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# Teachers in the Making:

## *An investigation of pre-service teacher experience in a maker faire setting, and the role of design thinking*

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Education

by

Sean Michael O'Brien

Committee in charge:

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December 2016

This dissertation of Sean Michael O'Brien is approved.

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October 2016

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## ABSTRACT

Teachers in the Making:

*An investigation of pre-service teacher experience*

*in a maker faire setting,*

*and the role of design thinking*

by

Sean Michael O'Brien

This qualitative research project applies a case study approach to investigating the nature of experience and interactions of four pre-service teachers who took part in facilitating an activity for a School Maker Faire. Additionally, the research looks for evidence of design thinking as a pedagogical practice, manifested by pre-service teachers in this environment. Data was collected in the form of stimulated recall interviews and semi-structured interviews. Analysis of the data was guided by the following three questions:

- What is the experience of pre-service teachers in a Maker Faire environment?
- How do pre-service teachers interact with children in a Maker Faire?
- How do pre-service teachers display their pedagogical understanding of design thinking, in a Maker Faire environment?

Findings reveal the following four phenomena as being important influences on interaction and experience: pre-Maker Faire preparation, types of questions asked, the role of assessment, and the role of parents.

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# CHAPTER 1: INTRODUCTION

## Statement of the Problem

The Next Generation Science Standards (NGSS) promote *engineering and design thinking* as a best practice for teachers to get students to engage in critical thinking, problem formulation, and problem solving (NRC, 2011). In the attempt to get these practices into classrooms, an increasing amount of attention is focused on looking to the Maker Movement and maker education for inspiration (T. Martin et al., 2014; Vossoughi & Bevan, 2014).

Design thinking (or "engineering and design thinking" as it is referred to in the NGSS), is an active and iterative approach to defining and solving novel problems and, "the growing enthusiasm for teaching and learning design thinking raises questions about how this complex set of ideas, processes, and concepts can best be taught" (Goldman et al., 2014, p.11). However, for most pre-service teachers, design thinking is not the predominant mode of education that they have been exposed to in their educational careers– neither as pre-service teachers, nor as students themselves. Therefore, practitioners seeking to educate pre-service teachers on the ways of design thinking are up against a significant amount of cultural pressure and experience that has likely informed incoming teachers to think otherwise. This is a hurdle worth recognizing and one that likely implies designing teacher education in a way that can work towards getting pre-service teachers to shift from one way of thinking about learning (the one informed by their experience in school) to another (design thinking and maker education). As teacher education programs look to integrate best practices from the Maker Movement and maker education into their methods coursework, we will want to understand how these new ways

of thinking about learning may impact pre-service teachers in these programs– especially in instances when pre-service teachers are attempting to apply their beginning understandings of design thinking.

The profession of teaching is unique in that most prospective teachers have experienced at least seventeen years worth of informal education before they even enter a teacher education program. As pre-service teachers enter teacher education programs, they have sat in classrooms from kindergarten through college and all the while have been in the presence of professional teachers "doing teaching" in myriad environments and scenarios. While they have observed the outcomes of teacher thinking on so many occasions, there remains the problem that observing teaching is not the same as doing teaching. The sociologist Dan Lortie (1975) writes that:

> *Students do not receive invitations to watch the teacher's performance through the wings; they are not privy to the teacher's private intentions and personal reflections on classroom events. Students rarely participate in selecting goals, making preparations or postmortem analysis. Thus they are not pressed to place the teacher's actions in a pedagogically oriented framework. (p.62)*

Coined as the "apprenticeship of observation" by Lortie (1975), this idea suggests a phenomenon by which pre-service teachers learn so much about teaching through the observation of other teachers and through their experience as students in school systems. Darling-Hammond & Bransford (2012) point out that teacher learning through such apprenticeship is good in the sense that pre-service teachers, "arrive with a great deal of experience in classrooms, and many draw inspiration from outstanding teachers who taught them. The bad news is that these apprenticeships can result in serious misconceptions about teaching" (p. 367). If you compare teaching to almost any other profession, teaching is distinctive in this regard.

Take for example, doctors. Upon entering medical school the vast majority of med students have not spent any significant amount of time diagnosing and healing people on a daily basis, nor have they spent any significant amount of time in the presence of doctors practicing their profession. Sure they have visited doctors, but the time spent in the presence of them is very little compared to students in the presence of teachers. Almost everything medical students learn about being a doctor happens through their education in medical school and through their residency training. The same holds true for lawyers, police, pilots, firemen, accountants, managers, psychologists, etc. None of them have spent the better part of their lives immersed in the culture of their to-be practice and profession.

