiness — physical, emotional, and intellectual — are continuously considered. My staff and I collaborate to research and purchase tools for the makerspace that young children can easily manipulate, and we also ensure that the physical space is arranged to encourage safe transitions and movement. In order to optimize the physical space, we changed the layout of furniture and tools to provide more workstations and collaborative meeting areas, which in turn streamlined student traffic patterns and their access to materials. Examples include smaller table configurations, removal of long tables, repurposing office space to create a TV studio and tinkering area, and also acquiring supplementary making spaces around the school, including the schoolyard, to create a school garden. In addition, as the teachers and I were simultaneously learning how to use the tools with the students, our learning needs also had to be considered. The teachers and I attended workshops and went to trainings across the state to learn how to scaffold the experiences for both-student and adult learners. We also practiced and played with different tools including Makey Makey invention kits to develop engineering and coding capabilities; Padcasters to enhance filming capabilities on iPads; Lego motors to reinforce engineering and design thinking; and Minecraft: Education Edition to help foster and sustain game-based learning, collaboration with peers, and problem-solving skills.

Assess existing materials, resources, and curricula. The New Jersey Department of Education mandated the switch from the Common Core State Standards to the New Jersey

Student Learning Standards for science, mathematics, and literacy for the fall of 2017. Therefore, the district had to evaluate all curricula during the 2016-17 school year, and then propose a new scope and sequence of curricula in order to be in compliance with the directive. All other areas including social studies and special areas such as art, music, physical education, media, and world languages, are to be fully aligned by the fall of 2018.

As part of this curriculum re-design process, we analyzed our current curricular objectives related to media studies to ensure we covered the mandated curriculum in the areas of technology and digital literacy whereas also embracing areas related to social studies, science, mathematics, reading, and writing. We continue to examine the possibilities of integrated thematic units across grade levels to connect work occurring in the makerspace to authentic outcomes. Most recently, we facilitated the study of plants in first-grade science classes through experiments in our gardens and greenhouse, and we established a community partnership with Clean Ocean Action, a national and regional non-profit organization working to protect waterways using science, law, research, education, and citizen action, to support the examination of land and water in third-grade science classes.

We also reconfigured existing resources (Chromebooks, desktops, laptops, tables, chairs, etc.) to meet our needs and launch our new ideas. Our school now has 1:1 Chromebooks for all students using the makerspace with access to Google Drive applications both inside and outside of the makerspace. We worked with our Parent Teacher Association (PTA) to build Lego walls throughout our school and to garner Lego blocks from community members. Our PTA also provides ongoing funding for Bricks for Kidz Lego engineering modules and artists in residence through the Kennedy Center Partners in Education with Count Basie Theatre and Red Bank Borough Schools. Most recently, we received ten thousand dollars in private donations that we plan to use to electrify our greenhouse, purchase additional tools for the Tinkering Studio, and establish a fashion design area complete with a brand new digital sewing machine. Based on our informal needs assessments of both students and colleagues, they all support the acquisition of these tools to enhance work in the makerspace and extend opportunities for making into their own classrooms.

Consider best practices current research, and global trends. We are fortunate to work with a progressive administration that values innovation. We are leaders in the national Future Ready initiative to promote best practices in schools including integration of social media, game-based learning, social service projects, and sharing information. Throughout the development of this research project, the teachers and I have attended several professional development opportunities specifically focusing on the transformation of libraries into makerspaces. We have also visited makerspaces in museums, libraries, K-12 public schools, and Rutgers University. By establishing a professional learning network with other educators, we have been able to incorporate new modules and tools into the makerspace. In addition, teachers in other content areas work with our makerspace facilitators to formalize our efforts with arts integration across the school. Currently the Art Teacher and Media Specialist collaborate on projects during which they create books for students in Rwanda. This school year, Grade 3 students created poems in the makerspace and then designed collages in the art studio to help tell the story of each poem. They had to research topics on the Chromebooks and collaborate with peers on Google Docs to write their poems.

Develop thematic units of study. When we first began the makerspace we created programming in the moment as materials became accessible, as new ideas emerged in the national marketplace, or as questions arose from the learning experiences in the makerspace. For example, we had access to free tools from Code.org to implement different coding units so that became one of our starting points. We had connections with Google through our Educational

Technology Specialist who has high profile on Twitter, and he arranged access to free trials of Minecraft.edu, Google Expeditions, Raspberry Pi’s, Makey Makey kits, Padcaster, and other tools to help us launch our programming. We then found additional funding for WeVideo a cloud-based video editing software. Based on these initial attempts at establishing learning experiences, we now have developed thematic units around these tools and connected them to learning in the both the general education classrooms (literacy, social studies, and science) as well as the different special areas (visual arts, music, physical education, and world language). Examples include designing communities for second grade students with the use of physical Lego models and then virtual models on Lego Chrome and Minecraft.

Evaluate additional items to support the makerspace. The evaluation process is ongoing and often done in the midst of other work already in progress. As new technologies emerge or students present us with their ideas or questions, we try to find additional tools or reconfigure existing units to better suit their needs. For example, we have provided extensive teacher-directed and teacher-guided projects but not enough student-driven projects. We realized we needed additional time in our schedule to facilitate these opportunities and access to more tools so that the open projects could be revisited. Rather than depending on the Bricks 4 Kidz Company to provide us with Lego motors during their monthly visits, we have purchased our own Lego motors so that students can apply the skills learned during the different Bricks 4 Kidz modules at their own pace.

Appendix E: Agency by Design Discussion Probes

Taken directly from the Agency by Design Thinking Routines, these questions will help teachers to scaffold and/or probe conversations and provide recursive feedback to students.

- What are its parts?
- What are its various pieces or components?
- What are its purposes?
- What are the purposes for each of these parts?
- In what ways could it be made to be more effective?
- In what ways could it be made to be more efficient?
- In what ways could it be made to be more beautiful?
- What perspectives can you look at it from?
- How are you involved?
- What connections do you have? What assumptions, interests or personal circumstances shape the way you see it?
- How does this person understand this system and their role within it?
- What is this person's emotional response to the system and to their position within the system?
- What are this person's values, priorities, or motivations with regard to the system? What is important to this person?

Appendix F: Design Tasks & Learning Activities in the Makerspace

Activities will evolve based on student interests, however descriptions of possible design challenges or tasks are included to contextualize the possible learning scenarios.

Makerspace Area	Design Tasks & Learning Activities
Lego Walls & Motors	Students will build or design different objects or systems utilizing assorted Lego pieces, Lego motors, and the Lego walls. They have already worked and will continue to work with the Bricks 4 Kidz prescriptive modules that explicitly direct students how to incorporate different engineering functions and necessary pieces (e.g. axle, gears, pulleys, etc.) to complete the tasks. Students will have the opportunity to create their own tasks or projects utilizing the Lego materials as models.
Tinkering Studio	The Tinkering Studio is dedicated to carpentry and building. Students have access to a variety of small tools including hammers, nails, screwdrivers, small saws, vices and other tools to help build new objects or refine current functioning/use of existing objects. An example of some work already underway includes making birdhouses and sculptures for our school garden.
TV Studio	In the TV studio, students have access to a green screen, iPads, Padcaster, tripods, and microphones. They can record in front of the green screen or take the camera on location in the school or on school grounds. They also have access to video editing software including iMovie and WeVideo.
Chromebooks	Students can have individual access to Chromebooks. They can use Google Drive tools like Docs, Sheets, Forms, Drawings, etc. to help convey their ideas and research new topics. They are familiar with the commenting features and often give each other feedback. In addition they will use the Chromebooks to post video summaries onto Flipgrid and other social media sites.
Minecraft: Education Edition	Our district has access to Minecraft: Education Edition. Students are familiar with navigation and the program itself. They create different “worlds” in this program and some of them have collaborated with peers in real time and virtually to play with the game.
Makey Makey Kits	The Makey Makey kits are a new purchase for our makerspace. We are currently planning to show the students how to use the kits and depending on their interest and skill sets, we will create different design challenges or games for them to complete.
Gardens & Greenhouse	Students are familiar with the concept of gardening and how to care for plants in the gardens. We will use the greenhouse this winter to begin

	seedlings and allow for students to design new parts of the garden to leverage sunlight, water absorption, and to gain a bigger harvest.
Self-Directed Project	Self-directed projects in the makerspace schedule will be a time when students themselves select an area in which to work to explore their own questions or develop solutions to real world problems. This has not yet been implemented but we plan to do so throughout each of the 7-week rotations.

Appendix G: Pre & Post Engagement Surveys

During Week 1 of each rotation students will complete the engagement form on Google Forms prior to entering the makerspace. This will be done in their homerooms utilizing their Chromebooks. Immediately following Week 7 of each rotation, students will complete the same engagement form on Google Forms in their homerooms utilizing their Chromebooks. Questions are based on the Reeve & Tseng (2011) Protocol, which specifically examines four aspects of engagement: agentic, behavioral, emotional, and cognitive. In the original study, the various attributes were measured with 1-7 response scale ranging from strongly disagree (1) to strongly agree (7). For the purpose of this study, students will select from a 1-3 response scale ranging from (1) always or most of the time, (2) sometimes, and (3) rarely or never.

Items to assess agentic engagement

1. During class I ask questions
2. I tell the teacher what I like and what I don't like
3. I let my teacher know what I'm interested in
4. During class I express my opinion
5. I offer suggestions to make the class better

Items to assess behavioral engagement

6. I listen carefully in class
7. I try very hard in school
8. The first time my teacher talks about a new topic, I listen carefully
9. I work hard when we start something new in class
10. I pay attention in class

Items to assess emotional engagement

11. I enjoy learning new things in class
12. When we work on something in class, I feel interested
13. When I am in class, I feel curious about what we are learning
14. Class is fun

Items to assess cognitive engagement

15. When doing schoolwork, I try to relate what I'm learning to what I already know
16. When I study, I try to connect what I am learning with my own experiences
17. I try to make all different ideas fit together and make sense when I study
18. I make up my own examples to help me understand the important concepts I study
19. Before I begin to study, I think what I want to get done
20. When I'm working on my schoolwork, I stop once in a while and go over what I have been doing
21. If what I am working on is difficult to understand, I change the way I learn the material

Appendix H: Student Focus-Panel Interview Script

To be administered by Principal Investigator or Principal Investigator appointed interviewer. Students will be seated in the makerspace when responding. Students will be chosen at random from those students with parental permission - Up to 10 from each class.

Good afternoon and welcome to our focus group session. Thanks for taking the time to join me to talk about your experiences in this class. As you know I'm Mrs. Cuddihy. I am interested in gathering more information about you and your work in our makerspace. All answers are welcome. Your feedback will help us to improve the makerspace for other classes.

You've probably noticed an electronic device out. I am video recording the session because I don't want to miss any of your comments. People often say very helpful things in these discussions and I can't write fast enough to get them all down.

I will ask different questions and you may respond to all of them, some of them, or none of them. Do whatever feels comfortable for you. Please let everyone have a chance to speak. Sound good? Any questions?

1. What is your favorite thing to do in our makerspace? Why?
2. Please describe the Agency by Design Thinking Routines.
    a. Which ones did you like the most?
    b. Which ones did you like the least?
    c. Did the Agency by Design Thinking Routines help you plan any projects in the makerspace? How?
3. Did you use any of the technology tools like Flipgrid? Google Comments? Twitter?
    a. If yes, did it help you with your thinking? How?
4. Did you use the Wonder Boards?
    a. If yes, did help you with you thinking? How?
    b. What did you like or dislike about the Wonder Boards?
5. Did Mrs. Smith or Mrs. Davis give you feedback during the classes?
    a. If yes, how did it make you feel? Did their feedback help you? How?
6. If you made a project, describe how you came up with the idea. What kinds of things did you do to make your project?
7. What are some projects you would like to design in the future?
8. What did you learn in our makerspace?
9. How can we make our makerspace better?
10. Is there anything else you'd like to tell me about the course design that might not have been addressed by any of the previous questions?

Thank you so much or taking the time to allow me to speak with you about your experiences in our makerspace. Your feedback is greatly appreciated.

Appendix I: Teacher Interview Script

To be administered by Principal Investigator or Principal Investigator appointed interviewer.

Good morning. Thank you for meeting with me today. I would like for you to provide feedback regarding our efforts in our makerspace thus far. All answers are welcome and will not be used towards [your professional evaluation] or [as part of your volunteer commitments]. Your feedback will help our school to improve the makerspace for other classes.

I am audio recording the session because I don't want to miss any of your comments. People often say very helpful things in these discussions and I can't write fast enough to get them all down. I will ask different questions and you may respond to all of them, some of them, or none of them. Do whatever feels comfortable for you. Sound good?

1. Please describe your observations of students using the Agency by Design Thinking Routines.
    a. Which ones did they like the most?
    b. Which ones did they like the least?
    c. Do you think the Agency by Design Thinking Routines helped students develop projects in our makerspace? Why or why not?
    d. Do you think the Agency by Design Discussion Stems helped you to guide the students towards more self-directed learning? How? Why not?
2. Did you find the use of the technology tools like Flipgrid, Google Comments, or Twitter helpful for students to articulate their thinking process? How? Why not?
3. Did you find the use of the Wonder Boards helpful for students to articulate their thinking process? How? Why not?
    a. What did you like or dislike about the Wonder Boards?
4. How did you feel when providing the discussion stems or recursive feedback to students? Do you think the students benefited from this type of scaffold? How? How can we make our makerspace better?
5. Is there anything else you'd like to tell me about the course design that might not have been addressed by any of the previous questions?

Thank you so much for taking the time to allow me to speak with you about your experiences in our makerspace. Your feedback is greatly appreciated.

Appendix J: Students' Project Scores

Project	Rotation	Gender	Material/Project	Creativity	Iteration	Initiative	Learning	Community	Average
C1	3.2	M	Cardboard -	4	4	4	4	3	3.80
C2	3.1	F	Cardboard - Bridge	4	4	3	4	3	3.60
C3	2.2	M	Cardboard - Building	4	4	4	4	3	3.80
C4	3.2	F	Cardboard - Castle	4	4	4	4	3	3.80
C5	3.2	F	Cardboard - Doghouse	4	4	4	4	3	3.80
C6	3.2	F	Cardboard - Doghouse	4	3	2	3	3	3.00
C7	3.1	M	Cardboard - Fortnight Store	4	4	4	4	3	3.80
C8	3.1	M	Cardboard - Fortnight Store	4	4	3	4	3	3.60
C9	3.1	F	Cardboard - Game	2	3	3	4	3	3.00
C10	2.2	F	Cardboard - House	3	3	3	3	3	3.00
C11	2.1	F	Cardboard - Jetpack	4	4	4	4	3	3.80
C12	2.1	F	Cardboard - Playground	3	3	3	3	3	3.00
C13	3.1	F	Cardboard - Robo Helpers	4	4	4	4	3	3.80
C14	2.1	M	Cardboard - Ship	4	4	4	4	3	3.80
C15	2.1	M	Cardboard - Skate park	4	4	4	4	3	3.80
C16	2.2	F	Cardboard - Store	3	3	3	3	3	3.00
C17	2.1	M	Cardboard - Warrior	4	4	4	4	3	3.80
C18	2.1	F	Cardboard- Tea set	4	4	3	3	3	3.40
CB1	3.1	F	Chromebook - Slides	2	3	3	3	3	2.80
CB2	3.1	M	Chromebook - HP Kahoot	4	4	4	4	4	4.00
CB3	3.2	M	Chromebook Makey Makey	2	2	3	4	3	2.80
CB4	3.2	F	Chromebook Makey Makey	2	3	4	4	3	3.20
L1	2.2	M	Lego – Beach house	3	3	3	3	3	3.00
L2	2.2	F	Lego – House	3	3	3	4	3	3.20
L3	2.2	F	Lego – house	4	4	4	4	3	3.80
L4	2.2	M	Lego – jungle	4	3	3	3	3	3.20
L5	3.2	M	Legos - Beyblades	4	4	4	4	3	3.80
M1	2.2	F	Minecraft- village	4	4	4	4	3	3.80
M2	3.1	M	Minecraft - house	4	4	4	4	3	3.80

M3	3.1	M	Minecraft	3	3	3	3	3	3.00
M4	3.1	M	Minecraft	4	4	4	4	3	3.80
M5	3.1	M	Minecraft	3	2	3	3	3	2.80
M6	3.1	M	Minecraft	4	4	4	4	3	3.80
M7	3.2	M	Minecraft	4	4	4	4	3	3.80
M8	3.2	M	Minecraft	4	4	4	4	3	3.80
M9	3.2	M	Minecraft	4	4	4	4	3	3.80
M10	2.1	F	Minecraft - LOL Doll Kingdom	4	4	3	4	3	3.60
M11	2.2	F	Minecraft - Portal	4	3	3	3	3	3.20
M12	2.2	M	Minecraft - Portal	4	4	4	4	3	3.80
			Total Average	3.62	3.59	3.54	3.72	3.03	3.50

Appendix K: Permission from the Digital Harbor Foundation to Use the Maker Project Rubric

Gmail Cheryl Cuddihy <cherylcuddihy@gmail.com>

Re: : Rutgers University Research - Permission to use Maker Rubric

Nicole Nistico <nicole@digitalharbor.org> Mon, Apr 15, 2019 at 1:55 PM
To: cherylcuddihy@gmail.com
Cc: coe@digitalharbor.org

Good Afternoon Cheryl,

Thank you for your interest in DHF and its materials. We are happy to have you use our Maker Rubric. All we ask is that your cite our organization and possibly share the project when it's completed!

Best of luck!

Thanks,

Nicole Nistico
Operations Manager at Digital Harbor Foundation

Phone (443) 681-9384
Email nicole@digitalharbor.org
Website http://www.digitalharbor.org

sign up for our newsletter: eepurl.com/I8aJX
check out our educator resources: blueprint.digitalharbor.org
support DHF with any purchase on Amazon smile.amazon.com/ch/45-2536579

---------- Forwarded message ---------
From: **Personal** <cherylcuddihy@gmail.com>
Date: Mon, Apr 1, 2019 at 8:48 AM
Subject: Rutgers University Research - Permission to use Maker Rubric
To: <contact@digitalharbor.org>
Cc: CUDDIHY CHERYL <cuddihy@scarletmail.rutgers.edu>

Hi,

As a graduate student at Rutgers University, I am working on my dissertation regarding the emergence of student agency in the elementary makerspace setting. The title of the research is "Once Upon a Makerspace: Elementary Students Document the Stories of their Thinking." I would like permission to use the Blueprint Maker Project Rubric from your website as the rubric to assess the projects completed as it is extremely helpful in assessing students' design process and project outcomes.

How do I go about securing permission to use the PDF/image? Is there a fee required? Will simply citing it to your organization suffice?

Please advise.

Thank you so much!

Sincerely,

Cheryl Cuddihy

Appendix L: Interview Transcripts

Teacher Interview

PI: ...done. They saw themselves as the one driving their learning. You have all these great ideas. Just talk. Free think.

Mrs. Smith: Free [crosstalk 00:00:05]. No, no, so like just a lot of the pre-planning wasn't really done a lot, because they just didn't ... They just wanted to get to work. They wanted to start. Then while they were working, if they were working with partners, then they would discuss about what they want to change or add, and it was more of that kind of social-

Mrs. Davis: Collaboration.

Mrs. Smith: Yeah, that was a big piece of it, rather than, "Okay, let's sit down and plan." Which is typical of just being a kid and not wanting to, "You know we're going to have to plan this, and do this." They just wanted to get to work, start doing it, see what works, what they liked, what they wanted to change, and then talk about it that way.

Mrs. Davis: It was more hands-on definitely. I thought they were succeeding much better with the hands-on than with the paper in the beginning of writing down what they were doing. Because they were really like overwhelmed with that I thought, because they asked a ton of questions about the questions on the paper. But, when they got to work they didn't ask that many questions.

Mrs. Smith: No, they didn't, yeah.

PI: So, do you think that using those routines detracted from their ability to just get right to work?

Mrs. Davis: I mean I think routine is good in a certain sense, but I do think that if they maybe chose their groups first and worked together, thought about it, talking about it first, and then maybe doing a group paper rather than an individual, I don't know. They just seemed to like to collaborate with their peers more so than individual papers.

Mrs. Smith: Yeah, yeah. They do. And some of them did do, they sat down with one huge piece of paper and did it together. That was helpful, I think for them. But, did they then exactly do what they said on their paper and go back to like, let's say, the Minecraft community and do exactly what was on the

paper? No, because as they're doing it some things are a little bit more difficult to kind of accomplish physically or virtually than it is on the paper, what they kind of anticipate. So.
PI: I felt like when I was watching them that sometimes it was more of a detour for them. They were like ... It's kind of like you know when we have to put in lesson plans or objectives. We're just so much better when we're in the moment. I saw that with them as well.
PI: So, what I'm going to do now is I'm going to actually read this, so I follow my script, because I'm always in trouble for not following the script. Good morning. Thank you for meeting with me today. I would like for you to provide feedback regarding our efforts in the makerspace thus far. All answers are welcome, and will not be used towards your professional evaluation. Your feedback will help our school to improve the maker space for other classes. I am auto-recording this session because I don't want to miss any of your comments.
PI: People often say very helpful things in these discussions, and I can't write fast enough to get them all down. I will ask different questions, and you may respond to all of them, some of them, or none of them. Do whatever feels comfortable for you. Sound good?
Mrs. Smith: Mm-hmm (affirmative).
PI: All right, so you had already started describing some of the Agency by Design Thinking Routines your thoughts. So, now I'm going to go off of like the official questions, and if you have no comment, or you think you already addressed it, you can just say, "Oh, I remember we talked about it before." So, please describe your observations of students using the Agency by Design Thinking Routines. Which ones did they like the most, if any?
Mrs. Smith: So, of those you mean?
PI: The Looking Closely, Exploring Complexity, and Fostering Opportunity.
Mrs. Smith: I think ...
PI: There was the one the Looking Closely was the first one.

Mrs. Davis: The [inaudible 00:03:33].

PI: The Exploring Complexity was the one with all the different views.

Mrs. Smith: I think this one, the Parts, Perspectives and Me, I think that was like the hardest for them to kind of grasp. I think this probably was the easiest, the Parts, Purposes ... And even, I mean the Complexities they kind of-

Mrs. Davis: Were confused.

Mrs. Smith: ... had a hard time with that word, and then kind of understanding. I mean, yeah, they could look at the parts. They could think about what it's used for, what the ... But, then in thinking about what's the relationship between the two, they were like, "What do you mean?" Well, why this item that you're looking at? So, it's a key chain, and what's the purpose. If it was made out of another material, or if it didn't have this little link to hold the keys ... You know that was kind of a harder thing for them to take that next step to think about. So, I think that's probably was the easiest for them to-

PI: The first one?

Mrs. Smith: ... kind of, the first one, to kind of look at.

PI: Okay. And then the second one where they did the Exploring Complexity, People, Parts, and Interactions. I noticed that they liked doing all the different angles. That was something that they got-

Mrs. Smith: Right, they did like that. They did like that, like how would you describe.

PI: So, maybe that's what we should have done, is maybe changed it to the beginning. Like have that had been part of that first routine, where they were able to look at it from the different angles? I don't know.

Mrs. Smith: Mm-hmm (affirmative).

Mrs. Davis: Yeah.

PI: Which ones do you think they liked the least?
Mrs. Davis: The Complexities what?
PI: Because we didn't ... I don't know the Fostering Opportunity, I don't think we really, we didn't get to that one I thought.
Mrs. Smith: That one, that's this one, this whole, right?
PI: Okay.
Mrs. Smith: So, the fostering opportunity.
PI: All right, so we did with the second group? Okay.
Mrs. Smith: Yeah, with that second group. What ways could it be more efficient? What ways could it be more effective?
Mrs. Davis: Is that the one when they looked at each other's on that, when they were able to give each other the feedback?
Mrs. Smith: They had to look at their own. They had to kind of, and then they had to look at two others to kind of say-
Mrs. Davis: I think they did like looking at two others, because then they kind of did spark some ideas for them.
Mrs. Smith: I think they also got lost in the whole ... Instead of answering that specific question, they would say, they would comment either on the Flipgrid, or, "You were speaking too softly." Or, "I saw a picture of the ceiling, and I couldn't see what you were holding." So.
PI: Gotcha. So, it was more a critique of their videography-
Mrs. Smith: Yeah.

PI: ... rather than the actual project? Okay. Well, that actually this is a good, because this leads into the next question. Did you find the use of technology tools like Flipgrid helpful for students to articulate their thinking process? How, or why, or why not?

Mrs. Smith: Yeah, I think-

Mrs. Davis: I like Flipgrid for that reason. I think they do like that Flipgrid, but I think they need to probably learn how to use it better for that one particular project. Because I think you're right. Some of them couldn't hear, and I think it had to do with the headphones-

Mrs. Smith: Right, it did.

Mrs. Davis: ... and not having the speaker, so they couldn't hear. Or-

Mrs. Smith: That was a big part. Like Anthony had headsets that had the one piece of a mic that was included. Because it's so noisy, they're all, some of them there are different processes. Yeah, we stop everybody to go on Flipgrid and do it all at one time. But, if they're all sitting in front of their computer, and there are 20 of them, and even if they spread out to the room, you could still hear the background noise. If they're kind of speaking quietly, you're hearing all that other background. But Anthony's because he had that mic, it didn't matter what was going on behind him, you heard everything that he said. So, that's what I-

PI: So, they would need to have the right recording devices? Okay.

Mrs. Smith: Recording, yeah, so they really could. And then, I guess just to make, you know hearing their Flipgrids the first time, and then reminding them, "You know, you're kind of answering these questions. I know that you're kind of responding to the whole Flipgrid experience, but focus on what you're supposed to be answering in that Flipgrid, rather than like, you know you've had the Flipgrid not on you."

Mrs. Davis: Let's put some sunglasses on.

Mrs. Smith: "I couldn't hear you. It's low. I think you did a good job."

PI: Because a few of them in their interview that I did with them last week, they were saying that they actually did take the comments very seriously. Which I was like, "Wow!" And this was in Ms. Bagwell's class, so the little ones. I was really surprised to hear that, that the second graders were more in tune to that than the third graders. And I don't know if it was an autonomy thing, where third graders were like, "Yeah, I don't really care what you think."

Mrs. Smith: Yeah, like, I, right. I'm doing. That's probably.

PI: Like, "I'm doing what I'm doing." Whereas, second grade maybe they were still seeking that approval?

Mrs. Smith: They're still looking, right. I think that's a big part of it too.

Mrs. Davis: Yes. Yeah. That's true.

PI: Yeah. So, that's interesting looking at their developmental readiness with that. We already, I'm not going to ask question number three. We did not ... Well, let me ask you this. Why do you think the Wonderboards weren't helpful? We found that we didn't really use them. Was it just a timing thing? Was it just one more step?

Mrs. Smith: I think it was one more step. They're so ready to get going, and then to ... Even to break for the Flipgrid, and they liked doing the Flipgrid, where the Wonderboard is more like ... I guess maybe they feel like they're not going to see anything from that. There's not going to be a response immediately, or that, I don't know. So, that was just like another step that they didn't really-

PI: Want to do, stop and do?

Mrs. Smith: Stop and do.

PI: We had one little boy commented that he ... In third grade, daily I think Rob and Sean they were like, "Oh, we did not even want to do the Flipgrids to be honest with you. We just want to do our work. We did not want to stop."

Mrs. Smith: They didn't want to stop.

PI: Like, "I know what I'm doing." And then they went through that. Whereas, second grade was like, "No, I liked doing it." And again, I don't know if they were seeking my approval, or they actually, genuinely did like. Did you find that second grade did actually enjoy stopping, or did they seem to get annoyed or irritated?

Mrs. Smith: Yeah, nobody, they don't really like to stop. I mean once they're, "No, no," then I would give the warning. You know, "Okay, five minutes and I'm going to ask you to stop and start cleaning up," because, I mean some of them for the cardboard thing that was a bigger mess than just you know. Like, "Okay, exit out of Minecraft."

Mrs. Smith: So, they always felt like they needed more time. So, I think they just don't like that whole transition thing is always. But never like, "Oh, I don't want to do this Flipgrid. It's not ..." I don't think that's an issue. I think it was just-

Mrs. Davis: Anything with the technology I think they're happy to do.

Mrs. Smith: Yeah, yeah.

PI: Okay, good. No, I think that this is all helpful. Let me ask you this. How did you feel? Were you able to use any of the discussion stems like we had talked about at the beginning? I don't know if you did. Like they sort of were ... I saw you doing it when you were doing the thinking routines. You kept using the verbiage that we provided from that routine. Do you remember? You were saying like, "What are its parts? What perspective?"

Mrs. Smith: Yes, yeah.

PI: Did you find that those helped you? Or, did you find that you were more in the moment and helping them with specific things on their project, like they needed more tools, or more parts, or more whatever?

Mrs. Smith: Yeah, probably more in the moment I would think, than going back to ... And, then maybe that was my kind of where I should have brought that more into it, but-

PI: Oh, that's an interesting idea, yeah.

Mrs. Smith: It was more of in the moment, you know.

PI: Well, even I found myself, and it was good that I was in there. I don't know, a couple of times I was in there. Not as many as I should have. And, I found myself, like I'm like, "Oh, no, that's not ..." Because that particular thing wasn't necessarily exactly how I wanted to word my response to the child, and I found myself getting in the same situation where I was like, "Oh, you could just go over there and grab this." The one thing that I found hard, and I was curious. It's not in my script, and of course I'm going off script, but, was it hard for you as a teacher not to provide explicit feedback? Like, "This is how you solve it."
Mrs. Davis: Yeah, yeah, yeah. Right.
PI: Like Billy it was killing me not to tell him, "Do it this way. If you just evened it out, it would fit." And, it was hard for me as an educator. So, tell me about that. Did you have any experiences like that?
Mrs. Smith: Yeah, no, because there would be something like they were trying to put it together, and well, "How do I do this? How can I?" I said, "Well, what do you want it do?" And then they would explain. I was like, without saying, "Okay, so this is what you need to do. You need to get a tape, and ... So, how can you solve that? How can you make this that would need to be flat? How can you make that flat?" "Well, I don't know." And then I would have to walk away. "Think about it. Take a look. Take a look and try different things, and I'll come back."
Mrs. Smith: And I think, "Maybe if I walked away, they would kind of figure out something." And usually they did, but sometimes they didn't. Sometimes they, you know ... But, it was hard to you don't not just say, "Here, you need to take this, and put it here, and then you can add this. What else could you add to that, that would make it?" You know it's like ...
PI: It's really. I even Carl, he was working with the Makey Makey. I'm like, I'm not the best Makey Makey person, but I kind of know the basics. It was so hard for me not to be like, "Here."
Mrs. Smith: You need to make that darker.
PI: "Just put it here. You need to color in more lead so that it conducts it better. Then I you know it was really hard. I'm like, "Why don't you Google it? Why don't you do this? Why don't you do that?" So, I found it really difficult when I was working with him, and also with Billy, not to give too much information.
Mrs. Davis: Just say, right, right.

PI: And it's hard, I think, as educators to do that.

Mrs. Davis: Yeah. And I think that even with the Makey Makey, like sometimes they forget to hold the white one, the ground one. So, they were wondering why it wouldn't work. Then you're always like, "Well, which one aren't, don't you need to hold one? Or which one is supposed to touch you?" So, then they finally would get it. But-

PI: So, you kind of scaffolded and gave them some minor-

Mrs. Smith: Yeah, why do you think it's not making the connection? What are you missing in that loop?

PI: Do you think as far as teachers go, like you've been in a lot of the classrooms. You know a lot of the staff here. Do you think that's something that everybody could use some work on, is sort of letting them go through that little bit of frustration, the kids, not so much the teachers?

Mrs. Smith: Yeah.

Mrs. Davis: I think it's hard for the kids, because I think the kids get frustrated quicker than, we-

Mrs. Smith: Oh, definitely.

Mrs. Davis: ... would as learners. So, I think it's hard for the teachers to be able to enter, to get into, you know to tell them not to stop, because they do get frustrated right away. They don't really ... They're not problem solvers right away.

PI: Did you see some of them become problem solvers as they progressed through this?

Mrs. Davis: Yes, I think so, yes.

Mrs. Smith: Yeah, oh yeah, yeah. Definitely. And, you know-

PI: Can you think of which ones that you're-

Mrs. Davis: But they're quick to ask a question before they actually stop and think, I find.
PI: Right, I agree with you.
Mrs. Smith: I mean Lisa was a problem solver. I felt like when she was making her thing she didn't really, "Well, how can I do?" I said, "You can." And, she had perseverance. I'm trying to think. Billy. Billy did. Who else? Freddie on Minecraft.
PI: He talked about that too. Carl did too. I just observed. And Holly as well. She was another one that I thought persevered through it, through everything.
Mrs. Davis: I always saw her on Makey Makey, because she was the one person at first didn't have it in her hand. But then, she was [inaudible 00:14:35] with the direction. In her paper she didn't know which way it went. So, then she really focused in on how her paper was laying down. Then finally, she figured out that her arrow was going the wrong way, and so she erased it and fixed her arrow, and then really fitted it in. So, she did problem solve on one of those.
Mrs. Smith: I mean could teachers use ... I mean, I guess it depends on what it is that they're doing.
PI: Like a mathematical operation I would think you would be like, "This is how you do double digit math. You know multiplication, or addition, or subtraction, regrouping." But then, getting them to persevere in other areas, that was always something I thought that would be kind of cool for them to start looking at.
Mrs. Smith: Yeah, to start looking at. Yeah.
PI: Well, see, I'm totally off script. Is there anything else you'd like to tell me about the course design that might not have been addressed by any of the previous questions? Like things you could think of, whether it was about the tools, the structure of the hour, anything? And that you like or didn't like? I'm totally fine with it.
Mrs. Smith: No, well I mean I think just the set up. We were talking about like even next year how things would be just more accessible and out. It would be great ... Mrs. Davis suggested this, which was a great thing ... to have like these bins on wheels, where everything is, "So, this is what you need-"
PI: Order them.

Mrs. Smith: I-

PI: You know what we could order? Going off track here. We have it in our garage. It's like a chrome, like a baker's rack almost. But it's a ... You know they have them at restaurants. Then they're filled with like gray bins. I think Chris has one over at the Innovation Lab.

Mrs. Smith: Yeah, and some of the, but some of them are for like little pieces and things. But, this would even be like just what would you put in there for everything that you would need for, if you were doing cardboard challenge. Or, this is what you would you need, everything that-

PI: I love that.

Mrs. Smith: ... you need if you were doing-

Mrs. Davis: Makey Makey.

Mrs. Smith: ... a Makey Makey. Or everything that you would need, for you know?

PI: That's a good idea. We have money, so if you want to.

Mrs. Davis: So, they could pull those to the tables when they decide they come in and they want to do a cardboard-

PI: And then they put them up.

Mrs. Smith: And then they can. Yeah.

Mrs. Davis: And then they clean up.

Mrs. Smith: They clean it up, and then return it, rather than-

PI: Yeah, I like that. I like that.

Mrs. Smith: Right?
PI: I like that. I like that. And then it's easier for you. They know they're, and you're giving them agency. And, they get to go over and see what they're looking at. That's a nice idea, Mrs. Davis.
Mrs. Smith: It's Mrs. Davis' idea. Nice idea, Mrs. Davis!
Mrs. Smith: With the organizational skills.
PI: Well, that's a bit, because that was the one some-
Mrs. Davis: That's what I'm good at!
PI: Yeah, that was the one thing, I feel like this year we had so much going on. It was so much between the groups. I mean you had the greenhouse and the gardens. That's over, no, well, that's a whole course?
Mrs. Smith: Right.
PI: You were mixing that all in with everything. Then I felt like the Makey Makey could have been its whole marking period. The Lego Motors could have been a whole marking period. The cardboard challenge could have been a whole marking period. So, that's something I was thinking about. And, I will talk to the new curriculum director. What could we do to structure it so it's easier for you guys to facilitate?
Mrs. Smith: Easy, right.
PI: Then also that they're getting basic skills in this is what you do. I don't know, is cardboard challenge appropriate for first grade with the tools? I don't think so.
Mrs. Smith: No, I had too many injuries.
PI: Yeah, I don't think so. But, like second and third grade. Tell me more about the injuries.

Mrs. Smith: Oh, they cut, because to those things. But, you know what, actually I said to Roseanne, something about because she was doing that for art. They were making those cardboard structures. And I said, "What do they use to cut the cardboard?" She said, "Scissors." I said, "Those little child scissors go through cardboard?" She said, "It works their muscles really well. Are they doing ..." I was like, "And it's frustrating when they're like this."

Mrs. Davis: And it takes them a while.

Mrs. Smith: It would take them a while.

PI: I think it would take them too. And, you're not going to get that straight edge. Like, I was watching the older kids, and they could really cut it.

Mrs. Davis: But you came up with that great idea about that big ball, and then it would like out of that cardboard?

Mrs. Smith: Yeah.

Mrs. Davis: So, then you would cut the cardboard. But then the first graders would color the image. Then by the time you get to third grade they're the ones putting it together. So, it's one huge project, but it's each class's participating.

Mrs. Smith: They're made with that Make Do, those tools you got. So, there was something I saw on Twitter where they had precut squares, and made like these geo-disk domes.

PI: Neat.

Mrs. Smith: So, they had to connect all the Make Do, and it was a ball.

PI: Oh, that's cool.

Mrs. Smith: And the class would all contribute. So, each part was theirs. They all had to contribute to make the whole thing circular. Then Peggy was saying about, "Oh, it would be great for the younger kids to be able to maybe-"

Mrs. Davis: Make the design on it.
Mrs. Smith: "... to design."
PI: That would be cool. That would be cool, yeah.
Mrs. Smith: So, something like that.
PI: There were so many things, and I know we talked about all that. I think you have enough tools right now. I can't imagine buying one more thing to put in there. Can you?
Mrs. Smith: No, now I probably would get more of the cutters, even though ... And they were not bad. I mean usually I just said, you know you can't if you're cutting, you can't then take your eyes off what you're cutting to have a conversation with somebody. And that's the way people were getting cut. So, I think they were pretty good about it.
Mrs. Davis: I did, yeah.
Mrs. Smith: You know out of all the classes maybe we'd have like one or two at a time, and that was it.
Mrs. Davis: I do think it's because they get sidetracked. Like the-
Mrs. Smith: They do. And you can see as they're going. Like, "No, I didn't, know." You know, so. Yeah.
PI: That is a hard thing. Anything else that you want to add that you can think of. Things you wish you had known, said, not done? I thought it was amazing. I was very proud of both of you really. Thank you for doing such a great job.
Mrs. Smith: It's a lot of data you have to look over.

THIRD GRADE CLEANED INTERVIEW DATA

Good morning and welcome to our focus group session. Thanks for taking the time to join me to talk about your experiences in the makerspace. As you know, I'm the PI. I am interested in gathering more information about you and your work in the makerspace. All answers are welcome. Your feedback will help us to improve the Makerspace for other classes. You probably noticed that Mr. D is filming you right now. We are video recording this session because I don't want to miss any of your comments. People often say very helpful things in these discussions and I can't write fast enough to get them all down. Alright? We will ask different questions and you may respond to all of them, some of them, or none of them. Do whatever feels comfortable for you and then we're going to let everyone have a chance to speak so we really will have to take turns. Sound good?
Students: Yes.
PI: Any questions?
Students: No.
PI: All right question number one. Think of all the things that we did in the makerspace, there's a ton of different things that happen in there. What is your favorite thing to do and why?
Oliver: My favorite thing to do in the makerspace is use the Chromebooks and play with the LEGOs to make Beyblades.
PI: We'll just go right around. Callan go ahead.
Callan: My favorite thing was to play with my friends and play LEGO wars.
PI: Kevin?
Kevin: Everything is to play with my friends. Playing Minecraft with them, and playing on the Chromebooks with them.
PI: Okay, Anthony?

Anthony: My favorite thing to do is play games on the Chromebooks.
Sean: So my favorite thing is I like to play on the Chromebooks.
James: My favorite thing is to play on the Chromebooks, play on Minecraft and play with the LEGOs.
PI: So this is one thing I forgot to tell you when you speak I need you to say my name is ... because even though I'll have the video sometimes I'll have it transcribed and it just might be what you're saying. If you could say, "Hi my name's Rob and this is ... Minecraft's my favorite thing because". A lot of you told me your favorite thing is Chromebooks but you didn't tell me why. James can you tell me why Chromebooks is your favorite thing?
James: Chromebooks is my favorite thing because I can go on multiple of different kinds of websites and I can play multiple games on each website.
PI: Sean?
Sean: My favorite ... the reason I like using the Chromebooks is because I like to play different games on the Chromebooks. It's simpler.
PI: Anthony why did you like the Chromebooks?
Anthony: Because there's ... because you can go play a lot of things on the Symbaloo which is the thing I really like.
PI: Okay. Does anyone else want to add a reason why they liked their activity the best? Kevin?
Kevin: I liked Chromebooks because it has Scratch and Scratch is a really fun website. Basically, you get to see other people's projects and I played other people's projects with my friends and also I can make my own project, which is really cool.
PI: Okay. Anybody else want to add anything? Oliver?

Oliver: My favorite thing to do on Chromebooks is go on to ABCya! onto Blue because there is a variety of different games that I can play and play with my friends [inaudible 00:04:05].
PI: Right. Now we're going to talk about the Agency by Design thinking routines. Do you remember doing those? You would get the little pieces of paper and you would do Looking Closely, Exploring Complexity, or Fostering Opportunity. Think back, do you remember doing those types of things?
So whenever you answer a question you're going to say your name, and then you'll answer the question. Does that make sense?
Students: Yes.
PI: Okay, so here are the questions. Can you describe one of the routines and which one did you like the best or which one did you like the least? And we'll go from there.
PI: Okay, but going back. Because we're going to talk about the Flipgrids to the Agency by Design thinking routines, those are the ones where you had those pieces of paper and you looked at things from different perspectives or you talked about the parts. Do you remember that?
James: My name is James, I also agree with Rob. I liked the first one that we did. Looking from different angles and giving the materials that we used. I was with Rob and Sean using ... we were on Minecraft and it was really easy like Rob said because in Minecraft you could go around the structure that you built and with the paper it made the structure even better because we looked at different angles and we could picture what it would look like in the future, the next time we go on that Minecraft book.
PI: So their routines helped you to plan what you were going to do down the road with your ... Okay, okay. Sean?
Sean: I definitely agree with James where ... My names Sean and I definitely agree with James because I thought it was really cool because we ... Like when we draw the pictures, it can help us plan out what we want to do next. And like, oh, we should take out this or maybe we should add this or we should reconfigure this.
PI: Okay. Anthony do you remember using the routines at all?
Anthony: A little bit.

PI: What do you sort of remember?
Anthony: How we looked at it from different perspectives.
PI: Perspectives. What did you look at?
Anthony: I looked at I think, my thing that I made.
PI: What, the Makey Makey thing or something else?
Anthony: No. My piece of paper when I look underneath it and I could see, when I put it up to the light I could see a pencil mark [inaudible 00:07:16].
PI: For that board that you made for ... Good, okay.
Anthony: Yeah.
PI: Good. How about you guys, do you remember using the routines at all?
Callan: My names Callan. I was in Dan's group and it was cool because we could breakdown the pieces that we had.
PI: Okay. Oliver?
Oliver: Hi. My name is Oliver and I really liked doing my LEGO projects because I could look at them from different areas and see what I did wrong and I could see what I could add and maybe get rid of to see if I could ... on my car I could add two wheels and two motors-
PI: What about with your Bay Blades? Did you use the routine with your Beyblades that you were making?
Oliver: Yeah.

PI: So you'd sketch those out too?
Oliver: Yeah, I would sketch those out too.
PI: Okay. Hailey?
Hailey: My names Hailey and I liked doing Makey Makey because I got to look at it from different perspectives.
PI: Perspectives? Good for you. So you used those routines to help you design that Makey Makey? Okay, good. Let me ask you this, I know you guys all know the answer to this one. We used some cool technology tools and one of the things that we used was Flipgrid. Can you tell me what you thought about it? How did it help you with your project and also how did it help you with your thinking, like how you thought about things? Think for just a minute, how does Flipgrid help you think about your thinking? What do you want to say there Anthony?
Anthony: It helps you think because you can go back over to it and you can redo that video just in case you forget a little bit about it and it helps you thinks because we did the thing where other people watched our videos and they told what they thought about it.
PI: You like it because you can redo it, so that you get all your information in and you also like it because other people can give you feedback.
Anthony: Mm-hmm (affirmative).
PI: Okay. Rob?
Rob: I liked it because we did the tours and when one person was on a [inaudible 00:10:15] and I really wanted to go I could look at the video of the tour and see what I should do when I go on. That helped me.
PI: Okay. James?