The argument here is that the duration and quality of exposure to teachers doing what they and others call "teaching" is influential and formative for pre-service teachers as they enter teacher training programs. Pre-service teachers have been steeped in the language and culture of schooling for so long that they can recreate much of it without giving it a second thought. An example of this can be seen when they enter a classroom for the first time as teachers. Rarely do they fail to gravitate to the front of the room, toward the board, as they wait for all eyes to fall on them. They pose questions, they expect raised hands to call on. They write on the board, they expect it to be copied down in notebooks. It is an elaborate dance that perpetuates itself time and time again. For most of us who are a product of the American education system, much of this scene should seem familiar. That is because most of us, including pre-service teachers, are a product of this culture and at this point we are fluent in its language and structures.

All of this implies that when and if pre-service teachers are being asked to design learning environments that have design thinking at their core they are also likely being

asked to think about learning in ways that are very different than what they themselves have experienced. Because design thinking and maker education demands teachers to think about teaching and learning in ways that are very different than what they have experienced and been exposed to, this may be prove to be a very rich point of focus for research. What we learn from these experiences can shed light on how to best bring teachers along into this different way of conceptualizing thinking and learning.

## Purpose and Significance of Study

This research project aims to investigate the experience of a group of pre-service teachers who were charged with putting their understandings of design thinking pedagogy into action in a School Maker Faire activity. Findings from this research will add to the growing body of knowledge pertaining to maker education and design thinking as it applies to teacher education.

## Research Questions

The goal of this research project consists of two goals. The first goal is to understand the nature of experience for pre-service teachers who participated in the School Maker Faire event; the assumption being that this Maker Faire event was likely asking them to act and think in ways they have not been exposed to extensively, making this a potentially rich environment for insights and observation. It is a second goal of this project to understand the ways, and extent to which, the pre-service teachers displayed their understandings of design thinking in the Maker Faire environment. In the support of these two goals, the following three questions guide the research:

- What is the experience of pre-service teachers in a Maker Faire environment?
- How do pre-service teachers interact with children in a Maker Faire?

- How do pre-service teachers display their pedagogical understanding of design thinking, in a Maker Faire environment?

## Dissertation Overview

The present chapter described the basic research problem, identified the purpose and significance of this study, and framed the questions that ultimately drive this research. Chapter 2 explores the literature pertaining to the Maker Movement and maker education, as well as design thinking. The histories of each of these ideas are explored as well as how they relate to the Next Generation Science Standards (NGSS) and teacher education. Chapter 3 describes the qualitative approach employed in this study as well as the methods of data analysis. Chapter 4 offers an analysis of the data. Chapter 5 discusses the results, provides recommendations for researchers and practitioners, and closes with concluding remarks.

# CHAPTER 2: LITERATRUE REVIEW

The literature review is divided into two parts. First, as the context of this study is a School Maker Faire, the Maker Movement and maker education will be explored in terms of its history as well as the ways in which it pertains to current shifts in the K-12 and teacher education landscape. Second, as design thinking functions as the conceptual framework for this study, design thinking will be explored both in terms of its history as well as how it pertains to teacher education.

## Part 1: Maker Movement and Education

### Making, the Maker Movement, and Makerspaces

It is more and more common that schools are developing designated places on the school grounds where students and classes can participate in the activity of *making*. While it is acknowledged that there is currently no agreed upon definition for "making" in its contemporary usage (Blikstein, 2013a; Sheridan et al., 2014a), Martin (2015) synthesizes the existing versions by defining making as "a class of activities focused on designing, building, modifying, and/or repurposing material objects, for playful or useful ends, oriented toward making a 'product' of some sort that can be used, interacted with, or demonstrated" (p. 31). In their literature review of making and makerspaces, Vossoughi & Bevan (2014) reinforce the notion that the current definition of making is ambiguous in the literature, but their analysis concludes that, at least in broad terms, "the range of practices involved in making can and often are viewed as mutually generative, and the forms of meaning making embedded in the process of creative problem solving and design can productively blur the lines between science, engineering and the arts." (p. 10). Making includes a variety of skills sets (woodworking, programming, sewing, jewelry making,

etc.), and can implement a variety of tools (3-D printers, welders, computers, etc), and can occur within a variety of places (schools, communities, garages, libraries, museums, etc.).