James: My name is James and I'm with Rob, if somebody else was on ... and I really liked the Flipgrid four that we did. We looked back at other people's invent-
PI: Projects?
James: Projects and we on Flipgrid four-
PI: I remember that, week four, yeah.
James: We did feedback for those people who we watched and so those people could do it and I got a really good feedback that we should maybe add more doors and add more entrances and we were thinking about maybe adding a drawbridge.
PI: So did you actually add in more doors from that feedback?
James: Yeah.
PI: On your Minecraft? Okay Sean anything on ...
Sean: I like the Flipgrid because you can look back at it and see what you could do to it and I also liked it because you could see what your other friends are doing so could see what other people are doing and I also liked it because it could help me do stuff like, okay maybe I can do that or-
Speaker 13: [inaudible 00:11:46]
PI: Sorry say that again Sean.
Sean: Because I can maybe add something on that I was like, Wow. I think my friends think I should add this or take away this.
PI: So you could go back and revise your first version of the project. Okay.
PI: Anybody else from that group want to say anything?

Kevin: No.
PI: Okay. Oliver do you want to say anything about Flipgrid?
Oliver: I really liked Flipgrid because I could see if I did anything right or wrong and I could also look at other people's work so I could give feedback to others to see if they could add on what I said.
PI: Okay. And how about you Hailey, do you like Flipgrid?
Hailey: Mm-hmm (affirmative)
PI: What did you think of it?
Hailey: I liked it because I could look back at ...
PI: At what you did?
Hailey: Mm-hmm (affirmative)
PI: Did anyone give you feedback on your Makey Makey project?
Hailey: Yes.
PI: Did you use any of their ideas or were you like "No way, I'm not using that feedback". What did they tell you to do, or suggest that you do, do you remember?
Hailey: I don't remember.
PI: No? It's okay I can go back and look. Anything else about Flipgrid?
PI: James?

James: Sometimes I didn't like Flipgrid, some days I didn't because I was really into it and when we got to fourth grade we had to stop working on our project and if we didn't have Flipgrid we could make more progress on our project.

PI: So you thought that having to do that interrupted your project and you could have had more time?

James: Yes.

PI: Okay. Sean?

Sean: I definitely agree with James because sometimes I really want to work on my project a little more but then we have to do the Flipgrid and stop doing what we're doing.

PI: All right, I get you.

Students: [crosstalk 00:14:17]

PI: You would have rather been doing your work. Okay, yeah-

Anthony: I just wanted to say that Kevin said copiers to them-

PI: Kevin, my professors are seeing this so it's really good to have feedback and sometimes it's okay if we have the same ideas because it will help us think about new ideas. Okay? All right so we're going to go, speaking of feedback, Mrs. Smith and Mrs. Davis ... I don't know if Mrs. Davis your class, sometimes maybe she was. But Mrs. Smith was usually always there and sometimes she would give feedback so I wanted to know if she gave you feedback did you use it? How did it make you feel? Did it help you with your projects? What do you think?

PI: Hey Anthony did Mrs. Smith give you any feedback about your Makey Makey?

Anthony: No.

PI: No. How about you Hailey?

Hailey: No.
PI: Not so much, how about you?
Oliver: No.
PI: Not so much.
Kevin: No.
PI: All right let me ask you this, I'm going off the script as usual, did we talk about your friends giving you feedback on the Flipgrid, so that you found helpful?
Students: Yes.
PI: Did anyone else give you feedback while you were actually working on your stuff? You were in the moment, you were working on the Flipgrid? You were working on the Minecraft or your Makey Makey? I think ... I was in there a couple of times. I think I saw, sometimes, somebody was giving you feedback.
Yeah.
James: I was walking up and Kevin B., he's not here, he came up and he was like, "Hey James" I don' remember but he was like, "maybe you could add this, it'll make it a lot cooler". Because he was working on the computer next to me.
PI: Ah, so he was right near you. He was like, "Hey, what are you doing? Let me tell you some ideas". Okay.
PI: I know, alright. I want to know, all of you, I picked you because you all have projects. I want you to tell me how you came up with your project idea and what kinds of things did you do to make your project?
My Minecraft group.

James: Originally I was doing Flipgrid-
PI: I remember.
James: Then when Mrs. Smith told us about the papers that we were going to get next and I was wondering to myself, "How am I going to do this with Flipgrid?"
Sean: I noticed Sean and Rob were working on a really cool Minecraft world and that week I asked them if I could join them because I didn't know how I was going to do that with Flipgrid. They said I could. I helped a lot. Instead of snowballs, I changed it into fire charges which are like fireballs-
PI: Cool.
James: And it made them go a lot farther.
PI: So you had some new talents.
James: Yeah.
PI: Sean.
Sean: I was in Rob and James's group. When we were making the castle because I gave Rob the Castle idea and the river. Because I use to play Minecraft all the time on my iPad and I used to build castles on top of hills and stuff and I never built one in the water. I was like, "Why don't we try to build a castle". I really like building castles in Minecraft.
PI: Okay. Anthony, how about you with your Makey Makey? Because that was challenging for you at the beginning. I remember when you were first starting with that. How did you decide to do that? Why did you decide to do that?
Anthony: I was thinking about first doing the LEGOs but then thought, no because I was having trouble coming up with what to make with the LEGOs [inaudible 00:19:02].

PI: So then you went to the Makey Makey?
Anthony: After that, I was thinking about what I should do and I thought about making a Makey Makey game board. Then I started out with just the normal [inaudible 00:19:19] and then I added on to the [inaudible 00:19:19] making them really thick.
PI: Why?
Anthony: Then I made some buttons.
PI: Why does making them thicker ... what does that do?
Anthony: It makes it so it's easier to use them.
PI: Nice. Okay.
Oliver: Make the signal stronger.
PI: Yup, I know what you're talking about. Yup, I know exactly.
What do you want to say there guys?
No permission Dan: First, it was just me and Callan and we started to build a underground lair house but that didn't work so good so we started to build a mini house. Then Kevin joined on and her was like, "How about we build a mansion?" We started to build that. We built stairs up to a deck and then we built fences around it. When you jump off the fence there's a pool and you land right in the pool.
PI: Wow. Callan.
Callan: Before that, we had us three work together. We started a basketball hoop. Then-
PI: I remember.

Callan: That didn't work. Kevin quit our group and then me and Dan [inaudible 00:20:27]. Then we didn't have ... people were joining our group and making then destroying it. Then me and Dan were like, "We need that someone else". So we got Kevin back.

PI: Okay. Oliver, what do you think about your ... How did you come up with your ideas?

Oliver: A long time ago, back in December ... I don't know if it was in December or not. We started making motor [inaudible 00:20:57], the entire class made durations with motor and memory boxes. Me, Alfie] and Kevin B. made Beyblades. Once we started [inaudible 00:21:11] Makerspace and wanted to do LEGOs because they were already taken apart. I said to myself, "I want to recreate what we did and make it even better than before".

PI: Okay.

Oliver: And for my car I figured that if I added one wheel it ... One big one it would go well, but then I saw that it could tip over and stuff. Then I added two wheels and two motors and two battery boxes so they could go in the same direction. The wheels kept on rolling down the street. I just tested it out today and it just popped a wheelie and kept on moving.

PI: Oh my gosh, I can't to see how these all turned out.

Hailey, how did you come up with your idea?

Hailey: I was playing on the computer [inaudible 00:22:08] was like, how about I start doing Makey Makey? I saw June doing it-

PI: So you saw your other friends doing it? Anthony was doing it right?

Hailey: Mmm-hmm (affirmative).

PI: And then you came up with a game board?

Hailey: Mmm-hmm (affirmative).

PI: Okay.
Alright, you guys okay?
Students: Yes.
PI: I know you're getting wiggly. I promise we aren't going to keep you much longer. I have to go do some interviews with people for something else.
Real quick, first thing that comes to your head. What are some projects you would like to design in the future if we had anything in the Makerspace? Anything at Sickle Studios. I'm going to go quickly right around. You don't have to put your hands up.
Callan, say your name and what would you like to design and why?
Callan: My name is Callan and I would like to ... on Scratch, make a game on the basketball.
PI: Okay.
Kevin: My name's Kevin and I would love to try to make a metal contraption as they do in sixth grade Knollwood as they let you do at the laser thing and they let you make stuff. I would like to do that [crosstalk 00:23:13]-
PI: Some laser work. Okay. Yeah, someone else was asking. I'll tell you what they added [inaudible 00:23:18]. I'll tell you later.
PI: How about you Oliver?
Oliver: Something else that I would like to do with LEGOs that's a lot more complex is try and work in a group and I could build a boat. That I could try and make float a little.
PI: Nice. Go to McCarter pond right?

Oliver: I on one of my Bey Blades there's this thing that looks like a propeller and I would build down a little with some bricks and put a motor there-
PI: Alright so-
Oliver: I would put the battery box on there.
PI: Okay.
Oliver: I would turn the battery box on, the motor would spin the propeller and would try and partly move in the water.
PI: Cool idea.
Hailey, what would you do? What would you want to design or build? Anything. Whatever you want. You want to think about it?
Anthony, how about you? If you could do anything in there, what would you do?
Anthony: Make a video game console.
PI: Cool.
How about you Sean? You can have the same idea, it's okay.
Sean: I'd like to keep working on a video game I've been working on.
James: I would want to make a video game console, similar to Xbox.
PI: Interesting because we saw with second grade, right, they talked about cardboard challenge being one of their favorite things but not so much ... It's interesting, each grade it's a little bit different.

PI: Alright, last thing. What did you learn in Sickle Studios? What did you actually learn? You were like, "Alright I did this [inaudible 00:25:33]. What do I know now that I didn't learn before or what do I learn about myself?" What did you learn?
Let's start with Hailey this time?
Hailey: I learned that ...
PI: You want to think about ... I'll come back to you. It's okay, you can think.
PI: James?
James: Rob, at first I was in the beginning of the Minecraft. Then when I joined I was terrible at Minecraft. I didn't know any of the controls. A few times Sean and Rob kept up with me and now I actually know what to do and I actually can make stuff. I'm not as good as them but I okay.
PI: You're okay because they helped you. You had feedback from your friends.
James: Yeah.
PI: Sean?
Sean: I didn't really learn anything-
PI: What! Nothing? Not one thing?
Sean: Nope.
PI: Did you learn anything about yourself as a learner? What kind of learner you are? Things you like to do? Something ... you discovered something different?
Sean: I learned I like to play Minecraft.
PI: Okay. Oliver what did you learn?

Oliver: I learned that LEGOs can ... if you make something like that, as a model and it works, you could lead to different inventions in the future.
PI: Anthony? What did you learn?
Anthony: That a piece of paper can help you with technology cause [inaudible 00:27:45] with the Makey Makey it was attached [inaudible 00:27:48].
PI: I see you shaking your head Hailey. Did you think the same thing?
Hailey: Mmm-hmm (affirmative).
PI: Wow. Go ahead.
Kevin: I learned how to use a bow on Minecraft PC. Dan and Callan taught me that cause I had no idea how to.
Is that anything we can do to make Sickle Studios better besides not making you do the Flipgrids at the end?
James: I think Sean might be thinking the same thing, maybe. He already has one-
PI: It's okay, go ahead, tell me. Go Go Go.
James: My mom said I'm allowed to make a YouTube channel in school, anytime, anywhere.
PI: Yeah, I have one. You could make a YouTube channel. You have a Gmail, you could totally make one. I don't know if you're allowed to but you have access.
Mr. D: No you don't.

PI: Can you?
Mr. D: Probably.
PI: Yeah-
Kevin: You need the right equipment.
James: I was thinking maybe we would make it better by making a YouTube channel and working on it at school.
PI: That's cool. Alright, you want to do more with video production.
James: Yeah.
PI: Alright. Anything else that could make Sickle Studios better? Yeah.
Sean: I agree with James, we could have these little recording studios where there would be a little desk and there would be a background and-
PI: We have that. The green screen and we do have Wee Video. We just let you guys pick what you wanted but we do have that if you want to do something like that.
Sean: And also letting us have a little more free time when we're ... Some days where we could just have free time. Where we would just go on [inaudible 00:29:47] and play if you-
PI: Kind of like what we did with genius hour but in all your class, right?
Sean: Yeah.
PI: Okay. Anything else? Do you guys actually like the makerspace?

Students: YEAH!

Oliver: It was probably my favorite thing [inaudible 00:29:58].

GRADE 2 CLEANED DATA

PI: Good morning, and welcome to our focus group session. Thanks for taking the time to join me to talk about your experiences in Sickle Studios. As you know, I'm PI. I'm interested in gathering more information about you and your work in Sickle Studios. All answers are welcome. Your feedback will help us improve the maker's space for other classes.

PI: You've probably noticed that we have the podcaster out. I'm video recording this session, or actually Mr. D. is, because I don't want to miss any of your comments. People often say very helpful things in these discussions, and I can't write fast enough to get them all down. So, what I'll do is, I'll record this and then I'll get it transcribed. It's really pretty cool.

PI: I will ask different questions and you may respond to all of them, some of them, or none of them. Do whatever feels comfortable for you. We'll give everybody a chance to speak. Sound good? Any questions before we officially start?

PI: Okay, so I'm gonna go right around the group, and you don't have to say the same things as your friends, okay? Really talk about what you liked doing. Think back to all the activities at Sickle Studios. We had coding, we had makey-makeys, we had cardboard challenge, we had Minecraft, we had the gardens, Legos, and other things that I may even totally be forgetting. So kinda think in your head, what were some of your favorite things. And every time you speak you say, "My name is Kayla, and my favorite thing was ... " Alright? Does that make sense? Okay. So, what is your favorite thing to do in Sickle Studios and why?

Nathan: My name Logan, and I like the cardboard challenge because it's fun to cut it and then build with it.

David: My name is David, and I like the Legos because you can make whatever you want.

Sophia: My name is Sophia, and I like makey-makey because you can really let your imagination run wild and make whatever you want.

Paige: My name is Paige, I really like Minecraft because you can be creative.

Mark: My name is Mark, and I like motorized Legos because you get to make it move.

PI: Okay, good! Does anyone want to add anything to any of those comments?

PI: No? Okay. So the next thing we're gonna talk about it is the Agency by Design Thinking Routines. Alright? So you remember the two that you worked with were Looking Closely and Exploring Complexity. First was Looking Closely and then Exploring Complexity.

PI: So which ones did you like the best? Actually I'm gonna do this. There's a couple questions. So first you're gonna describe the routine that you liked the best. Does that sound good? And you can add in and we'll go from there.

No permission Jude: What do you mean by the routine?

PI: Remember you did Looking Closely? Which is when you had that paper, and you looked at it from one angle and you labeled all the parts. You talked about your object and how you can make it more beautiful and all that. And the Exploring Complexity, you were looking at the relationship. Why did they use this particular fabric? Or why did they use this particular product to make it? And if you don't remember it, it's okay, that's part of the study. Like if you totally forget what you did, it's okay!

Sophia: Wait, was Exploring Complexity a different day [inaudible 00:04:02]?

PI: Yes, so the first one was Looking Closely and the second one was Exploring Complexity.

Sophia: I wasn't there for Exploring Complexity.

PI: So you might not have been, okay. And this is part of what's gonna happen in the study, sometimes you guys are kids and you forget and it was a long time ago, so that's fine.

PI: We'll change it a little bit. If there's anything that you remember about doing them, or whatever you remember. So Caleb, why don't you go first. And if you don't remember you can say, "I really don't remember using them."

Nathan: I can't.

PI: You can't remember? Okay.

David: I can't remember.

Sophia: I can't remember.

PI: (laughs) Do you remember any of it? It's okay if you don't.

Paige: Nope.
PI: You're not in trouble! Mark?
Mark: Did a garden.
PI: So did you design the garden? Is that you what you did for yours?
Mark: Yeah.
PI: Yeah, and I remember Mrs. Smith used that as an example. Sone kids looked at an Ipod, some kids looked at Minecraft, and some kids looked at a Lego.
Paige: I just remembered it .
PI: You remembered it! Okay! See this is why we do a focus panel! Go Paige, what do you remember?
Paige: I remember I had my object, which was a dead Ipad, and looking at it from the different angles.
PI: And do you think that skill helps you with doing projects in the makerspace
Paige: Yes.
PI: How come? Why?
Paige: Because then you can look at stuff and say, "I don't really like my thing from this angle, but I really like it from this angle." So then you can change from it from that angle to this angle.
PI: Anybody else remember anything?
Sophia: I remember something.

PI: Okay, keep going. Say your name, tell us what you remember.

Sophia: I'm Sophia and I had an Ipad. I remember that I looked at it, and what kind of parts there was, like the "home" button and the screen and everything.

PI: And what did you notice about it? Did that make you think about how the object works or anything?

Sophia: Yeah. It made me think about how people make it work by just pressing a button. Like, how?

PI: I know, it's really cool.

Paige: Interesting.

Nathan: My name is Nathan, and I remember that I brought in a gizmo, and I said all the parts and how to make it better.

PI: Do you remember what you said about making it better?

Nathan: No.

PI: Okay.

Mark: [inaudible 00:07:01]

PI: What do you want to say Mark?

Mark: I brought in a puppet chicken, and I remember that it had no wrist band on its leg.

PI: Okay. Someone was saying something over here, can you explain what it is? What did you say?

Nathan: That was him.
PI: Anybody else think of anything with the Agency by Design Thinking Routines? Paige?
Paige: I also remember how I could make the iPad that was dead more beautiful. I could put a better background than it had on it, and get a case for it.
PI: You mean the background for the screen?
Paige: Yeah.
PI: Okay.
Paige: The background for the screen, so it can look better when I turn it on. I could get one of those things that you put behind it like a phone thingy.
Mark: A pop socket?
Paige: No, a phone case, but something for an IPad.
PI: Mm-hmm (affirmative)
Paige: So it doesn't look like a plain thing that no one really goes on.
PI: Okay. Anybody else wanna add anything that they remember? It's okay, if you think of something later you can always tell me and we can back pedal. Okay?
PI: Alright, so the next thing we're gonna talk about are technology tools. One of them that we used a lot in this class was Flipgrid. And I think you remember using that a lot because I looked through your videos and some of them were really interesting, some of them were silly. What did you do with the Flipgrid to help you with your thinking? Not just to do your acting or be silly, but how did the Flipgrid help you with thinking about your project?

PI: So think for a minute. Put it in your head and kind of think, "How did that help me with my thinking?"
PI: Alright, you had 90 seconds to talk on the Flipgrid, and you had a prepared statement. So how did that help you with your thinking? What did you have to do? Mark?
Mark: It helps you remember what your project will be.
PI: Okay. Jude, do you remember anything? Okay. We'll come back to you. Paige?
Paige: You could think about something that you did, and then record it and you could think, "I could do this, I could make a unicorn house", but you didn't do it yet, and then you could put into your Flipgrid and say, "I'm gonna do it." Then next time when you look back on you Flipgrid you could be like, "Oh yeah, I could make a unicorn house this time!"
PI: Did you end up making a unicorn house?
Paige: We did!
PI: I know! I remember seeing it in your video! So that helped you to remember what you wanted to do the next time?
Paige: Yeah.
PI: Interesting. Sophia, you wanna add to that?
Sophia: I think the Flipgrids helped me think more. It helped me think of stuff to add onto mine, and just review what I did for the past week or so.
PI: Okay. So it helped you remember, and make plans, is what you're thinking.

Paige: [inaudible 00:11:17] build and then you can put that into your Flipgrid as a compliment to the other person's Flipgrid.

Sophia: The Flipgrid also helped me because, as they said the feedback, you should add onto it and make something. And it would help you, so then you could use that feedback to make your build better.

PI: Paige, then I want to make sure we go to Nathan

Paige: I'm gonna add onto Sophia's. It could really help you because when you get that feedback from the other person you could think, "Oh yeah, I could really build that." And you could thank the person who gave you that feedback, and tell them that you like their feedback, or you didn't like their feedback. And you could either do their feedback, or don't do their feedback.

PI: Okay, so it gives you the confidence to use their feedback as well? Interesting. Nathan? Anything you can think of to add about the Flipgrid?

Nathan: No.

PI: Alright. Well I was gonna talk to you about the Wonderboards but I don't think we used them at this class. We tried it with our first session and we didn't find that to be helpful. So I'm gonna take that question out.

PI: But you were just talking about feedback, and your teachers, Mrs. Smith and Mrs. Davis, did they give you any feedback during their classes? And if they did, did you use it? Did it help you? Were you like, "Eh, I don't wanna do it"? Whoever wants to go first can go.

PI: Let me ask you this, did you guys like the feedback that you got for your peers?

Nathan: Pretty decent, decent.

PI: Pretty decent?

Nathan: Yeah.

PI: So let's go back to Mrs. Smith and Mrs. Davis. So did their feedback help you at all? Sophia?

Sophia: Well when me and Paige showed Mrs. Smith our world, she asked us how we made it. We had a little turtle named Jeff ...
PI: Is he in your Minecraft video?
Sophia: Yeah!
PI: Okay.
Sophia: We had a little turtle named Jeff, and she asked us, "How did you make him different colors?" Because when you get him he's green, he doesn't have anything on, but you can change it to have a crown on his head, and he can be blue.
PI: So she gave you that feedback, that you should go look at the commands on Minecraft. Did you? What's his name again, Joe?
Sophia: Jeff.
PI: Did you change Jeff the turtle?
Sophia: Mm-hmm (affirmative)!
PI: Alright, I'll have to go check it out!
Sophia: He's King Jeff now.
PI: And he's in that video right? In your Flipgrid?
Sophia: Yeah.
PI: Okay, I'll go back and look at that. Paige?