This shift towards a hands-on approach to making and working with both digital and analog tools and materials, is widely referred to as the *Maker Movement* (Colegrove, 2013; Dougherty, 2012; Hlubinka et al., 2013; L. Martin, 2015; Stager, 2013). In his book, Makers: The New Industrial Revolution, Chris Anderson (2012) describes the Maker Movement as being as much about the connection between making in the real world with hand tools as it is about the a reliance on digital tools to output design ideas to desktop fabrication machines (3-D printers, laser cutters, CNC routers, etc). Anderson also points out that those who identify with the Maker Movement consistently leverage the internet to, "instinctively share their creations online" (p. 21), thus identifying the distinctly social nature inherent in the movement. The Maker Movement represents an increased awareness of, participation in, and research on making and makers as it, "stretches across the formal/informal instructional divide" (Halverson, E. & Sheridan, 2014, p. 501); thereby locating making both in and outside of formal schooling environments (Vossoughi & Bevan, 2014).

Many trace the origins of the Maker Movement to around 2005/2006 which corresponds with the inaugural year of *Make Magazine*- a magazine dedicated the do-it-yourselfers ("DIYers") and makers of all persuasions (Blikstein, 2013a; Dougherty, 2012; Halverson, & Sheridan, 2014; Hira, Joslyn, & Hynes, 2014). One of the key catalysts leading to the growth in attention on this movement seems to be the first World Maker Faire in 2006, where participants from all over the world could bring their self-made creations for others to see and experience. Since its conception, these World Maker Faires

have grown in volume of participants, as well as in the numbers of events over the last 11 years. Currently there are a number of "Featured Faires" throughout the year taking place in large cities all around the world. The larger faires reportedly receive as many as 100,000 visitors (source: makerfaire.com).

The popularity of these World Maker Faires has inspired communities, and some schools, to organize their own independent Maker Faires or School Maker Faires. Maker Faires of this scale may self-organize, however if they are to use the "Maker Faire" namesake they need to register with "makerfaire.com," which will then provide support, guidelines, and branding parameters for organizing an independent event (this research project, in particular, is a look into a registered School Maker Faire).

Different from the event-like nature of Maker Faires are *makerspaces,* which are usually more permanent in nature. Conceptually, the term *makerspace* still lacks an agreed upon definition in the literature, and the definitions that do exist are broad in scope (Davee, Regalla, & Chang, 2015; K. M. Oliver, 2016a). There does seem to be general agreement that makerspaces are much more defined by the tools, resources, and mindset that drives them, than they are about the actual physical space (Dougherty, 2012; Hlubinka et al., 2013; Oliver, 2016a). Makerspaces can exist in a space in the corner of a classroom ("distributed"), just as much as they can be a fully outfitted, independently run, and permanent space ("dedicated") (Davee et al., 2015). Colegrove (2013) claims that makerspaces encompass a continuum of activity that includes environments such as "co-working spaces", "hackerspaces", and "fab labs":

> *A fab lab is about fabrication. Realized, it is a workshop designed around personal manufacture of physical items— typically equipped with computer controlled equipment such as laser cutters, multiple axis Computer Numerical Controlled*

> *(CNC) milling machines, and 3D printers. In contrast, a "hackerspace" is more focused on computers and technology, attracting computer programmers and web designers, although interests begin to overlap significantly with the fab lab for those interested in robotics. Co-working space is a natural evolution for participants of the hackerspace; a shared working environment offering much of the benefit of the social and collaborative aspects of the informal hackerspace, while maintaining a focus on work" (Colegrove, 2013, p.3)*

Makerspaces, in all of their forms may also represent a physical manifestation of the democratization of information (Blikstein, 2013b) that is occurring as people of almost every socio-economic class have access to the internet in one form or another (via smart phones, laptops, internet cafés, and public libraries). For the motivated individual, one can go online and find inspiration or instructions on how to do or make something, find a local makerspace, and ultimately leverage the space and its community towards making the product or concept that is in mind. The conceptual nature of the internet, combined with the physical and social nature of a makerspace, creates a powerful dynamic where everyday people can learn and make extraordinary things.

When placed in the context of schools, the idea of making begins to take on a more focused approach which can be attributed to its potential to yield specific learning outcomes where,

> *there is growing interest among educators in bringing making into K-12 education to enhance opportunities for students to engage in design and engineering practices, specifically, and science, technology, engineering, and mathematics (STEM, or STEAM when art is included) practices, more generally. (Martin, 2015, p. 30)*

The assumption here appears to be that such opportunities and skill sets will better prepare our students for jobs of the future.

In his immensely popular TEDTalk: *Do Schools Kill Creativity?,* Sir Ken Robinson articulates the following problem: *How do we prepare our students for jobs that don't even exist yet?* In other words, "a child in middle school today will be entering the prime of their careers in 2040. We have no idea what the world will be like then. Therefore it is crucial to develop timeless skills such as curiosity, creativity, and the ability to learn on one's own" (Hlubinka et al., 2013, p. 4). The posing of such a question is largely attributed to a society, economy, and a world that in part can be defined by the unprecedented rate of technological change that is happening. Many of us have experienced firsthand that at this current rate of change, technology can make enormous leaps that transform our lives in unimaginable and dramatic ways. We have experienced the rise of the internet which changed the world and the flow of information, and how we access that information. In relatively short time, we also experienced the huge technological leap of having the internet accessible in our pockets in the form of smart phones. These rapid advances in technology are dramatically changing the way we work, communicate, socialize, and manufacture. We now live in a world where we can control and automate features of our houses remotely, our cars are beginning to drive themselves, and tiny devices on our wrists can track and visualize data about our health and activity. Makerspaces may represent a *physical response* to the question of how to prepare students (or allow students to prepare themselves) for a skill and job landscape that will likely be vastly different, technologically speaking, than the one we know at this moment in time.

While a strong argument can be made for the ways in which makerspaces provide a solution for the problem of preparing people for uncertain and rapidly changing futures, makerspaces and the Maker Movement do much more. Makerspaces can serve as playful

places for learning (L. Martin, 2015), as hubs for community involvement and empowerment (Davee et al., 2015), as a place to learn how to manage and leverage failure towards learning and success (Blikstein, 2013b), and as environments that can spark and nurture creativity (Brahms & Wardrip, 2014; Oliver, 2016b). In a school context, makerspaces provide a place where students can access a wide variety of technologies in hands-on environments that are often designed to foster creativity, divergent thinking, collaboration, and innovation. While the idea of makerspaces is a relatively new phenomenon, related concepts have swirled around in the conversations on schooling for some time and they share a number of common outcomes and goals with the Maker Movement and makerspaces.

In the early 1900's John Dewey conceptualized and created the Laboratory School (a version of which still exists today at the University of Chicago), where learning was intended to be driven by interests and activities that every child was said to have possessed:

> (1) communication and intercourse,
>
> (2) making and building,
>
> (3) exploring and investigating, and
>
> (4) artistic expression and self-realization. (Knoll, 2014, p. 456)

While the physical concept of the Dewey's Laboratory school never really gained widespread and lasting traction, his philosophy of learning has been at the core of educational conversations for over a century now. As makerspaces gain traction in our modern world, it is easy to build a logical connection between the foundation of Dewey's Laboratory School and the ethos that is at the foundation of the maker movement.

A contemporary of Dewey, Maria Montessori, developed the Montessori approach to education that is still in use today all around the world. The Montessori Method is a version of learning that is child-centered and focused very much on learning through tactile and hands-on exploration; a version of exploration that defines the child/student as one who wants to emulate and take part in the "real-life" activities of day-to-day life and places an immense amount of importance on experiential learning, creating, and making (Montessori, 1912). In contrast to Dewey's Laboratory School, the Montessori approach is active and present in our educational culture not only as a philosophy, but also as a widespread network of schools that uphold and implement the Montessori approach. Similar to Dewey, many of the guiding beliefs that are at the foundation of the maker movement can be mapped on to the core values and beliefs that comprise the Montessori approach.

In 1980, before the dawn of the internet as we know it, Seymour Papert's book Mindstorms: children, computers, and powerful ideas gave a glimpse of what was to come. When one reads this book from the perspective of the current makerspace landscape, it is amazing how visionary his ideas were in terms of the technological spaces he suggests for learning. In conceptualizing how such spaces might form, Papert prescribes that "powerful new social forms must have their roots in the culture, not be the creatures of bureaucrats" and that "this must be true too of any new successful forms of associations for learning that might emerge out of the mathetic computer culture" (Papert, 1980, p. 181).