Paige: I'm gonna add onto Sophia's. When Mrs. Smith came over to us she did say, "How did you build this? How did you get the idea to do this?" And she gave us feedback to help us do more stuff.
PI: Can you give an example?
Paige: Like with Jeff ...
PI: Jeff the turtle.
Paige: Yes.
PI: The king turtle.
Paige: When we first showed her, she was just green but on someone else's screen. Mrs. Smith saw that she was blue, so Mrs. Smith said to us, "Do you know how to change the colors?" And she gave us feedback and said that we did good at doing that, because you could also go into the turtle and be the turtle.
PI: What?!
Sophia: It's really cool! It's really cool!
Paige: You tap this video thing and you can ride the turtle.
Sophia: Yeah.
PI: So like virtual reality, that is cool!
Paige: So she said, "Do you know how to do stuff like this? Can you do it?" And she gave us compliments and a lot of good feedback on it.
PI: Mark?

Mark: We got feedback from Mrs. Smith, but when she gave us the idea to put a garden in-
PI: Mm-hmm (affirmative).
Mark: In the backyard because then we would [inaudible 00:16:46] with it because we thought it would be a good idea. And now since we really like the garden, we keep changing it to make it better and better.
PI: Cool! I can't wait to see some of your drawings. Do you have models of your garden? Or you're doing it as a class project?
Mark: [inaudible 00:17:04] are doing it.
PI: Okay good. I'll check that out. Nathan.
Nathan: I remember that we did the compliment sandwich ...
PI: A compliment sandwich, yeah! What's a compliment sandwich?
Nathan: You give them a compliment, then they can add to your compliment.
PI: Mm-hmm (affirmative). And did people give you compliments sandwiches?
Nathan: Yeah.
PI: How did you feel when you got a compliment sandwich?
Nathan: Happy.
PI: Did you use any of their feedback? The middle piece?

Nathan: Yeah.

PI: Yeah? Can you give me an example?

Nathan: I think they said to put a drawer and then we put it on.

PI: Paige what do you like [inaudible 00:18:18]?

Paige: On the compliment sandwich, I remember David giving me and Sophia really good feedback. Like we could add a pool around our beacon, and we did do that.

PI: So you did incorporate their feedback.

Paige: To make it look better.

PI: Nice! Any other comments about Mrs. Smith and Mrs. Davis giving you feedback?

Students: No.

PI: That's what I thought. So, if you could design any project in the future in Sickle Studios, you guys are gonna be third graders next year right? What are some things that you would like to design? Think about it, and I'll go-

Sophia: Like anything?

PI: Anything. Sophia?

Sophia: I wanna do wood carvings, and then we could paint it. I wanna do that.

Paige: I agree with Sophia, we could do wood carvings and paint them but we do it as team or something. Like you could have four people as partners and you have to agree on something to do. So you can cooperate with each other, and build something that you all agree on, but you would have your own part.

PI: So you like it better doing it as a team. Sophia, do you like doing it by yourself, or as a team?
Sophia: I like to do it by myself because you can do anything to want. And with a team, you have to agree, and don't really like to agree that much. I like to do my own thing.
Paige: I mean, make something you agree on, but in it you have your own part that you work on separately. But then once you have it all built, painted, and dried and everything, then you could put it where you want it. So it's sort of yourself.
PI: You can ask her a question, go ahead.
Sophia: But the arguing of who's gonna take it home ...
PI: So, you all wanna have your own product to take home, is that what you mean?
Sophia: Yeah.
Paige: What I mean, is then when it's done you could take it apart, and then take away the part that you did. I mean, you would use it with tape on the inside, if you made something like that you could put it on the inside. If you're having an argument about who takes it home, but if you agreed on someone then that person could just take it all.
PI: Okay. What are some other things you guys would like to make in Maker's Space in Sickle studios? Nathan.
Nathan: I wanna look at 3D makers.
PI: 3D printers?
Nathan: Yeah.
PI: What are you gonna make with a 3D printer?
Nathan: I don't know.

PI: You don't know? Just want one?
Paige: I have an idea.
PI: Sure.
Paige: Maybe before you actually build what you wanna build, you could get a piece of paper, and sketch out what you wanna build before you actually build it.
Sophia: Like blueprints?
Paige: Yeah, like blueprints. Because if you build it, and it doesn't look how you want it look, you could sketch it out so you know what you want it to look like.
PI: Okay.
Paige: So it doesn't just [crosstalk 00:34:53].
PI: Yeah! So you feel like we need to do more sketching.
Paige: Yeah.
PI: Okay.
Sophia: In media, I wanna do more do-it-yourselves and more customizing things. I feel like those are really fun, because you can create something that you really like.
PI: Okay, so more opportunities to do things yourself?
Sophia: Like in stores, say you wanna find a specific thing, but they don't have that, so you just have to get a different one, so then you can make it how you want it to look, and then you can have whatever you want.
PI: Okay. Alright, let me ask just one more questioning Paige, and then we'll come back to you.

PI: So, you told me about some of the projects you'd like to do. You told me that some of you like working by yourself, and some of you like working in partners. You told me some of the things that would make The makerspace better. I'm just curious, what did you actually learn? Think about it for a second. What did you actually learn during this whole process? Nathan.
Nathan: When we did Makey-Makey, I really liked it, so then I bought one, I put it on my Christmas list, and now I have one.
PI: So prior to the study, you played with Makey-Makey, and then you got it for Christmas.
Nathan: Yeah.
PI: Nice.
Sophia: It helped me learn how to do more stuff, and create more stuff. In the makerspace, they really let you basically do anything you want that they have, so it helped me learn how to control stuff, and use stuff better.
Paige: It helped me to cooperate with other people, because sometimes I take over a project, I just become the boss of it. The makerspace helped me learn how to cooperate with other people, like a partner or in a group.
PI: Nice!
Sophia: Same with me.
PI: Same with you? What did you want to say?
Paige: I have something to add to Sophia for the last one.
PI: Okay.

Paige: For the last question that we did, I agree and disagree with Sophia. Like I said, I disagree with Sophia because you should sort of work with a partner, because you could cooperate a lot, and work as a team. But I agree with Sophia that you could do your own private thing, which is good because you could create even more than when you work with a couple. But I disagree again with Sophia because ...
Sophia: I learned a lot about the world in the makerspace.
PI: What do you mean?
Sophia: There's a lot of stuff to learn about, so when they let us take out books, I usually take out some non-fiction books, and it helps me learn about stuff. And-
PI: And you get to pick whatever book you want?
Sophia: Yeah, and now I can help my mom with stuff, like when she asks me some questions.
PI: Okay.
Sophia: That second graders won't usually answer
PI: Okay.
Sophia: I can actually answer them.
PI: Alright. So this is my last question. So, when I first [inaudible 00:39:27] you guys, I promised a pizza party, right? What's today? June 13th?

Appendix M: Student Focus-Panel Interview Code Book

Code	Definition	Examples
Peer Feedback		
Peer Model (PM)	Any reference to the impact of a peer physically or verbally modeling how to use a particular tool but not verbally giving feedback to the participant about his or her project.	Hailey: I was playing on the computer and I was like, how about I start doing Makey Makey? I saw Jill doing it.
Verbal peer feedback (VPF)	Any reference to the impact of verbal peer feedback while working in real-time in the makerspace on the development of a project (not on the Flipgrid).	James; I was walking up and Kevin B., he's not here, he came up and he was like, 'Hey James…maybe you could add this, it'll make it a lot cooler.' because he was working on the computer next to me.
Peer Flipgrid Feedback (PFF)	Any reference to how a peer provided feedback on the Flipgrid regarding the project to the participant	Paige: I'm gonna add onto Sophia's. It could really help you because when you get that feedback from the other person you could think, "Oh yeah, I could really build that." And you could thank the person who gave you that feedback, and tell them that you like their feedback, or you didn't like their feedback. And you could either do their feedback, or don't do their feedback.
Teacher Feedback		
Teacher – Project Affirmative (TP+)	Any reference to interactions with a teacher during which she provided students with advice or guidance about a specific aspect of making the projects.	Paige: When we first showed her, she was just green but on someone else's screen. Mrs. Smith saw that she was blue, so Mrs. Smith said to us, "Do you know how to change the colors?" And she gave us feedback and said that we did good at doing that, because you could also go into the turtle and be the turtle.
Teacher – Project Negative (TP-)	Any reference to the lack of feedback or interactions with a teacher when asked if the teacher provided feedback to the participant.	PI: Hey Anthony did Mrs. Smith give you any feedback about your Makey Makey? Anthony: No.
Teacher – Materials (TM)	Any reference to interactions with a teacher during which she provided students with information about the makerspace materials/tools available or how to use the materials/tools.	WE DID NOT END UP USING THIS ONE.

Making Students' Thinking Visible		
Flipgrid Self-Monitoring (FSM)	Any reference to how the use of the Flipgrid helped the participant track his or her progress..	"I think the Flipgrids helped me think more. It helped me think of stuff to add onto mine, and just review what I did for the past week or so." (Student)
Application of AbD Thinking Routines (AoAbDTR)	Any reference the participants articulated about they used the AbD Thinking Routine to help them develop their projects or how a teacher observed students using the AbD Thinking Routines during the development of their projects.	"I liked [Exploring Complexity]. Looking from different angles and giving the materials that we used. I was with Rob and Sean using ... we were on Minecraft and it was really easy like Rob said because in Minecraft you could go around the structure that you built and with the paper it made the structure even better because we looked at different angles and we could picture what it would look like in the future, the next time we go on that Minecraft book."
Learning		
Learning – Skill (LS)	References to how students reported they learned to use a makerspace tool or a skill they developed	"I learned that LEGOs can…(be a) model and (if) it works, you could lead to different inventions in the future."
Learning – Self as Learner (LSaL)	Any reference to how students viewed themselves as learners, aware of what they were doing or how they processed information to work on their projects.	"Then when Mrs. Smith told us about the papers that we were going to get next and I was wondering to myself, "How am I going to do this with Flipgrid?"
Engagement		
Engagement – Tools (ET)	Any references to preferences of tool usage.	"Chromebooks is my favorite thing because I can go on multiple different kinds of websites and I can play multiple games on each website."
Engagement - Perseverance (EP)	Any reference to how a participant behaved when frustrated in the makerspace.	"That didn't work. Kevin quit our group and then me and Dan [inaudible 00:20:27]. Then we didn't have ... people were joining our group and making then destroying it. Then me and Dan were like, 'We need that someone else.' So we got Kevin back."

Grade	Area	Idea Unit	Coder I	Coder 2	Coder 3
3	Engagement	James: Sometimes I didn't like Flipgrid, some days I didn't because I was really into it and when we got to fourth grade we had to stop working on our project and if we didn't have Flipgrid we could make more progress on our project. PI: So you thought that having to do that interrupted your project and you could have had more time? James: Yes.	EP	EP	EP
3	Engagement	Sean: I definitely agree with James because sometimes I really want to work on my project a little more but then we have to do the Flipgrid and stop doing what we're doing.	EP	EP	EP
3	Engagement	Anthony: I was thinking about first doing the LEGOs but then thought, no because I was having trouble coming up with what to make with the LEGOs [inaudible 00:19:02]. PI: So then you went to the Makey Makey? Anthony: After that, I was thinking about what I should do and I thought about making a Makey Makey game board. Then I started out with just the normal [inaudible 00:19:19] and then I added on to the [inaudible 00:19:19] making them really thick.	EP	EP	EP
3	Engagement	Callan: That didn't work. Kevin quit our group and then me and Dan [inaudible 00:20:27]. Then we didn't have ... people were joining our group and making then destroying it. Then me and Dan were like, "We need that someone else". So we got Kevin back.	EP	EP	EP
3	Engagement	Oliver: A long time ago, back in December ... I don't know if it was in December or not. We started making motor [inaudible 00:20:57], the entire class made durations with motor and memory boxes. Me, Alfie and Kevin B. made Beyblades. Once we started [inaudible 00:21:11] Makerspace and wanted to do LEGOs because they were already taken apart. I said to myself, "I want to recreate what we did and make it even better than before".	EP	EP	EP
3	Engagement	Oliver: And for my car I figured that if I added one wheel it ... One big one it would go well, but then I saw that it could tip over and stuff. Then I added two wheels and two motors and two battery boxes so they could go in the same direction. The wheels kept on rolling down the street. I just tested it out today and it just popped a wheelie and kept on moving.	EP	EP	EP
2	Engagement	Nathan: My name is Nathan and I like the cardboard challenge because it's fun to cut it and then build with it.	ET	ET	ET
2	Engagement	David: My name is David, and I like the Legos because you can make whatever you want.	ET	ET	ET

2	Engagement	Sophia: My name is Sophia, and I like Makey Makey because you can really let your imagination run wild and make whatever you want.	ET	ET	ET
2	Engagement	Paige: My name is Paige, I really like Minecraft because you can be creative.	ET	ET	ET
2	Engagement	Mark: My name is Mark, and I like motorized Legos because you get to make it move.	ET	ET	ET
2	Engagement	Nathan: When we did Makey-Makey, I really liked it, so then I bought one, I put it on my Christmas list, and now I have one.	ET	ET	ET
3	Engagement	Callan: My favorite thing was to play with my friends and play LEGO wars.	ET	ET	ET
3	Engagement	Oliver: My favorite thing to do in the makerspace is use the Chromebooks and play with the LEGOs to make Beyblades. My favorite thing to do on Chromebooks is go on to ABCya! onto Blue because there is a variety of different games that I can play and play with my friends	ET	ET	ET
3	Engagement	Kevin: Everything is to play with my friends. Playing Minecraft with them, and playing on the Chromebooks with them.	ET	ET	ET
3	Engagement	Anthony: My favorite thing to do is play games on the Chromebooks because you can go play a lot of things on the Symbaloo which is the thing I really like.	ET	ET	ET
3	Engagement	James: Chromebooks is my favorite thing because I can go on multiple of different kinds of websites and I can play multiple games on each website.	ET	ET	ET
3	Engagement	Sean: My favorite ... the reason I like using the Chromebooks is because I like to play different games on the Chromebooks. It's simpler.	ET	ET	ET
3	Engagement	Kevin: I liked Chromebooks because it has Scratch and Scratch is a really fun website. Basically, you get to see other people's projects and I played other people's projects with my friends and also I can make my own project, which is really cool.	ET	ET	ET
3	Engagement	Sean: I learned I like to play Minecraft.	ET	ET	ET
2	Learning	Paige: It helped me to cooperate with other people, because sometimes I take over a project, I just become the boss of it. The Maker's Space helped me learn how to cooperate with other people, like a partner or in a group.	LSaL	LSaL	LSaL
2	Learning	Sophia: Same with me. (Adding on to Paige's comments)	LSaL	LSaL	LSaL
2	Learning	Paige: For the last question that we did, I agree and disagree with Sophia. Like I said, I disagree with Sophia because you should sort of work with a partner, because you could cooperate a lot, and work as a team. But I agree with Sophia that you could do your own private thing, which is good because you could create even more than when you work with a couple.	LSaL	LSaL	LSaL
3	Learning	James: Then when Mrs. Smith told us about the papers that we were going to get next and I was wondering to myself, "How am I going to do this with Flipgrid?"	LSaL	LSaL	LSaL
3	Learning	James: I noticed Sean and Rob were working on a really cool	LSaL	LSaL	LSaL

		Minecraft world and that week I asked them if I could join them because I didn't know how I was going to do that with Flipgrid. They said I could. I helped a lot. Instead of snowballs, I changed it into fire charges which are like fireballs-			
2	Learning	Sophia: It helped me learn how to do more stuff, and create more stuff. Sickle Studio, they really let you basically do anything you want that they have, so it helped me learn how to control stuff, and use stuff better.	LS	LS	LS
2	Learning	Sophia: I learned a lot about the world in Sickle Studios. PI: What do you mean? Sophia: There's a lot of stuff to learn about, so when they let us take out books, I usually take out some non-fiction books, and it helps me learn about stuff. And-	LS	LS	LS
3	Learning	Anthony: Then I made some buttons. PI: Why does making them thicker ... what does that do? Anthony: It makes it so it's easier to use them. PI: Nice. Okay. Oliver: Make the signal stronger.	LS	LS	LS
3	Learning	James: Rob, at first I was in the beginning of the Minecraft. Then when I joined I was terrible at Minecraft. I didn't know any of the controls. A few times Sean and Rob kept up with me and now I actually know what to do and I actually can make stuff. I'm not as good as them but I okay.	LS	LS	LS
3	Learning	Oliver: I learned that LEGOs can ... if you make something like that, as a model and it works, you could lead to different inventions in the future.	LS	LS	LS
3	Learning	Anthony: That a piece of paper can help you with technology cause [inaudible 00:27:45] with the Makey Makey it was attached [inaudible 00:27:48].	LS	LS	LS
3	Learning	Kevin: I learned how to use a bow on Minecraft PC. Dan and Callan taught me that cause I had no idea how to.	LS	LS	LS
2	Making Students' Thinking Visible	PI: Yeah, and I remember Mrs. Smith used that as an example. Some kids looked at an Ipod, some kids looked at Minecraft, and some kids looked at a Lego. Paige: I just remembered it . PI: You remembered it! Okay! See this is why we do a focus panel! Go Paige, what do you remember?	AoAbDTR	AoAbDTR	AoAbDTR

		Paige: I remember I had my object, which was a dead Ipad, and looking at it from the different angles. PI: And do you think that skill helps you with doing projects in the makerspace Paige: Yes. PI: How come? Why? Paige: Because then you can look at stuff and say, "I don't really like my thing from this angle, but I really like it from this angle." So then you can change from it from that angle to this angle.			
3	Making Students' Thinking Visible	James: My name is James, I also agree with Rob. I liked the first one that we did. Looking from different angles and giving the materials that we used. I was with Rob and Sean using ... we were on Minecraft and it was really easy like Rob said because in Minecraft you could go around the structure that you built and with the paper it made the structure even better because we looked at different angles and we could picture what it would look like in the future, the next time we go on that Minecraft book.	AoAbDTR	AoAbDTR	AoAbDTR
3	Making Students' Thinking Visible	Sean: I definitely agree with James where ... My names Sean and I definitely agree with James because I thought it was really cool because we ... Like when we draw the pictures, it can help us plan out what we want to do next. And like, oh, we should take out this or maybe we should add this or we should reconfigure this.	AoAbDTR	AoAbDTR	AoAbDTR
3	Making Students' Thinking Visible	PI: Okay. Anthony do you remember using the routines at all? Anthony: A little bit. PI: What do you sort of remember? Anthony: How we looked at it from different perspectives. PI: Perspectives. What did you look at? Anthony: I looked at I think, my thing that I made. PI: What, the Makey Makey thing or something else? Anthony: No. My piece of paper when I look underneath it and I could see, when I put it up to the light I could see a pencil mark [inaudible 00:07:16].	AoAbDTR	AoAbDTR	AoAbDTR

		PI: For that board that you made for ... Good, okay. Anthony: Yeah.			
3	Making Students' Thinking Visible	Callan: My names Callan. I was in Dan's group and it was cool because we could breakdown the pieces that we had.	AoAbDTR	AoAbDTR	AoAbDTR
3	Making Students' Thinking Visible	Oliver: Hi. My name is Oliver and I really liked doing my LEGO projects because I could look at them from different areas and see what I did wrong and I could see what I could add and maybe get rid of to see if I could ... on my car I could add two wheels and two motors- PI: What about with your Bay Blades? Did you use the routine with your Beyblades that you were making? Oliver: Yeah. PI: So you'd sketch those out too? Oliver: Yeah, I would sketch those out too.	AoAbDTR	AoAbDTR	AoAbDTR
2	Making Students' Thinking Visible	Mark: It helps you remember what your project will be.	FSM	FSM	FSM
2	Making Students' Thinking Visible	Paige: You could think about something that you did, and then record it and you could think, "I could do this, I could make a unicorn house", but you didn't do it yet, and then you could put into your Flipgrid and say, "I'm gonna do it." Then next time when you look back on you Flipgrid you could be like, "Oh yeah, I could make a unicorn house this time!" PI: Did you end up making a unicorn house? Paige: We did!	FSM	FSM	FSM
2	Making Students' Thinking Visible	Sophia: I think the Flipgrids helped me think more. It helped me think of stuff to add onto mine, and just review what I did for the past week or so.	FSM	FSM	FSM
3	Making Students' Thinking Visible	Anthony: It helps you think because you can go back over to it and you can redo that video just in case you forget a little bit about it and(CONTINUED IN PEER FEEDBACK)	FSM	FSM	FSM
3	Making Students' Thinking Visible	Sean: I like the Flipgrid because you can look back at it and see what you could do to it and	FSM	FSM	FSM
3	Making Students' Thinking Visible	Oliver: I really liked Flipgrid because I could see if I did anything right or wrong	FSM	FSM	FSM
2	Peer Feedback	Paige: [inaudible 00:11:17] build and then you can put that into your Flipgrid as a complement to the other person's Flipgrid.	PFF	PFF	PFF
2	Peer Feedback	Sophia: The Flipgrid also helped me because, as they said the feedback, you should add onto it and make something. And it would help you, so then you could use that feedback to make your build better.	PFF	PFF	PFF

2	Peer Feedback	Paige: I'm gonna add onto Sophia's. It could really help you because when you get that feedback from the other person you could think, "Oh yeah, I could really build that." And you could thank the person who gave you that feedback, and tell them that you like their feedback, or you didn't like their feedback. And you could either do their feedback, or don't do their feedback.	PFF	PFF	PFF
3	Peer Feedback	(Anthony continued) it helps you thinks because we did the thing where other people watched our videos and they told what they thought about it. PI: You like it because you can redo it, so that you get all your information in and you also like it because other people can give you feedback. Anthony: Mm-hmm (affirmative).	PFF	PFF	PFF
3	Peer Feedback	James: My name is James and I'm with Rob, if somebody else was on ... and I really liked the Flipgrid four that we did. We looked back at other people's invent- PI: Projects? James: Projects and we on Flipgrid four- PI: I remember that, week four, yeah. James: We did feedback for those people who we watched and so those people could do it and I got a really good feedback that we should maybe add more doors and add more entrances and we were thinking about maybe adding a drawbridge. PI: So did you actually add in more doors from that feedback? James: Yeah.	PFF	PFF	PFF
3	Peer Feedback	Sean: I also liked it because you could see what your other friends are doing so could see what other people are doing and I also liked it because it could help me do stuff like, okay maybe I can do that .....(Inaudible) PI: Sorry say that again Sean. Sean: Because I can maybe add something on that I was like, Wow. I think my friends think I should add this or take away this. PI: So you could go back and revise your first version of the project. Okay.	PFF	PFF	PFF
3	Peer Feedback	(Oliver continued) and I could also look at other people's work so I could give feedback to others to see if they could add on what I said.	PFF	PFF	PFF
3	Peer Feedback	Sean: I was in Rob and James's group. When we were making the castle because I gave Rob the Castle idea and the river. Because I use to play Minecraft all the time on my iPad and I used to build castles on top of hills and stuff and I never built one in the water. I was like, "Why don't we try to build a castle". I really like building castles in	PM	PM	PM