It could be said that makerspaces are a version of Papert's "powerful new social forms" and have emerged from the confluence of the internet and social media ("the mathetic computer culture"). The internet as we know it is a place that is largely

associated with the passive consumption of information, and with the social networking opportunities it affords. In a sense, makerspaces seem to serve as a sort of pressure relief valve, manifested in the physical environment, to the ever-growing glut of information that is the internet. One study identifies that the increase in numbers of those who identify themselves as makers is in part due to, "the emergence of a strong community of self-identified makers connected through social networks online," (Martin & Dixon, 2013). Framed in this manner, it is arguable that makerspaces may in fact serve as a real-world outlet for ideas and relationships formed in the online world.

As the term *making* evolves towards a more cohesive definition in the literature, Vossoughi et al. (2014) caution that as making makes inroads to mainstream education, "narrow definitions [of making] may also overlook subtle distinctions between rote forms of assembly and moments when following a model or recipe may be intellectually generative" (p. 10). While maker education is currently thought of as largely being open-ended and learner-directed, Vossoughi et al. (2014) acknowledge that there may be forms of making which are just as powerful for learning but which rely on more scripted or "rote" experiences. "Rote" forms of making might include using a set of plans for how to build something.

The term *maker education* is used with increasing frequency (in mostly non-academic literature) to address the ways in which making is intentionally being folded in to, and in some cases, driving curriculum in traditional education settings. While maker education is definitely learner/participant centered, and rooted in exploration, it is not simply a reincarnation of Dewey's Lab School (nor is it the Montessori Model). Maker education is also about creating spaces geared towards leveraging a variety of cutting edge

tools, machines, and equipment, however it is not simply a re-vamping of the high-school shop classes with all the latest technological equipment (nor is it a reconfiguration of the vocational school). And while maker education absolutely depends and thrives on collaboration and the cross-pollinization of ideas, it is not just a synonym for communities of practice or affinity groups. Maker education is in part the sum of all of these influences, and can be looked at through each of their conceptual lenses, but at the same time maker education is completely unique as it is a product of, and response to, the extremely dynamic technological landscape that defines the current times. Vossoughi & Bevon further make the case that making is something new and unique in that, "the aesthetic and playful qualities of many making activities may operate to create a particularly low barrier for participation. Making thus looks and feels different from more traditional open-ended inquiry activities" (2014, p. 4).

While there appears to an absence of academic papers that work to define maker education, let alone use it in the first place, the term "*maker education*" can be found more frequently in non-academic sources (e.g.: makered.org, edutopia.org). Maker education implies a pedagogical stance in ways that the terms *making* and the *Maker Movement* seem unable to do on their own. More specifically, maker education suggests a stance towards education and learning that places making at the foundation of how learning is designed, facilitated and assessed in formal educational settings. For example, maker education might look like a history unit on ancient civilizations, where a culminating project asks students to leverage 3-D printing and laser cutting technologies as they work in teams designing their own civilization (Blikstein, 2013b). Maker education might also look like a music student leveraging pneumatics (pressurized air) and computer controllers to design a

robotic flute in the pursuit of understanding the complexity of human breath control when playing aesthetically appealing music (Blikstein, 2013b). This research project will use the term *maker education* to refer to making being placed at the foundation of designing, facilitating, and assessing learning in formal educational environments.

There are some who would criticize the claim that environments that embrace maker education are sound environments for learning (Kirschner, Sweller, & Clark, 2006). Kirschner, Sweller, & Clark describe inquiry learning (which maker education can be described as a form of- see: Blickstein 2013; Resnick & Rosenbaum 2013) as being synonymous with "minimal interaction" from adults (2006). They back up their perspective by citing evidence from brain research on the ways in which working memory acquires new information in very limited capacities and that inquiry/exploration based learning overloads these capacities as learners have to decipher for themselves which information is most important to focus on and commit to memory. They argue that direct instruction works to provide information in formats and doses that working memory can handle and process to long-term memory. In other words- kids won't learn unless there is a more knowledgeable adult present to organize and disseminate information in discrete and manageable pieces. Of course, these arguments assume that learning is purely a memory-based function, and that children cannot drive their own learning.