		Minecraft.			
3	Peer Feedback	Hailey: I was playing on the computer [inaudible 00:22:08] was like, how about I start doing Makey Makey? I saw Jill doing it- PI: So you saw your other friends doing it? Anthony was doing it right? Hailey: Mmm-hmm (affirmative). PI: And then you came up with a game board? Hailey: Mmm-hmm (affirmative).	PM	PM	PM
2	Peer Feedback	Nathan: You give them a compliment, then they can add to your compliment. PI: Mm-hmm (affirmative). And did people give you compliments sandwiches? Nathan: Yeah. PI: How did you feel when you got a compliment sandwich? Nathan: Happy. PI: Did you use any of their feedback? The middle piece? Nathan: Yeah. PI: Yeah? Can you give me an example? Nathan: I think they said to put a drawer and then we put it on.	VPF	VPF	VPF
2	Peer Feedback	Paige: On the compliment sandwich, I remember David giving me and Sophia really good feedback. Like we could add a pool around our beacon, and we did do that. PI: So you did incorporate their feedback. Paige: To make it look better.	VPF	VPF	VPF
3	Peer Feedback	James: I was walking up and Kevin B., he's not here, he came up and he was like, "Hey James" I don' remember but he was like, "maybe you could add this, it'll make it a lot cooler". Because he was working on the computer next to me.	VPF	VPF	VPF
3	Teacher Feedback	PI: Hey Anthony did Mrs. Smith give you any feedback about your Makey Makey? Anthony: No.	TP-	TP-	TP-

3	Teacher Feedback	PI: No. How about you Hailey? Hailey: No.	TP-	TP-	TP-
3	Teacher Feedback	PI: Not so much, how about you? Oliver: No.	TP-	TP-	TP-
3	Teacher Feedback	PI: Not so much. Kevin: No.	TP-	TP-	TP-
2	Teacher Feedback	Sophia: Well when me and Paige showed Mrs. Smith our world, she asked us how we made it. We had a little turtle named Jeff ... PI: Is he in your Minecraft video? Sophia: Yeah! PI: Okay.Sophia: We had a little turtle named Jeff, and she asked us, "How did you make him different colors?" Because when you get him he's green, he doesn't have anything on, but you can change it to have a crown on his head, and he can be blue. PI: So she gave you that feedback, that you should go look at the commands on Minecraft. Did you? What's his name again, Joe? Sophia: Jeff. PI: Did you change Jeff the turtle? Sophia: Mm-hmm (affirmative)! PI: Alright, I'll have to go check it out! Sophia: He's King Jeff now.	TP+	TP+	TP+
2	Teacher Feedback	Paige: I'm gonna add onto Sophia's. When Mrs. Smith came over to us she did say, "How did you build this? How did you get the idea to do this?" And she gave us feedback to help us do more stuff. PI: Can you give an example? Paige: Like with Jeff ... PI: Jeff the turtle. Paige: Yes. PI: The king turtle.	TP+	TP+	TP+

Paige: When we first showed her, she was just green but on someone else's screen. Mrs. Smith saw that she was blue, so Mrs. Smith said to us, "Do you know how to change the colors?" And she gave us feedback and said that we did good at doing that, because you could also go into the turtle and be the turtle.

PI: What?!

Sophia: It's really cool! It's really cool!

Paige: You tap this video thing and you can ride the turtle.

Sophia: Yeah.

PI: So like virtual reality, that is cool!

Paige: So she said, "Do you know how to do stuff like this? Can you do it?" And she gave us compliments and a lot of good feedback on it.

Appendix N: Flipgrid Posts

Week*	Post
1	Please describe what you made in [the makerspace] today, (date). You have 90 seconds to respond. You can show your actual product, pictures, sketches, or anything that you would like. If you have questions about your project, you can ask them on the video too!
2	Today you used the thinking routine, "Looking Closely." • What kinds of things did you observe about your object? • What are its parts? • What are its purposes? • What are its complexities - meaning how do the parts and purpose relate to one another? • What kinds of questions or ideas do you have about your object?
3	Today you explored complexity of objects by analyzing its parts, perspectives, and how you interact with the object. Please answer the following questions about your object: • What are its parts? • What are its various pieces or components?
4	Today you engaged in the IMAGINE IF Thinking Routine. Consider the parts, purposes, and people who interact with your object or system, and then ask: • In what ways could it be made to be more effective? • In what ways could it be made to be more efficient? • In what ways could it be made to be more beautiful?
5	You now have the opportunity to choose your own projects and we are so interested to learn more details about your work. Use this Flipgrid to talk about your project, ask questions, or explain next steps.
6**	No Flipgrid this week for first rotation. Final Flipgrid for the second rotation (see prompt below).
7**	You now have the opportunity to choose your own projects and we are so interested to learn more details about your work. Use this Flipgrid to talk about your project, ask questions, or explain next steps.

*The first rotation of the study ran for seven weeks and followed the outline above.
**The second rotation of the study only ran for six weeks, so, the Week 7 prompt is actually the Week 6 final prompt for the second rotation.

Appendix O: Engagement Survey Analysis

Surveys designed to measure engagement were administered online via Google Forms before the study began and then again when the study was completed. Although four classes in total completed the surveys, one of the second grade class's data was not included as during the pre survey, because of a formatting error, participant emails were omitted and prohibited the research team from validating the different data entries. The team was concerned that some of the students in that class may have responded more than once; thus, their data was excluded. From the remaining three classes, three students submitted the survey more than once. Their data sets were averaged by each participant and included in the final results. Five students completed the pre survey but did not complete the post survey; therefore that data set was excluded from the results. In total, forty-three students' results from three classes are included.

Survey prompts were based on the Reeve & Tseng (2011) Protocol (Appendix G), which specifically examined four aspects of engagement: agentic, behavioral, emotional, and cognitive. Indicators were grouped by each engagement category. Differences in pre and post data ranged from -0.34 to 0.33 (Table 15). Two-tailed paired *t*-tests were used to compare students' pre and post survey data by each indicator. While there were not significant differences in most of the data collected, there were some trends across each set of prompts, which will be detailed by each type of engagement in the next sections.

Agentic engagement. Agentic engagement refers to "students' constructive contribution into the flow of the instruction they receive" (Reeve & Tseng, 2011, p. 258). This means students can personalize their learning and act with intentionality in determining the content and rationale of what is being learned. Prompts 1-5, measures of possible agentic engagement, indicated that students' self-reported agentic engagement did not increase, despite opportunities for self-directed learning and exposure to the AbDTR during the study. In response to Prompt 2, “I tell the teacher what I like and what I don’t like,” participants indicated a higher likelihood of doing so in the pre survey (1.70) than in the post survey (1.51). The two-tailed paired *t*-tail test indicated statistical significance for Prompt 2 (0.01).

Behavioral engagement. “Behavioral engagement refers to participation in the learning environment and…has often been operationalized in terms of how constructively or cooperatively children engage in classroom tasks and activities” (Ladd & Dinnella, 2009, p. 190). Responses to Prompts 6-10, possible indicators of behavioral engagement, documented that students’ self-reported interest in carefully listening to the teacher declined in the post survey (-0.3). However, Prompt 7 revealed students did self-report trying harder (+0.11) and Prompt 10 indicated students perceived themselves as paying more attention in class (+0.33) in the post survey. Both Prompt 7 (0.03) and Prompt 10 (0.00) are considered statistically significant based on the two-tailed paired *t*-test.

Emotional engagement. “Emotional engagement has been defined as students’ sentiments toward school, and has been operationalized as children's feelings about peers, teachers, schoolwork, or their affective reactions to the classroom or the larger school context” (Ladd & Dinella, 2009, p.190). Prompts 11-14, potential measures of emotional engagement, revealed students’ self-reported levels of enjoyment (-0.8), interest (-0.24), and curiosity (-0.1) actually decreased in the post survey. Specifically, Prompt12, “When we work on something in class, I feel interested,” indicated statistically significant results (0.01), with a decline of 0.24 in the post survey data collected.

Cognitive engagement. Cognitive engagements refer to students’ ability to self-regulate and monitor their thinking (Archambault & Dupéré, 2017, p. 188). Prompts15 -20, measures of possible cognitive engagement, implied slight improvements in engagement as shown by students' self-reported increases in synthesizing ideas (+0.02) (Prompt 17), creating examples to help them understand important concepts (+0.07) (Prompt 18), and acting with purpose and intentionality (+0.26) (Prompt 19). The two-tailed paired *t*-tail test indicated statistical significance for Prompt 19. Responses to Prompt 15, "When doing schoolwork, I try to relate what I'm learning to what I already know," revealed a statistically significant decrease (-0.34) from the pre to the post survey.

Table 15

Results of the pre and post engagement surveys

ENGAGEMENT INDICATOR PROMPTS	PRE	POST	+/-	Two-tailed paired *t*-test*
Agentic Engagement				
1. During class I ask questions.	2.14	2.13	-0.01	0.584837535
2. I tell the teacher what I like and what I don't like.	1.70	1.51	-0.19	0.009574001
3. I let my teacher know what I'm interested in.	1.95	1.91	-0.04	0.403394808
4. During class I express my opinion.	1.89	1.74	-0.15	0.164560155
5. I offer suggestions to make the class better.	1.61	1.54	-0.07	0.327809897
Behavioral Engagement				
6. I listen carefully in class.	2.83	2.83	0.00	0.9155172613
7. I try very hard in school.	2.89	3.00	0.11	0.0394313772
8. The first time my teacher talks about a new topic, I listen carefully.	2.80	2.77	-0.03	0.4407634270
9. I work hard when we start something new in class.	2.73	2.81	0.08	0.5237900215
10. I pay attention in class.	2.36	2.69	0.33	0.0042836250
Emotional Engagement				
11. I enjoy learning new things in class.	2.71	2.63	-0.08	0.5283576333
12. When we work on something in class, I feel interested.	2.48	2.24	-0.24	0.0185316456
13. When I am in class, I feel curious about what we are learning.	2.31	2.30	-0.01	0.5174774678
14. Class is fun.	2.68	2.69	0.01	0.8940184537
Cognitive Engagement				
15. When doing schoolwork, I try to relate what I'm learning to what I already know.	2.36	2.02	-0.34	0.0020487938
16. When I study, I try to connect what I am learning with my own experiences.	2.00	1.77	-0.23	0.1244727892
17. I try to make all different ideas fit together and make sense when I study.	2.07	2.10	0.02	0.9096492742
18. I make up my own examples to help me understand the important concepts I study.	1.93	2.00	0.07	0.6370209026
19. Before I begin to study, I think what I want to get done.	2.12	2.37	0.26	0.04979279231
20. When I'm working on my schoolwork, I stop once in a while and go over what I have been doing.	2.18	2.15	-0.03	0.8282459551
21. If what I am working on is difficult to understand, I change the way I learn the material.	1.84	1.84	0.00	0.9110200332

* Statistically significant results are highlighted in yellow.

Appendix P: Looking Closely Worksheet

Each worksheet was printed double-sided on 11 X 17 paper to form a booklet.

3. What are its complexities?
How is it complicated in its parts and purposes,
the relationship between the two, or in other ways?

Once Upon a Makerspace
CLASS NAME - Week 2
PARTS, PURPOSES, COMPLEXITIES
LOOKING CLOSELY

My Name: ____________________

Object's Name: ________________

1. What are its parts?
What are its various pieces or components?

2. What are its purposes?
What are the purposes for each of these parts?

Appendix Q: Exploring Complexity Worksheet

Each sheet was printed double-sided on 11 X 17 paper to form a booklet.

3. How are you involved?

What connections do you have? What assumptions, interest or personal circumstances shape the way you see it?

Once Upon a Makerspace
TEACHER NAME - Week 3
PARTS, PERSPECTIVES, & ME
EXPLORING THE COMPLEXITY OF OBJECTS AND SYSTEMS

My Name: ______________________

Object Name: _________________

1. What are its parts?

What are its various pieces or components?

2. What are its perspectives?

What perspectives can you look at it from? Different users, makers; different physical perspectives?

_____________View	_____________ View
_____________View	_____________ View
_____________View	_____________ View

Appendix R: Fostering Opportunity Worksheet

Each sheet was printed double-sided on 11 X 17 paper to form a booklet.

3. In what ways could it be made to be more <u>beautiful</u>?

Once Upon a Makerspace
CLASS NAME - Week 4

IMAGINE IF...FOSTERING OPPORTUNITY

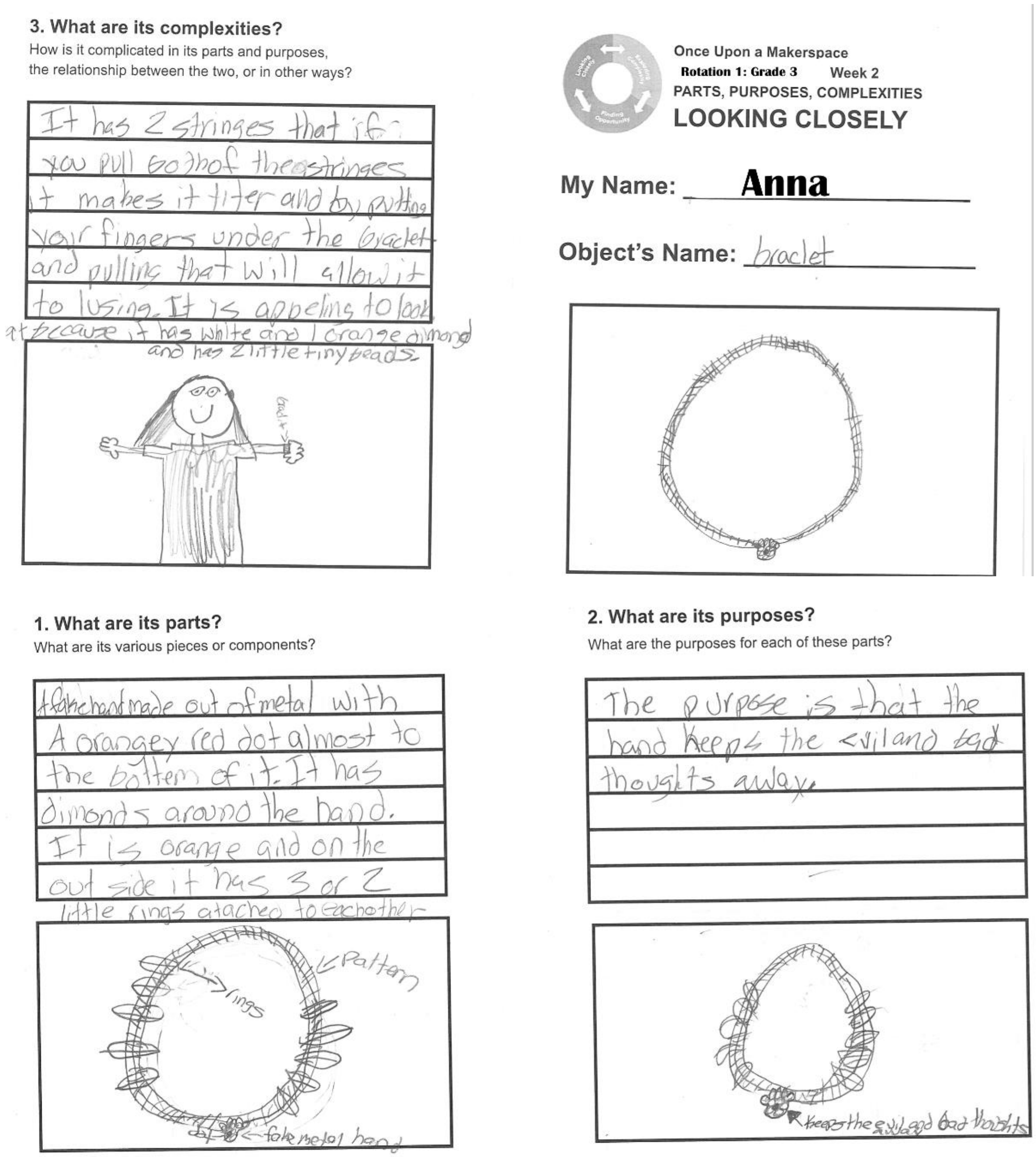
My Name: ______________________

Object's Name: _________________

1. In what ways could it be made to be more <u>effective?</u>

2. In what ways could it be made to be more <u>efficient?</u>

Appendix S: Anna's AbD Thinking Routine Worksheets



3. What are its complexities?
How is it complicated in its parts and purposes, the relationship between the two, or in other ways?

It has 2 stringes that if you pull both of the strings it makes it titer and by putting your fingers under the braclet and pulling that will allow it to lusing. It is appeling to look at because it has white and 1 orange dimond and has 2 little tiny beads.

Once Upon a Makerspace
Rotation 1: Grade 3 Week 2
PARTS, PURPOSES, COMPLEXITIES
LOOKING CLOSELY

My Name: Anna

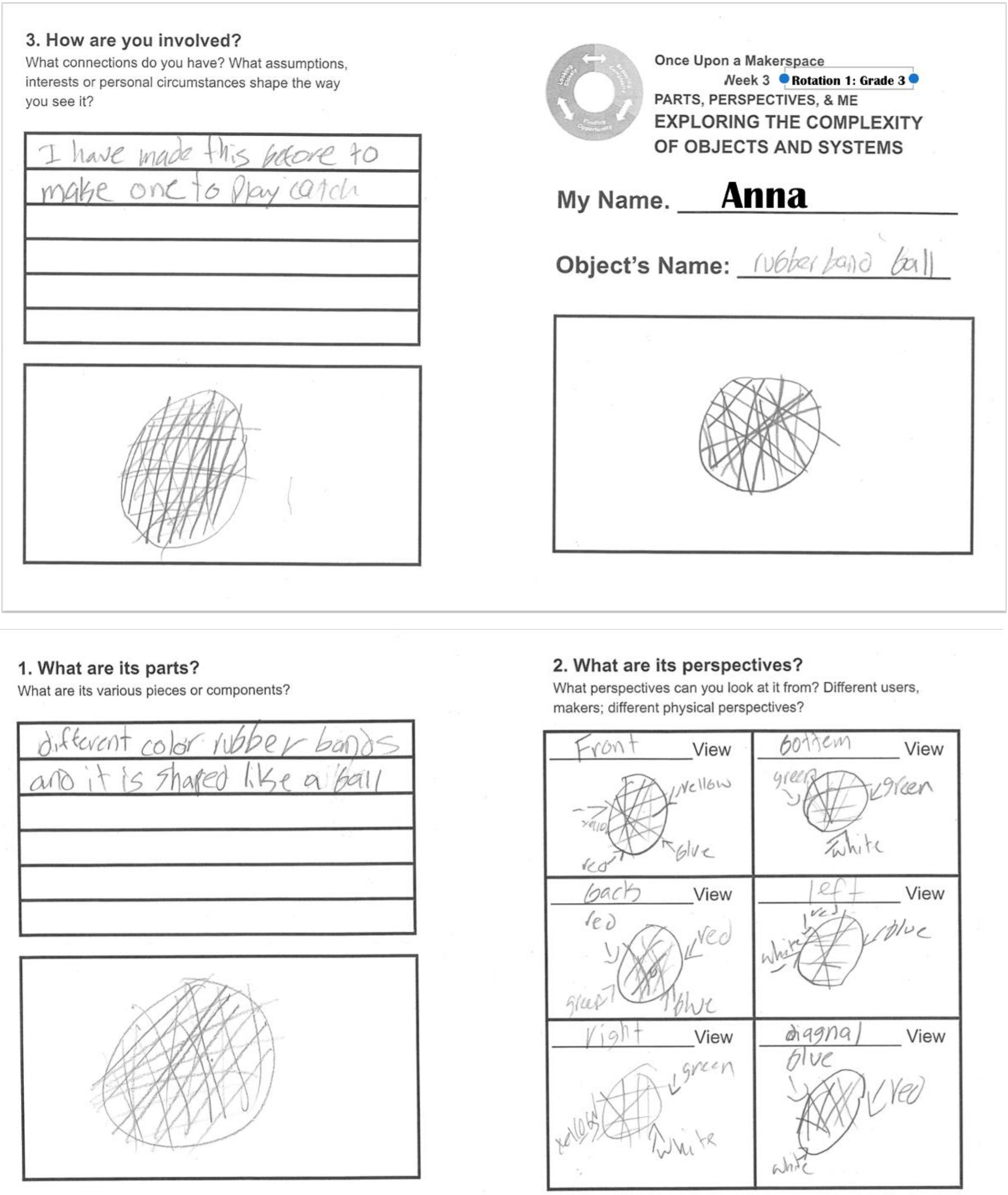
Object's Name: braclet

1. What are its parts?
What are its various pieces or components?

Fake hand made out of metal with A orangey red dot almost to the bottem of it. It has dimonds around the hand. It is orange and on the out side it has 3 or 2 little rings atached to eachother

2. What are its purposes?
What are the purposes for each of these parts?

The purpose is that the hand keeps the evil and bad thoughts away.



Once Upon a Makerspace
Week 3 Rotation 1: Grade 3
PARTS, PERSPECTIVES, & ME
EXPLORING THE COMPLEXITY OF OBJECTS AND SYSTEMS

My Name. Anna

Object's Name: rubber band ball

3. How are you involved?
What connections do you have? What assumptions, interests or personal circumstances shape the way you see it?

I have made this before to make one to play catch

1. What are its parts?
What are its various pieces or components?

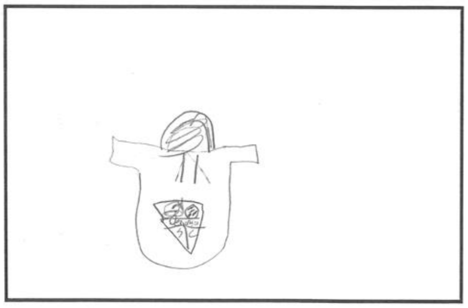
different color rubber bands and it is shaped like a ball

2. What are its perspectives?
What perspectives can you look at it from? Different users, makers; different physical perspectives?

Front View: yellow, yellow, blue, red	bottom View: green, green, white
back View: red, red, green, blue	left View: red, white, blue
right View: green, yellow, white	diagnal View: blue, red, white

3. In what ways could it be made to be more beautiful?

Make it more colerful like pink of purple.

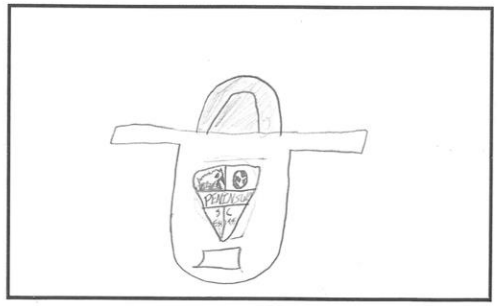


Once Upon a Makerspace
- Week 4 **Rotation 1: Grade 3**

IMAGINE IF...FOSTERING OPPORTUNITY

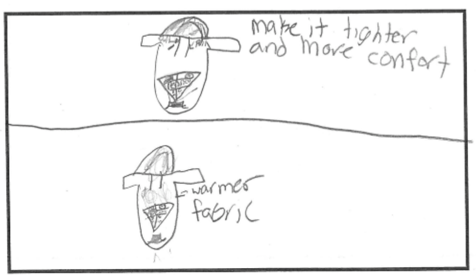
My Name: Anna

Object's Name: peninsula sweatshirt



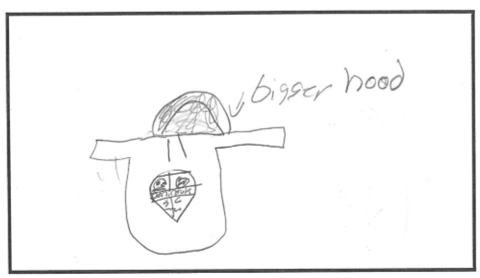
1. In what ways could it be made to be more effective?

#1 When you pull two stringes it gets tighter and way more confertable.
#2 If it had a different fabric to keep it warmer.

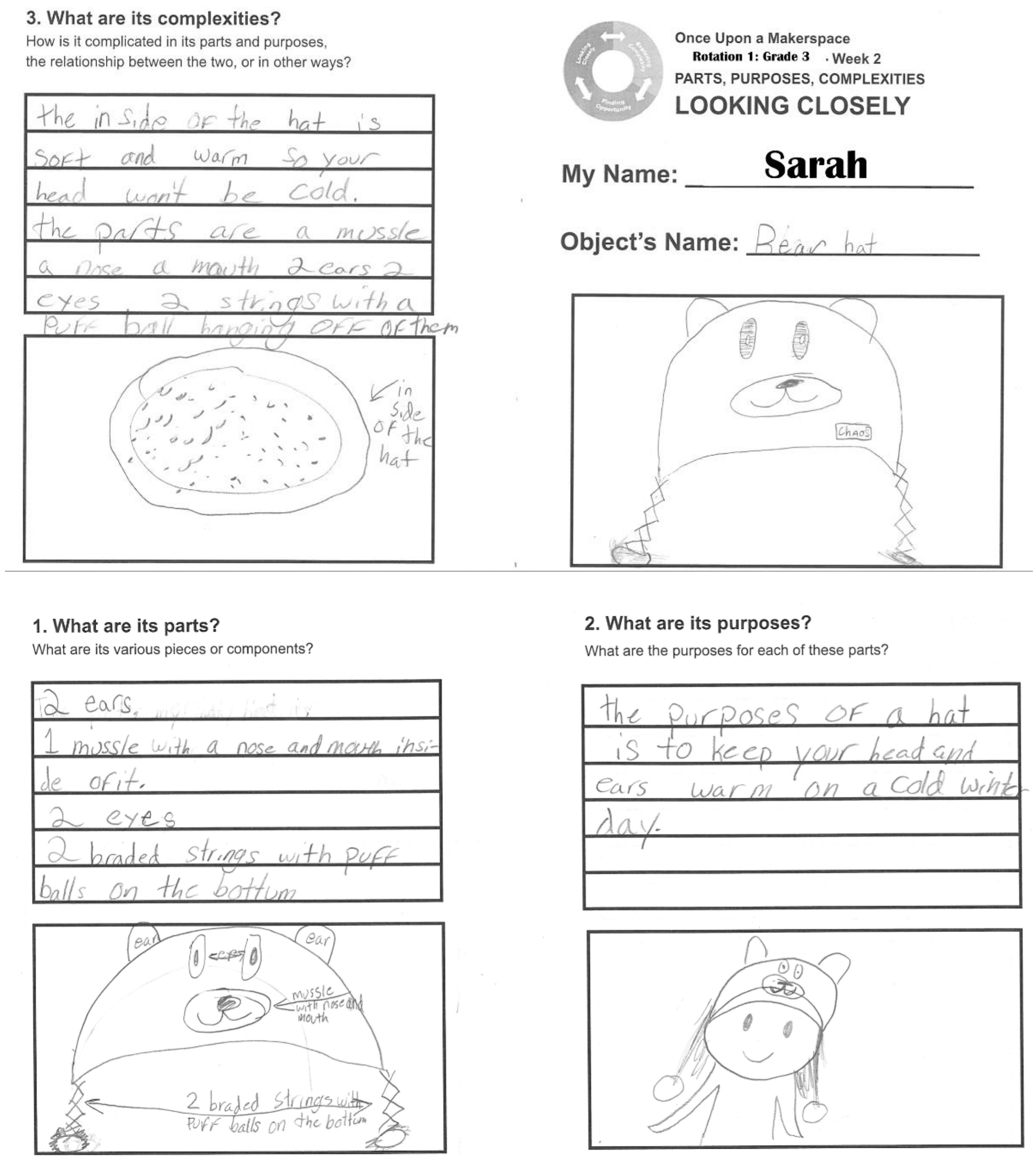


2. In what ways could it be made to be more efficient?

I would make it bigger in the head to make it easier to get on and off.



Appendix T: Sarah's AbD Thinking Routine Worksheets


3. What are its complexities?
How is it complicated in its parts and purposes, the relationship between the two, or in other ways?

the inside of the hat is soft and warm so your head won't be cold. the parts are a mussle a nose a mouth 2 ears 2 eyes 2 strings with a puff ball hanging off of them

Once Upon a Makerspace
Rotation 1: Grade 3 · Week 2
PARTS, PURPOSES, COMPLEXITIES
LOOKING CLOSELY

My Name: Sarah

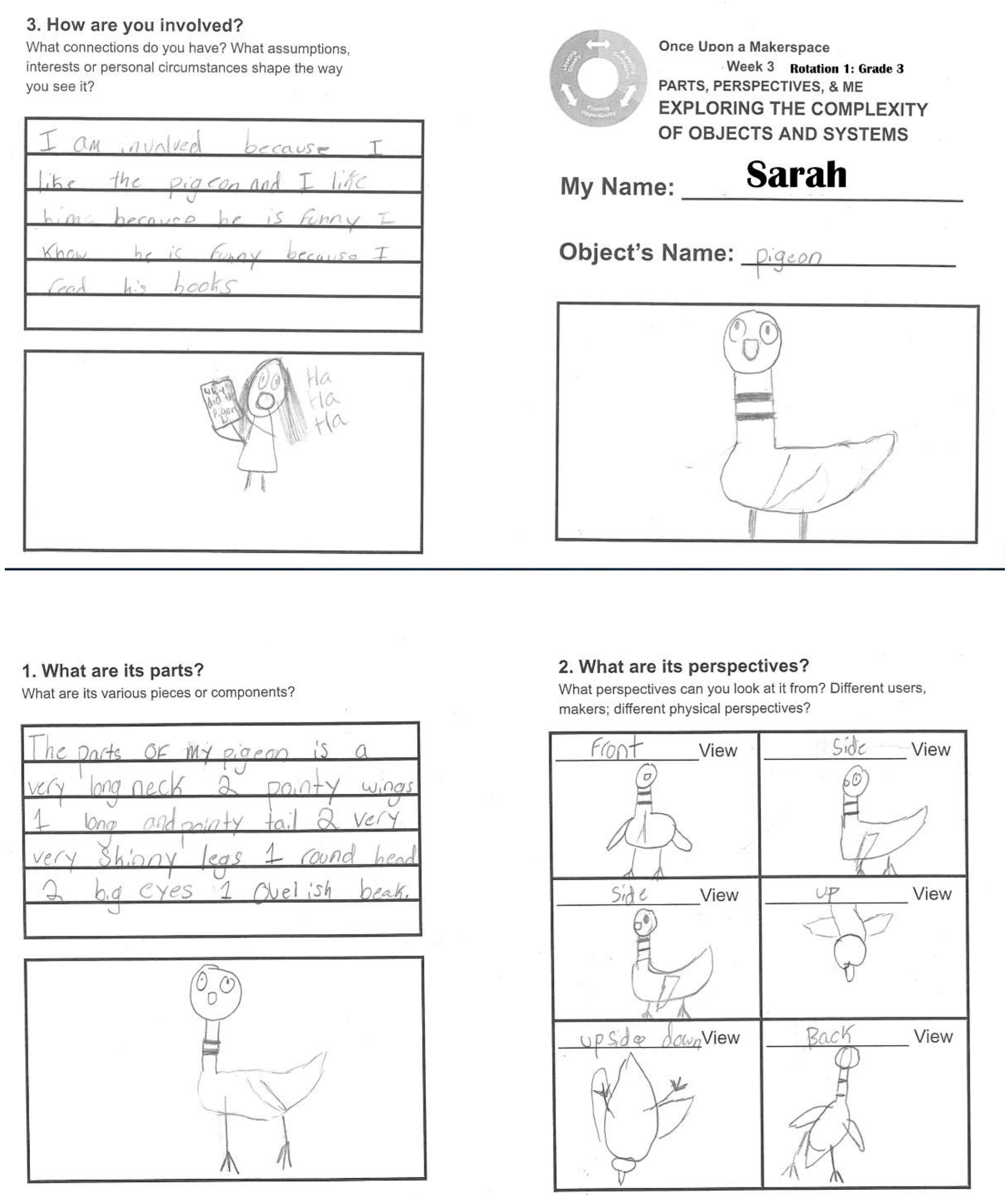
Object's Name: Bear hat

1. What are its parts?
What are its various pieces or components?

2 ears,
1 mussle with a nose and mouth inside of it.
2 eyes
2 braded strings with puff balls on the bottom

2. What are its purposes?
What are the purposes for each of these parts?

the purposes of a hat is to keep your head and ears warm on a cold winter day.


3. How are you involved?
What connections do you have? What assumptions, interests or personal circumstances shape the way you see it?

I am invulved because I like the pigeon and I like him because he is funny I know he is funny because I read his books

Once Upon a Makerspace
Week 3 Rotation 1: Grade 3
PARTS, PERSPECTIVES, & ME
EXPLORING THE COMPLEXITY OF OBJECTS AND SYSTEMS

My Name: Sarah

Object's Name: pigeon

1. What are its parts?
What are its various pieces or components?

The parts of my pigeon is a very long neck 2 pointy wings 1 long and pointy tail 2 very very shiny legs 1 round head 2 big eyes 1 ovel ish beak.

2. What are its perspectives?
What perspectives can you look at it from? Different users, makers; different physical perspectives?

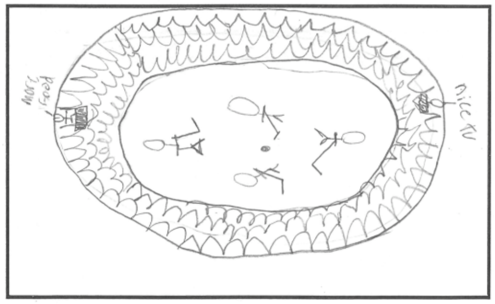
Front View
Side View
Side View
Up View
upside down View
Back View

Once Upon a Makerspace
Week 4 **Rotation 1: Grade 3**

IMAGINE IF...FOSTERING OPPORTUNITY

My Name: **Sarah**

Object's Name: Hockey statium

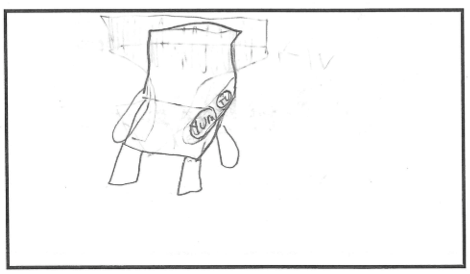


3. In what ways could it be made to be more <u>beautiful</u>?

it could be more butiful by making every thing shiny

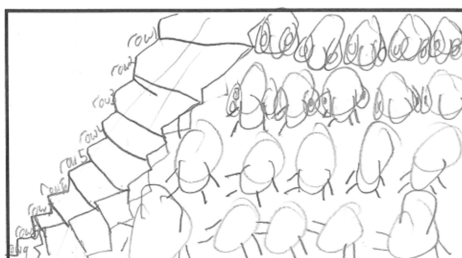
1. In what ways could it be made to be more <u>effective?</u>

I can make it more effective by make ing new seats like add two buttons 1 botton is for a TV so you can see the game better another botton is for Food and Drinks so you do not have to get up in the middle of the game



2. In what ways could it be made to be more <u>efficient?</u>

To make it more efficient the stairs are escelators so you don't have to walk arond the whole Statieum.

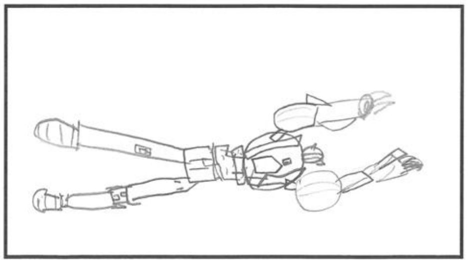


Appendix U: Connor's AbD Thinking Routine Worksheets

3. What are its complexities?

How is it complicated in its parts and purposes, the relationship between the two, or in other ways?

He kan move his arms to fly and to entertan you.



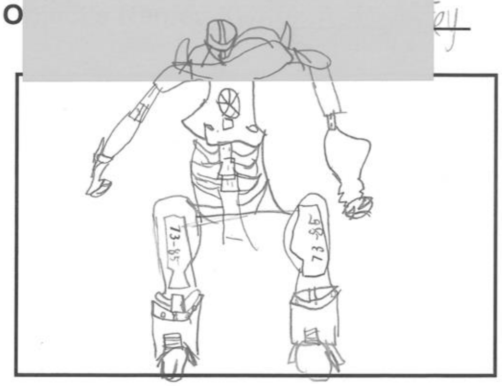
Once Upon a Makerspace

Week 2 - Rotation 1 - Grade 3

PARTS, PURPOSES, COMPLEXITIES

LOOKING CLOSELY

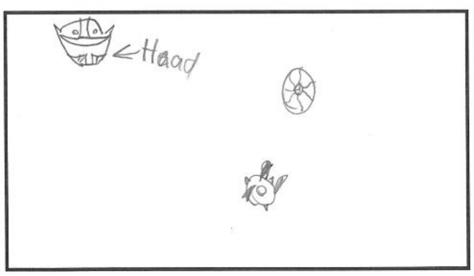
My Name: **Connor**



1. What are its parts?

What are its various pieces or components?

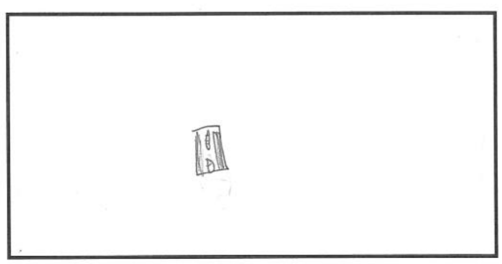
Alot of diffrent colred molded moled plaic pices

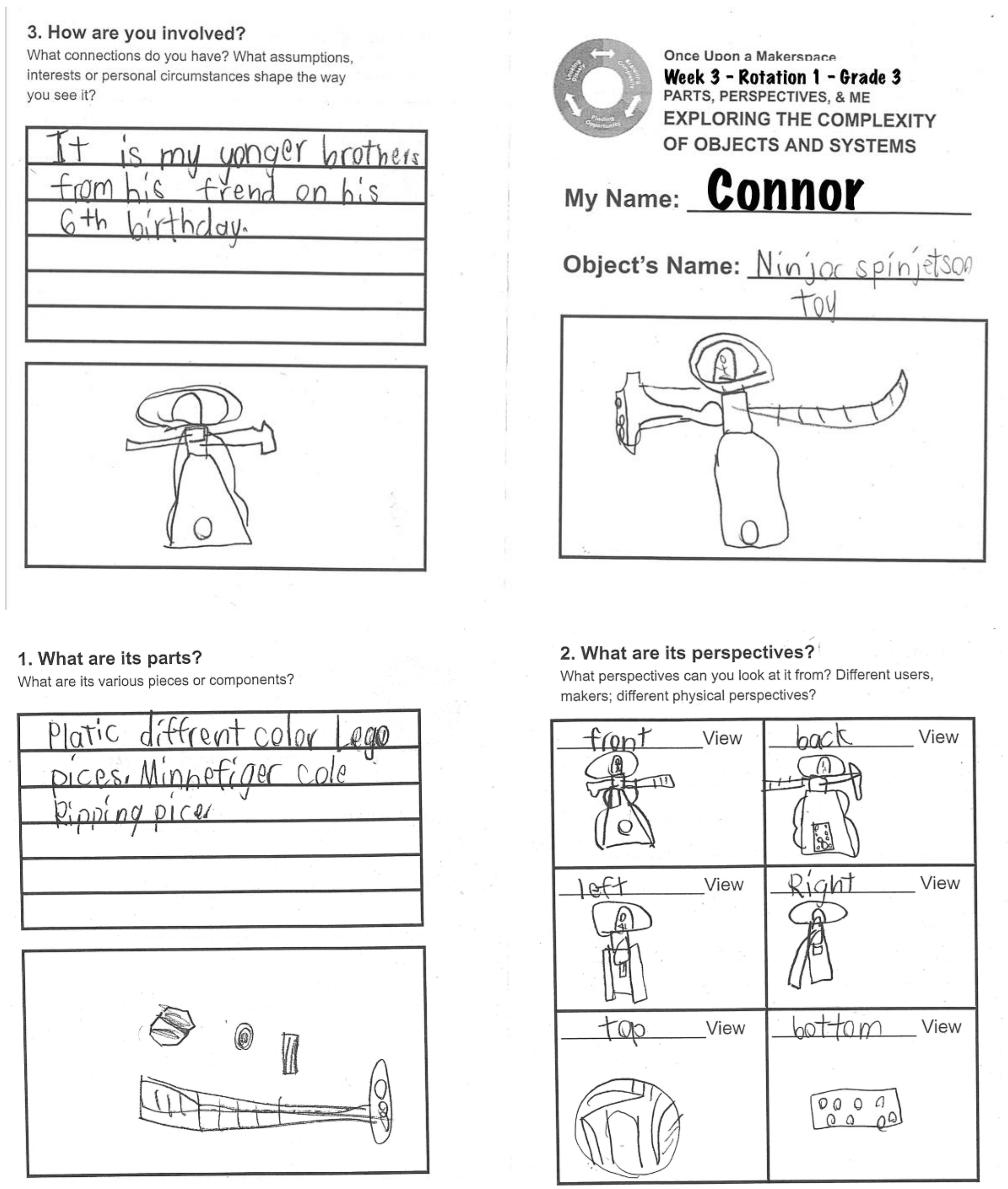


2. What are its purposes?

What are the purposes for each of these parts?

The purposes is to Kepp evrything together and make it move. To entertan and and fight whith them





3. How are you involved?
What connections do you have? What assumptions, interests or personal circumstances shape the way you see it?

It is my yonger brothers from his frend on his 6th birthday.

Once Upon a Makerspace
Week 3 - Rotation 1 - Grade 3
PARTS, PERSPECTIVES, & ME
EXPLORING THE COMPLEXITY OF OBJECTS AND SYSTEMS

My Name: Connor

Object's Name: Ninjoc spinjetson toy

1. What are its parts?
What are its various pieces or components?

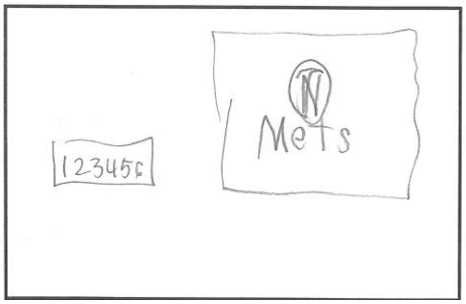
Platic diffrent color Lego pices. Minnefiger cole Ripping picer

2. What are its perspectives?
What perspectives can you look at it from? Different users, makers; different physical perspectives?

front View
back View
left View
Right View
top View
bottom View

3. In what ways could it be made to be more beautiful?

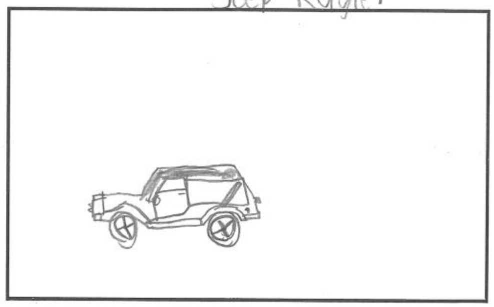
Buper stickers, licen Plate.



Once Upon a Makerspace
Week 4 - Rotation 1 - Grade 3
IMAGINE IF...FOSTERING OPPORTUNITY

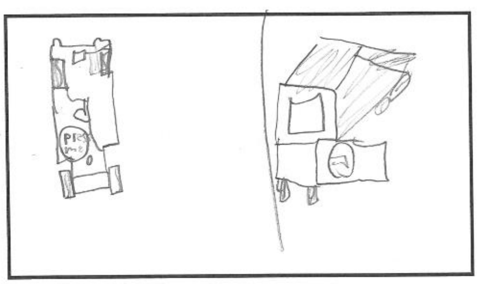
My Name: Connor

Object's Name: Toy (Green) Jeep Ragler



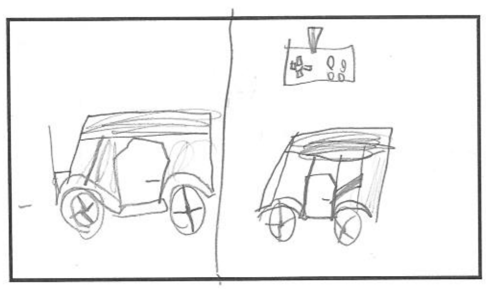
1. In what ways could it be made to be more effective?

Kids, Cardealer. Botten, on bttom to change colors Truck open.

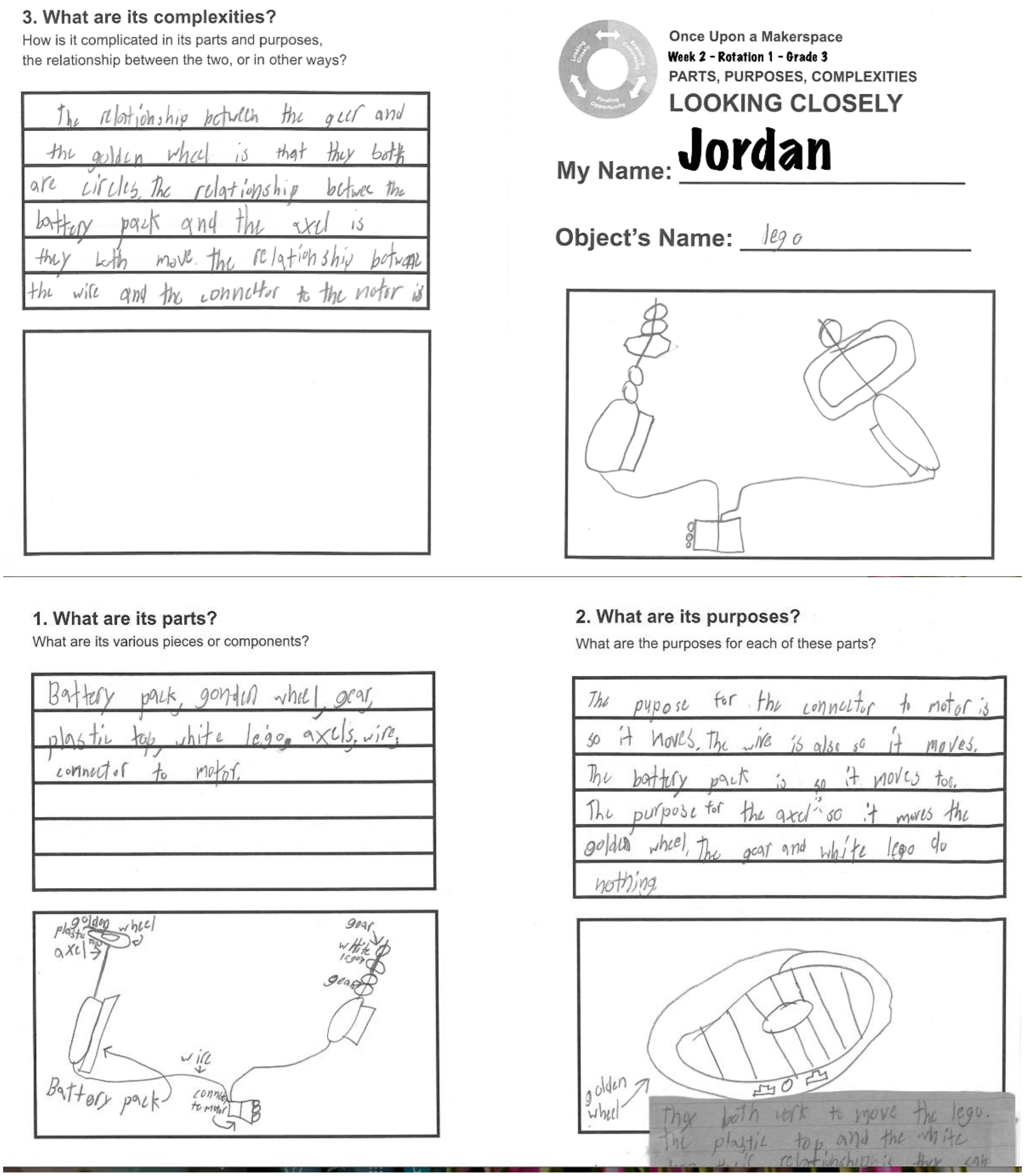


2. In what ways could it be made to be more efficient?

when press botten change coler. romot control.



Appendix V: Jordan's AbD Thinking Routine Worksheets



Once Upon a Makerspace
Week 2 - Rotation 1 - Grade 3
PARTS, PURPOSES, COMPLEXITIES
LOOKING CLOSELY

My Name: Jordan

Object's Name: lego

1. What are its parts?
What are its various pieces or components?

Battery pack, gonden wheel, gear, plastic top, white lego, axcls, wire, connector to motor.

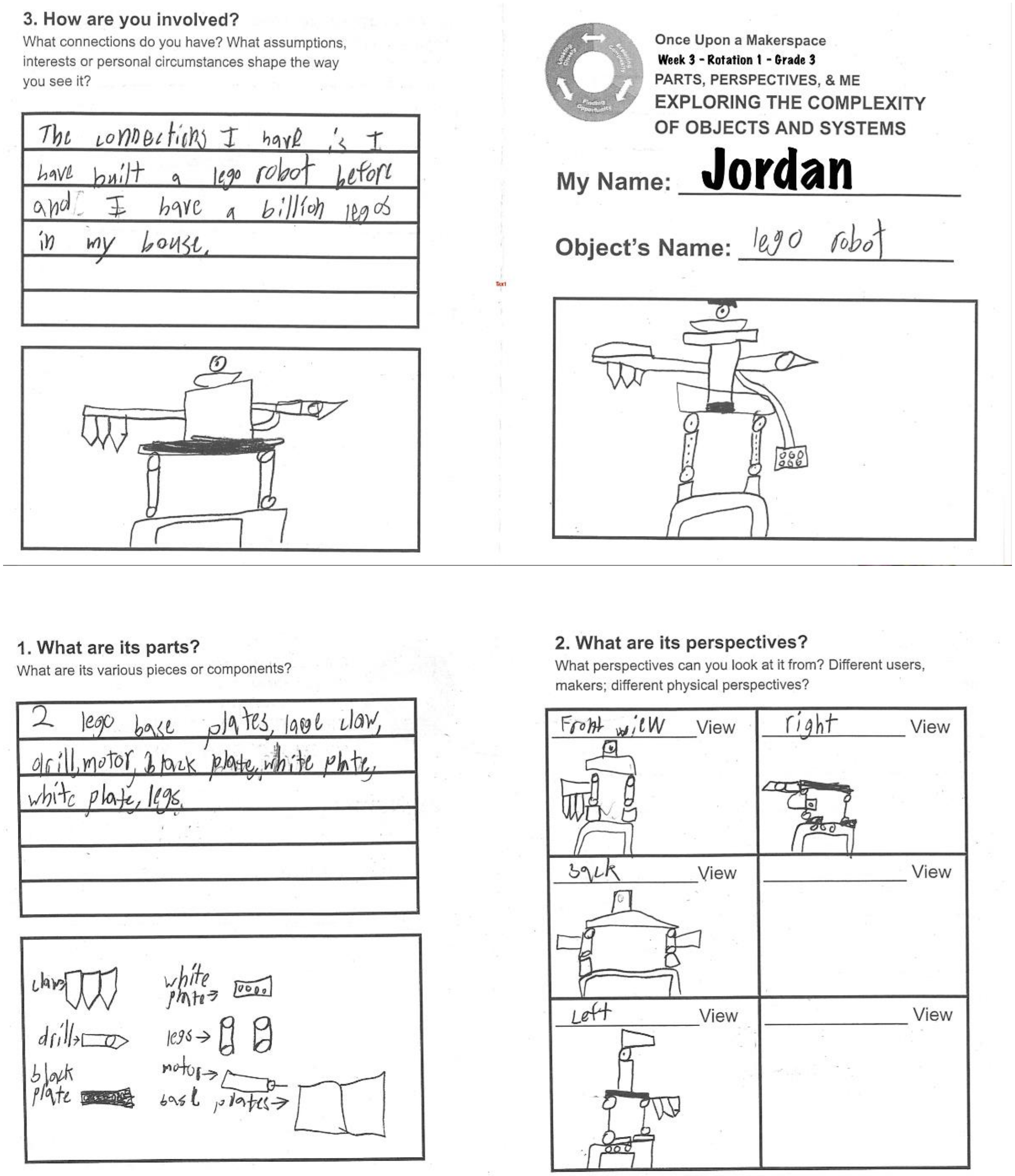
2. What are its purposes?
What are the purposes for each of these parts?

The pupose for the connector to motor is so it moves. The wire is also so it moves. The battery pack is so it moves too. The purpose for the axcl so it moves the golden wheel. The gear and white lego do nothing

They both work to move the lego. The plastic top and the white

3. What are its complexities?
How is it complicated in its parts and purposes, the relationship between the two, or in other ways?

The relationship between the geer and the golden wheel is that they both are circles. The relationship betwee the battery pack and the axcl is they both move. the relationship betwe the wire and the connector to the motor is



3. How are you involved?

What connections do you have? What assumptions, interests or personal circumstances shape the way you see it?

The connections I have is I have built a lego robot before and I have a billion legos in my house.

Once Upon a Makerspace

Week 3 - Rotation 1 - Grade 3

PARTS, PERSPECTIVES, & ME

EXPLORING THE COMPLEXITY OF OBJECTS AND SYSTEMS

My Name: Jordan

Object's Name: lego robot

1. What are its parts?

What are its various pieces or components?

2 lego base plates, lego claw, drill, motor, black plate, white plate, white plate, legs.

2. What are its perspectives?

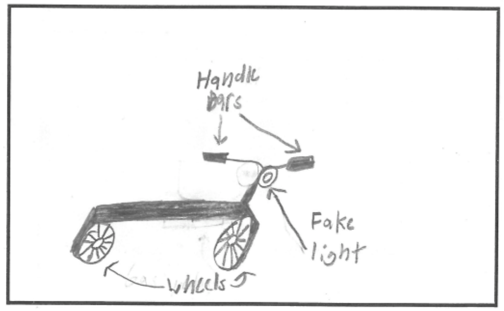
What perspectives can you look at it from? Different users, makers; different physical perspectives?

Once Upon a Makerspace
Week 4 - Rotation 1 - Grade 3

IMAGINE IF...FOSTERING OPPORTUNITY

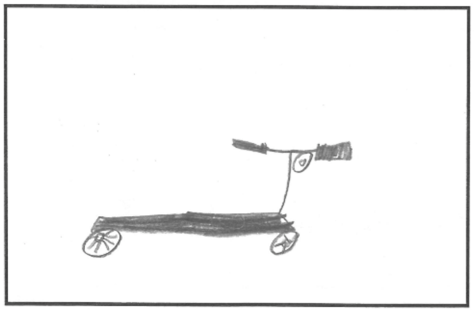
My Name: Jordan

Object's Name: Lego motorcycle



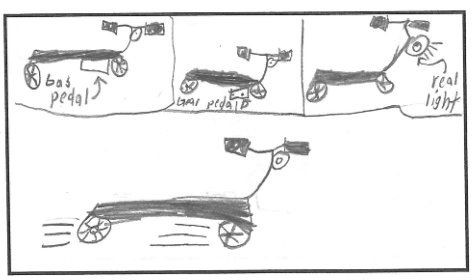
3. In what ways could it be made to be more beautiful?

More colorful than black and white.



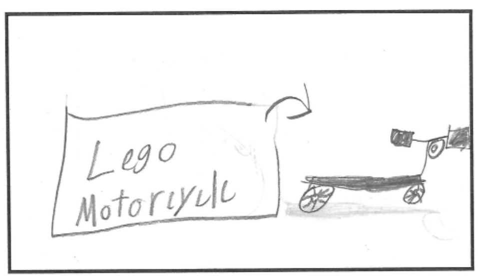
1. In what ways could it be made to be more effective?

Uzer: kids. If it had a gas pedal, a gear pedal, a real light, and if it could move on its own it would be more effective.

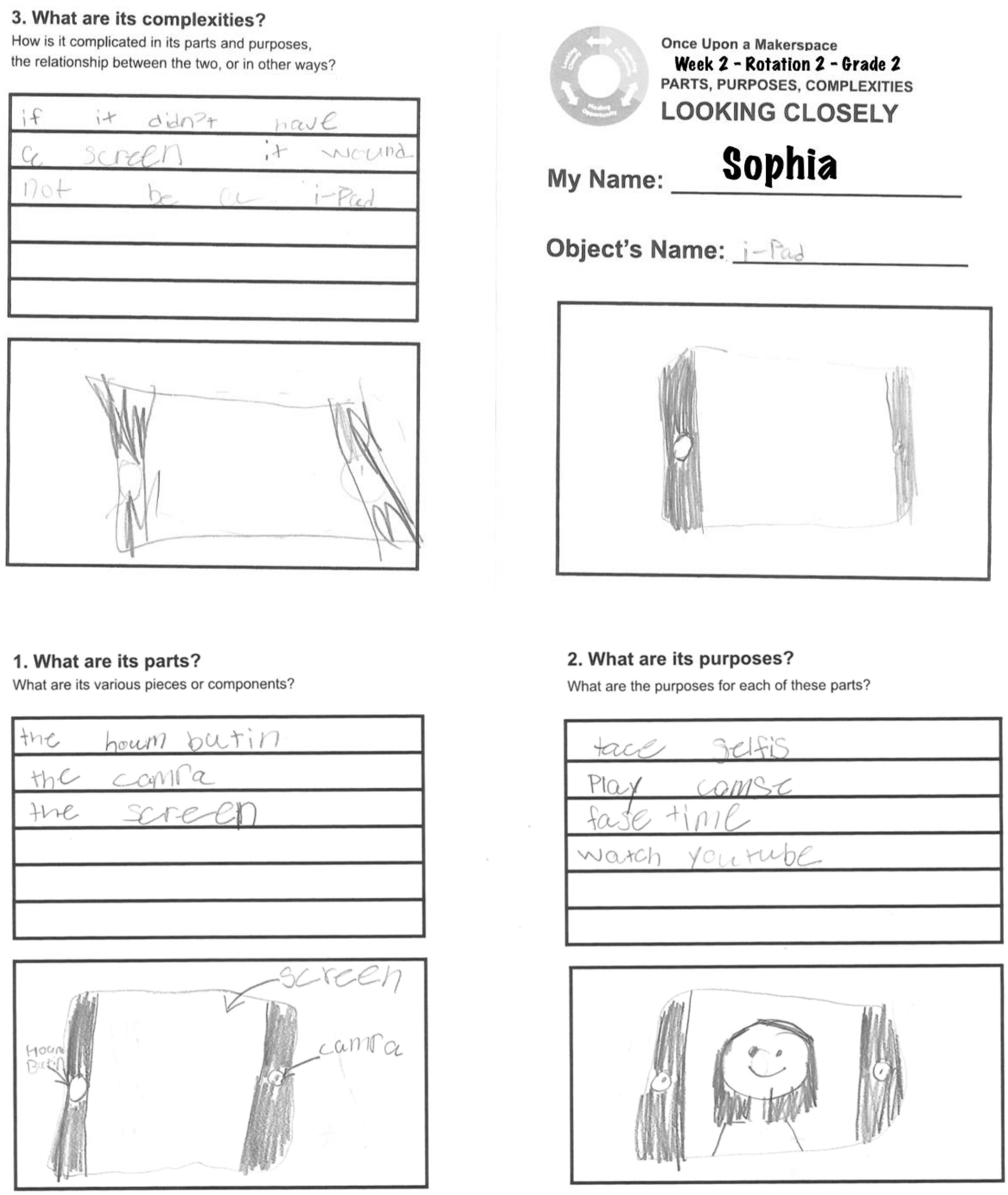


2. In what ways could it be made to be more efficient?

It would come built in a box instead of you needing to build it.



Appendix W: Sophia's AbD Thinking Routine Worksheets



3. What are its complexities?
How is it complicated in its parts and purposes, the relationship between the two, or in other ways?

if it didn't have
a screen it would
not be a i-Pad

Once Upon a Makerspace
Week 2 - Rotation 2 - Grade 2
PARTS, PURPOSES, COMPLEXITIES
LOOKING CLOSELY

My Name: Sophia

Object's Name: i-Pad

1. What are its parts?
What are its various pieces or components?

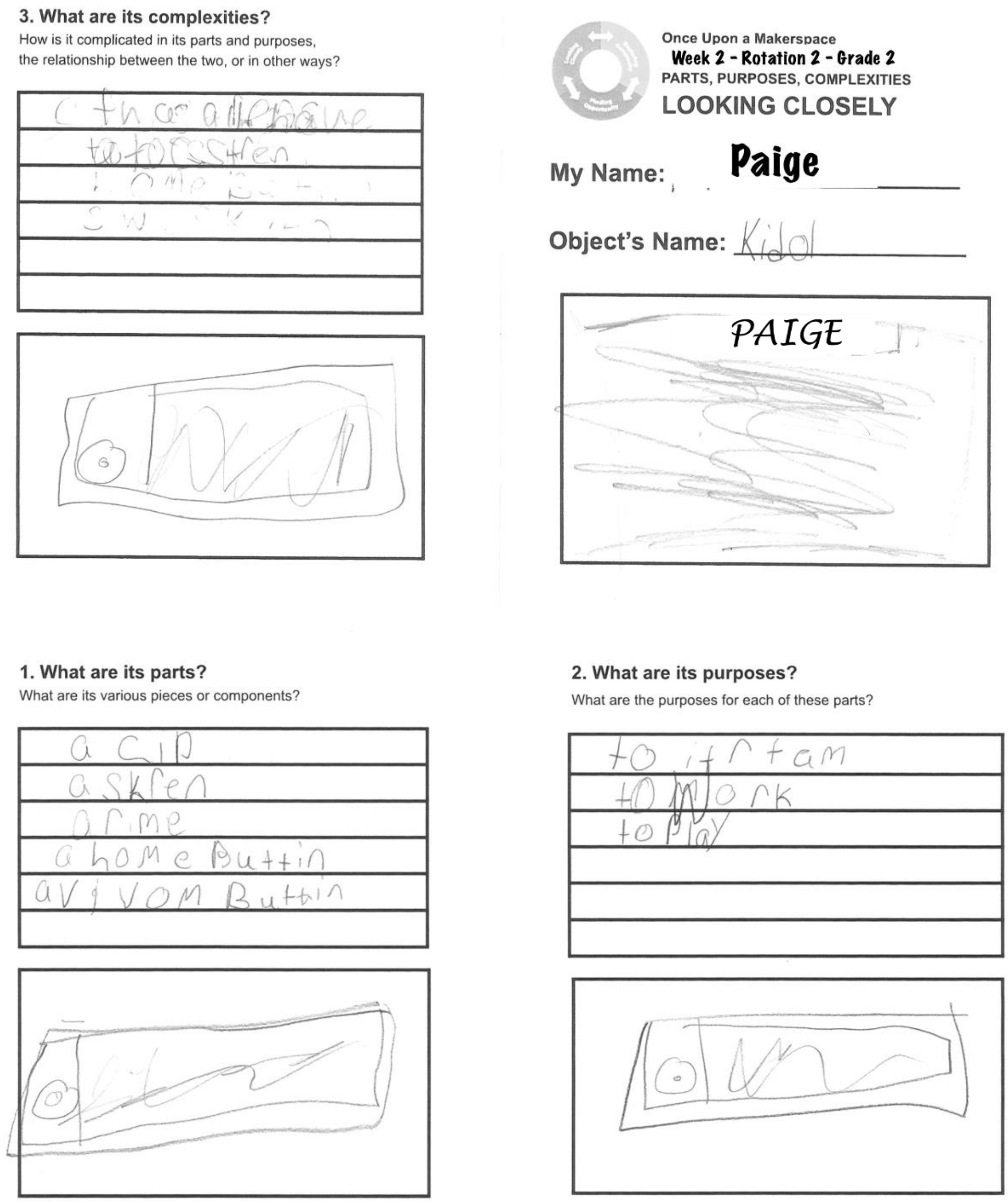
the houm butin
the camra
the screen

screen
camra
Houm Butin

2. What are its purposes?
What are the purposes for each of these parts?

face selfis
Play gamse
fase time
watch youtube

Appendix X: Paige's AbD Thinking Routine Worksheets


3. What are its complexities?
How is it complicated in its parts and purposes, the relationship between the two, or in other ways?

Once Upon a Makerspace
Week 2 - Rotation 2 - Grade 2
PARTS, PURPOSES, COMPLEXITIES
LOOKING CLOSELY

My Name: Paige

Object's Name: Kidol

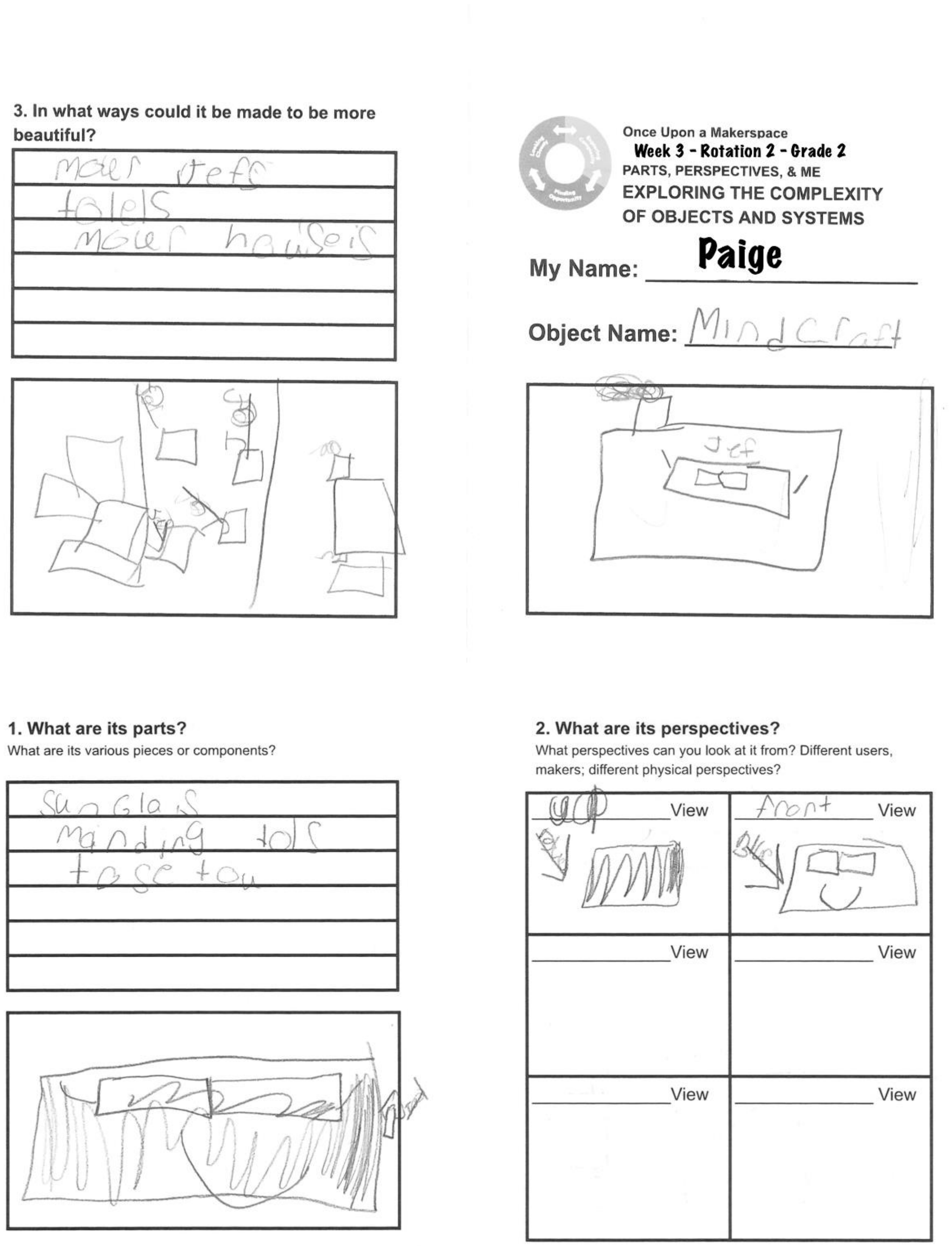
PAIGE

1. What are its parts?
What are its various pieces or components?

a CiP
a Skfen
a rme
a home Buttin
a vivom Buttin

2. What are its purposes?
What are the purposes for each of these parts?

to it r tam
to work
to play


3. In what ways could it be made to be more beautiful?

Maer Jefs
toleis
maer hauseis

Once Upon a Makerspace
Week 3 - Rotation 2 - Grade 2
PARTS, PERSPECTIVES, & ME
EXPLORING THE COMPLEXITY OF OBJECTS AND SYSTEMS

My Name: Paige

Object Name: Mindcraft

1. What are its parts?
What are its various pieces or components?

sunGlaS
manding tols
fase tou

2. What are its perspectives?
What perspectives can you look at it from? Different users, makers; different physical perspectives?

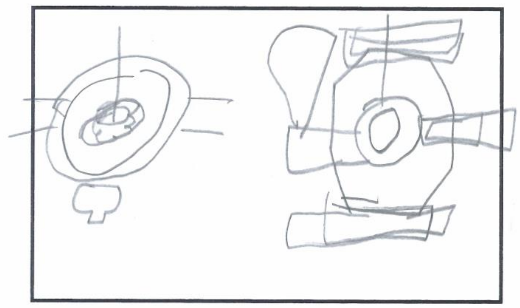
up View	front View
______ View	______ View
______ View	______ View

Appendix Y: Oliver's AbD Thinking Routine Worksheets

Once Upon a Makerspace
Week 2 - Rotation 2 - Grade 3
PARTS, PURPOSES, COMPLEXITIES
LOOKING CLOSELY

My Name: **Oliver**

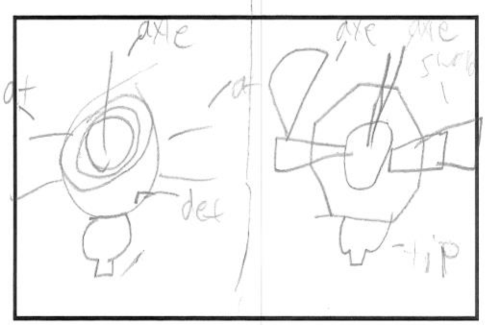
Object's Name: Bey blade



3. What are its complexities?
How is it complicated in its parts and purposes, the relationship between the two, or in other ways?

1. What are its parts?
What are its various pieces or components?

Kerbevs	Valtryek
attacking	axe
defence	sword
axle	axle
tip	tip



2. What are its purposes?
What are the purposes for each of these parts?

to battle each other

3. In what ways could it be made to be more beautiful?

I made beyblade number 2 better by making even sides

I need to make the motor cords not tangle

Once Upon a Makerspace

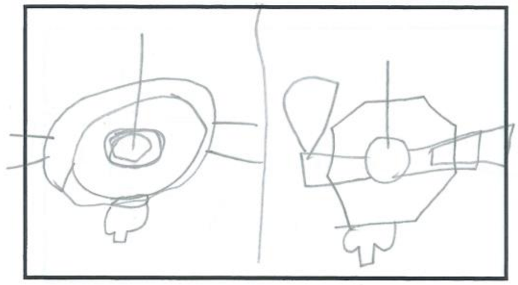
Week 3 - Rotation 2 - Grade 3

PARTS, PERSPECTIVES, & ME

EXPLORING THE COMPLEXITY OF OBJECTS AND SYSTEMS

My Name: Oliver

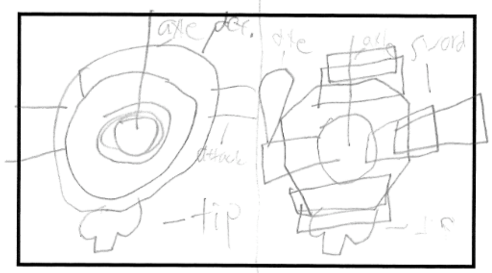
Project Name: Beyblade



1. What are its parts?

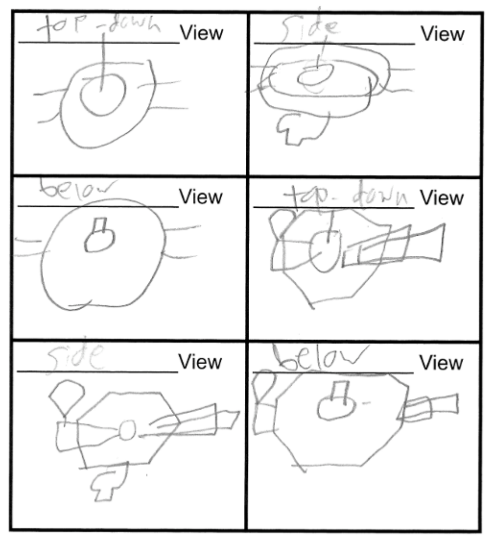
What are its various pieces or components?

tip
defence
attack
axle



2. What are its perspectives?

What perspectives can you look at it from? Different users, makers; different physical perspectives?



Appendix Z: Case Study Code Book

Code	Definition
Peer Feedback	
Peer Model (PM)	Any observation of the impact of a peer physically or verbally modeling how to use a particular tool but not verbally giving feedback to the participant about his or her project.
Verbal Peer Feedback (VPF)	Any observation of the impact of verbal peer feedback while working in real-time in the makerspace on the development of a project (not on the Flipgrid).
Peer Flipgrid Feedback (PFF)	Any observation of how a peer provided feedback on the Flipgrid regarding the project to the participant.
Teacher Feedback	
Teacher – Project Affirmative (TP+)	Any observation of interactions with a teacher during which she provided students with advice or guidance about a specific aspect of making the projects.
Teacher – Project Negative (TP-)	Any observation of the lack of feedback or interactions with a teacher when asked if the teacher provided feedback to the participant.
Making Students' Thinking Visible	
Flipgrid Self-Monitoring (FSM)	Any observation of how the use of the Flipgrid helped the participant track his or her progress.
Application of AbD Thinking Routines (AoAbDTR)	Any observation of the participants articulating how they used the AbD Thinking Routine to help them develop their projects or how a teacher observed students using the AbD Thinking Routines during the development of their projects.

Learning	
Learning – Skill (LS)	References to how students reported they learned to use a makerspace tool or a skill they developed
Learning – Self as Learner (LSaL)	Any observation of how students viewed themselves as learners, aware of what they were doing or how they processed information to work on their projects.
Engagement	
Engagement – Tools (ET)	Any student reference to preferences of tool usage.
Engagement - Perseverance (EP)	Any observation of how a participant behaved when frustrated in the makerspace.

Week #	Case	Source	Observation	Coder 1	Coder 2	Coder 3
5	4	Flipgrid	Oliver reported that one of the teachers in the media room gave more parts (Mrs. Davis) "I added a lot more and one of them looked like helicopter with gatons so I added that on the attacking one and I added some parts on defense. I made them a lot better."	EP	EP	EP
6	4	SMBB.mov	Oliver manually synchronized the “on” function on the Lego battery packs and the car was propelled right off the table	EP	EP	EP
6	4	SMBB.mov	Oliver said he would think about some solutions. explaining that he wanted to make the battery packs stand up so that they didn’t get in the way of the spinning Beyblades	EP	EP	EP
6	4	SMBB.mov	As the Beyblades continued to spin, the propeller blades fell off. Oliver noted that he thought they were too long and said, “I have to do something about that.”	EP	EP	EP
1	1	MVI0005	Anna selected cardboard while working with Makey Makey.	ET	ET	ET
1	1	MVI0005	Anna added, "We need a computer" and then went to get a computer for the Makey Makey game.	ET	ET	ET
1	4	Flipgrid	When showing the viewer his Beyblades prototype, Oliver said, "One really great feature is that it can go higher or lower (modeling first spinner and how it slides on the axle) this one it doesn’t have i as good of a feature. This one is a shield and this one is an axe. And this is also kind of looks like the handles and it spins especially. If this is high enough that part can obliterate (the other spinner) it and go like this (he bangs them). It’s supposed to do this…."	ET	ET	ET
1	4	Flipgrid	These are Beyblades...they are tops that battle Tops that battle are fun, right?	ET	ET	ET
6	1	MVI0277	Sarah looks for her cardboard from last week. She finds it on the stage.	ET	ET	ET
1	1	Flipgrid	Anna described how she made the Makey Makey Game with cardboard and Sarah described how she started a Lego project with friends - they smashed it. It had a pool. She explained how you use the pool and diving board. She also described how you have rebuild the Lego house.	FSM	FSM	FSM
1	2	Flipgrid	Connor described how he created a Flappy Bird game and demonstrated how it worked. Jordan showed the viewer the Makey Makey game he and his partner created.	FSM	FSM	FSM

Week #	Case	Source	Observation	Coder 1	Coder 2	Coder 3
1	3	Flipgrid	Sophia and Paige actually worked together during the first week. They designed a room in Minecraft which had a bed, window, and Jeff. Paige asked Sophia to show the viewers what they made outside. Sophia explained they planted trees and water. Paige corrected her to say you don't plant water.	FSM	FSM	FSM
1	4	Flipgrid	Do you think I need to add anything else? Tell me.(Oliver was seeking PFF about his Beyblades)	FSM	FSM	FSM
5	3	Flipgrid	We are thinking about adding some lava and some portals. It's all in a village in Flat World - Jeff has changed. He is now King Jeff with a crown and he is now red. (Sophia)	FSM	FSM	FSM
5	4	Flipgrid	Oliver rejected his first classmate's advice about improving his video recording techniques specifically related to his camera angles. He explained that he did not find the feedback about his video recording techniques helpful and that he did not have time to record a new post. Classmate suggested Oliver make the Beyblades smaller but Oliver said he planned to keep the Beyblades the same size because he felt it would be less entertaining b/c not as many people could see them.	FSM	FSM	FSM
6	3	Flipgrid	The girls explained that they asked their peers for feedback about how to design a beacon in Minecraft and that one of the boys helped them. (review of video footage from Week 5 confirms this)	FSM	FSM	FSM
6	4	Flipgrid	"I first started doing I made these and I added a lot of things onto them because as you can see there like this, this, two things are the same. I also added to my attack type - it's kind of like a helicopter - it's so big it barely fits on the screen - let me pull back the screen - you know what else I have in mind? The bases so the battery boxes could be held up and not get tangled in the motors. I also have a new idea for a Spiderman car I started doing this -	FSM	FSM	FSM
6	1	Flipgrid	(Anna and Sarah are now working together.) They made a drawbridge out of cardboard and described where they will put the screws to allow the drawbridge to open. Anna said they would make a model of a boat and then demonstrated how the bridge would open as the boat passed through. She described how they would put tubes on each corner to lift the bridge and one in the middle for extra support. Sarah described how they would put up walls so the cars just don't fall into the ocean.	FSM	FSM	FSM
6	2	Flipgrid	Connor and Jordan each created a Flipgrid and summarized what they had built describing the levers, pistons, doors, and other features they created in their Minecraft world.	FSM	FSM	FSM

Week #	Case	Source	Observation	Coder 1	Coder 2	Coder 3
7	1	Flipgrid	Anna and Sarah - final Flipgrid Hi this is Anna and my project. We made a bridge out of cardboard. It took us a long time. Sarah: Here is one of the ramps so that a boat can go under it from here. Anna: Come up here and there's a boat that we're going to bring in. Not a real boat. A toy one. Look a car can go over here and then under here is where the boat goes through look at the bubble wrap. It's the water. Sarah: It took us a long time and A very long time. You see all of this tape. It kept just breaking. Anna: Yeah, it hasn't always been secure. So every time it broke, we had to put on more cardboard. We had to put a couple more layers on top of it. Sarah: First we thought of coloring the tape brown but it didn't really work. See look over here. We put this bar over here to kind of make it a little ramp. Anna: Stable? Sarah: Yeah. Sarah: This is our Number 2 Flipgrid. Sarah: What did you add to your project? Anna: What we added from our project? We added a ramp, and we colored it, and we added a lot more tape. Sarah: What would you do differently? Anna: I would try to get the tape more stable and or blend it in. Sarah: Would you change anything? What and why? Anna: Maybe if we had colored the bubble wrap blue then it would look like the ocean	FSM	FSM	FSM

			Sarah: What were the most difficult parts of the project? Anna: The most difficult was making it stable to put a ball over it, blending it in, and trying to make it look like an actual Bridge. Sarah: What were the easiest parts of your projects? Anna: The easiest part was taping two pieces of cardboard together and drawing on it. That was our Number 2 Flipgrid and we made a bridge.			
7	2	Flipgrid	Connor: This is our water and sewer drain. First we have this it cuts off the water. As well as this. I made this part myself. And then we have this one. It also blocks off the water. As you can see. Over here, now my friend Jordan will take over to show you our house. Jordan: So we're not at your house yet. This is the bridge that we made today. There's a spider on it. We're not going to kill that spider. Our house should be around here. There's our house. It's very hard to get into. Because he needs to go on the top of it. Those are Pistons. No those are trap doors, so good to open all of them. Close the trap doors. Connor and I made. This is a couch here. And then we want to show you more of our Bridge. So we can say the contraption of what it does. First let me get out of here. Wait, so he's going to get out of there. You can get out using the doorway. I do not want to do that. My God, it's so hard to get out of here. Yeah it is. It makes it very safe though so nobody can get in. Make sure the contraption of her Bridge. This is how it works. You might want to see a closer. It's up right now but I can make a close. Like this. Just pulled on the levers. This is a drawbridge. That's basically it. Will go back and try the other stuff if we have time. No this is the other stuff. Bye. See you next time.	FSM	FSM	FSM
1	1	MVI0005	"Can I draw a line so I know where to cut it?" (Anna says in reference to cutting cardboard)	LSaL	LSAL	LSal

Week #	Case	Source	Observation	Coder 1	Coder 2	Coder 3
1	4	Flipgrid	Oliver explained how his Beyblades worked. "I used these two motors and the battery box to make them spin I can hold them myself or I can at least try to. They can come in and smash into each other" (shows them banging into each other).	LSaL	LSAL	LSaL
5	3	Flipgrid	We are thinking about adding some lava and some portals. It's all in a village in Flat World - Jeff has changed. He is now King Jeff with a crown and he is now red. (Sophia)	LSaL	LSaL	LSaL
5	4	MVI0244	Oliver self-talked about how he needed another battery pack, predicting that it was going to be difficult to make both Beyblades move with just one battery pack. Oliver was holding both the Beyblades and could not turn on the battery pack. "I'm going to need another pack."	LSaL	LSaL	LSaL
6	4	SMBB.mov	Oliver noted when adding Lego battery packs to his Spiderman Lego car that both battery packs had to be turned on at the same time or the wheel that started moving first would cause car to turn and not move in a straight line. He manually synchronized the “on” function and the car was propelled right off the table	LSaL	LSaL	LSaL
6	4	Flipgrid	"I first started doing I made these and I added a lot of things onto them because as you can see there like this, this, two things are the same. I also added to my attack type - it’s kind of like a helicopter - it’s so big it barely fits on the screen - let me pull back the screen - you know what else I have in mind? The bases so the battery boxes could be held up and not get tangled in the motors. I also have a new idea for a Spiderman car I started doing this -	LSaL	LSaL	LSaL
1	4	Flipgrid	Do you think I need to add anything else? Tell me.(Oliver was seeking PFF about his Beyblades)	PFF	PFF	PFF
5	4	Flipgrid	Oliver rejected his first classmate’s advice about improving his video recording techniques specifically related to his camera angles. He explained that he did not find the feedback about his video recording techniques helpful and that he did not have time to record a new post.	PFF	PFF	PFF
5	4	Flipgrid	Classmate suggested Oliver make the Beyblades smaller but Oliver said he planned to keep the Beyblades the same size because he felt it would be less entertaining b/c not as many people could see them.	PFF	PFF	PFF
1	2	MVI0007	Ryan says to Jordan, "Just do it like this." (and then models how to cut the board for the Makey Makey game screen they created).	PM	PM	PM

Week #	Case	Source	Observation	Coder 1	Coder 2	Coder 3
1	2	MVI0012	They laughed and modeled for each other how to play Flappy Bird. Connor asked Declan to help him logon.	PM	PM	PM
5	1	MVI0088	Sarah observes group of three boys working on their cardboard objects. She notices how they cut the board as she screws in the Makedo screws. She used the same tools as the boys to cut the cardboard in subsequent weeks.	PM	PM	PM
5	3	MVI00119	Paige observes two classmates working on the computer monitors next to her. They are collaborating on features in Minecraft. She then shares those observations with her partner and they include some of the features in their final project.	PM	PM	PM
6	1	MVI0277	She was also able to show her partner, Anna, how to cut the cardboard during Week 6 as evidenced by the video footage recorded.	PM	PM	PM
1	1	MVI0010	Lara gives Anna advice on how to finish her circuit on Makey Makey - "No, that' s the left side. You have to touch it. Oh wait, I have an idea." She then shows Anna how to complete the circuit, which Anna applies to her project for that day.	VPF	VPF	VPF
1	1	MVI0010	Sarah came over to Anna's group to see what she was doing. The video shows them collaborating on the Makey Makey board to build a game controller.	VPF	VPF	VPF
1	2	MVI0007	Declan coaches Connor on Flappy Bird, "You need to add one click - "Look! Every time you click you are a different thing." Declan added, " I can set an obstacle, make gravity random, make it laser. Best game ever!	VPF	VPF	VPF
1	2	MVI0007	Christopher says, “I like that! That's a nice idea." (in reference to the above)	VPF	VPF	VPF
1	2	MVI0012	Connor and Declan worked near each other on Flappy Bird to code a new game. They had the Chromebooks set up directly in front of each other as they sat together. They were able to hop between the two devices. Look! How did you do that? They laughed and modeled for each other. Connor asked Declan to help him logon.	VPF	VPF	VPF
5	1	MVI0083	Skylar tells Anna what to do with Google slideshow. Anna grabs the Chromebook. Skylar tells Anna to share the file with her and then goes to retrieve another Chromebook.	VPF	VPF	VPF

Week #	Case	Source	Observation	Coder 1	Coder 2	Coder 3
5	2	MVI0275	Jordan is working on Minecraft. Ryan comes over and says they have to work together. Ryan starts crying. Jordan lets him on the computer. Jordan is fidgeting, rocking, and pacing as he appears to want to get on the computer. Ryan won't let Jordan on. Jordan says: Can I help you? And tries to get on the mouse or the keyboard. Ryan moves his hand away and says: I don't think you'll be able to do this. Jordan says: I know how to do this. I'm an excellent house builder. Ryan lets him on. Jordan shows Ryan how to create on Minecraft.	VPF	VPF	VPF
5	3	MVI00119	Paige returns to her partner, Sophia, and suggests they include the features she just saw her peers implement.	VPF	VPF	VPF
6	1	MVI0108	Sarah suggests to Anna that they could use a box to help build the bridge. Anna is twirling tape around a paper towel tube. Later both girls are trying to connect the tubes with tape. Sarah says to Anna: Anna I'm cutting a slot like this - Hard to determine what was happening as they were off camera - not audio near them.	VPF	VPF	VPF
6	2	MVI0108	Connor and Jordan are working together on the same monitor to build in Minecraft. Jordan tells Connor he can make a piston and "I have a plan!"	VPF	VPF	VPF
6	3	Flipgrid	The girls explained that they asked their peers for feedback about how to design a beacon in Minecraft and that one of the boys helped them. (Review of video footage from Week 5 confirms this)	VPF	VPF	VPF
6	4	MVI0122	James stops in to see what Oliver is doing. Oliver shows him the Beyblades and James tells Oliver, “Cool!” Then Oliver asks James to hold a Beyblade to test them out. They laugh and James shows his approval by smiling and engaging with Oliver and the Beyblades.	VPF	VPF	VPF
5	4	MVI0244	They turned off the battery packs and Oliver observed that one Beyblade continued to spin. Mrs. Davis commented that she thought it was interesting that one of the Beyblades continued to spin even though the battery had been turned off.	TP+	TP+	TP+
6	4	Flipgrid	Oliver described how he problem solved to create his motorized Spiderman car, "Mrs. Smith and someone else had an idea. I think we attach two motors, an axle and a pulley and I think that might let it go. It works. A pulley here and it will make the car go." (Review of video footage from Week 6 confirms this interaction.)	TP+	TP+	TP+