While adults (including teachers and facilitators) play a different role in maker education environments than in direct instruction environments, describing adults as providing minimal interaction seems to misconstrue the nature of adult influence in maker education environments. While adults can and do take more of a back-seat role in these spaces, interaction is also more broadly defined in an environment designed for making. It

can include ways that the space is intentionally designed by adults (Brahms & Wardrip, 2014; Holbert, 2016), it can include how adults model an activity or behavior (Exploratorium, 2016), and it can even be the way that adults observe learning as it unfolds (Brahms & Wardrip, 2014; Exploratorium, 2016). Research suggests that such environments (inquiry/exploratory/maker) benefit enormously from adults who can be present to help learners work through problems as they act as co-thinkers, or even as more knowledgeable experts in some cases (Brahms & Wardrip, 2014; Horvath & Cameron, 2015; Vossoughi & Bevan, 2014).

Furthermore, these criticisms seem problematic as they question the merits of maker education from within an *instructionist* perspective (Papert & Harel, 1991) while maker education itself seems more closely aligned with a *constructionist* perspective. Each of these perspectives have very different assumptions about how learning works. First, these two perspectives are at odds with one another on the basis of how they describe who has authority and how authorship of knowledge is distributed; in this case authorship is about who drives the generation of knowledge building. From a *constructionist* perspective, the learner owns and shares authorship with others in the learning environment (including the teacher/facilitator/present adult) as knowledge is co-created. In contrast, those who view the learning environment from an *instructionist* perspective, place authorship in the hands of those who hold the knowledge- and in most cases this implies the teacher.

In summary, maker education has its roots in making and the Maker Movement. Makerspaces are the physical spaces in which making can happen and they take on a wide variety of forms and functions among the different versions. While maker education and

the Maker Movement share a lineage with, and bear strong resemblance to, concepts described by important thinkers such as Dewey, Montessori, and Papert the Maker Movement is arguably its own phenomenon, worthy of study in its own right, as it is a product and response to our current culture and times. The next section will explore the role of making within STEAM (Science, Technology, Engineering, Art, and Science) education, the Common Core, and the Next Generation Science Standards.

**STEAM, the CCSS, and the NGSS and the role of making**

Among the arguments for bringing the maker movement into formal education settings is the assertion that making engages students in STEM/STEAM learning in new and relevant ways. STEM stands for *science, technology, engineering and math*- with the option to include *art* in the acronym, depending on the goals of an organization. (This paper will use the acronym STEAM in order to be inclusive of a broader range of perspectives in this area.) Although an emphasis on STEAM subjects existed prior to the Maker Movement, and were relegated to more, "text-based, test-driven, teacher-centered STEM instruction" (Vossoughi & Bevan, 2014, p. 4), as maker education becomes more prominent in mainstream education STEAM subjects are benefiting from the inherently cross-curricular nature of maker education.

In a maker environment children may take apart every day objects, repurpose them into new creations, engage in computer coding and robotics, and design solutions for identified problems in their communities and every day lives. In the process they are constantly weaving in and out of various STEAM subject domains fluidly. In a sense, making enables the silos of these otherwise distinct subject domains to be more permeable, and in some cases less distinguishable from one another– a reality that is more reflective of

the nature of real life. Incidentally, both the new Common Core State Standards (CCSS) and the NGSS call for a more cross-curricular style education that also aims to blur the lines between subject matter domains (NRC, 2011).

In June of 2010 the final version of the Common Core State Standards was released to public K-12 education institutions. The standards were developed in recognition of, "the value of consistent, real-world learning goals and launched to ensure all students, regardless of where they live, are graduating high school prepared for college, career, and life" (Common Core State Standards Initiative, 2016). The impetus for this new set of standards was in response to the fact that every state, "had its own definition of proficiency, which is the level at which a student is determined to be sufficiently educated at each grade level and upon graduation. This lack of standardization was one reason why states decided to develop the Common Core State Standards in 2009" (Common Core State Standards Initiative, 2016). Present in this new policy is an expressed value to promote skills that will best prepare students for success upon graduation.

At the same point in time that the CCSS were getting under way, a new set of standards for science were being defined in parallel:

> *The Common Core State Standards (CCSS) for Literacy were written to help students meet the particular challenges of reading, writing, speaking, listening, and language in their respective fields—in this case, science. The literacy standards do not replace science standards-they supplement them. The NGSS (Next Generation Science Standards) lay out the disciplinary core ideas, science and engineering practices, and crosscutting concepts that students should master in preparation for college and careers." (Next Generation Science Standards, 2016)*

Much like the goals of the CCSS, the NGSS were created with the intent to develop skills that would prepare students for success in the world beyond school. The NGSS standards describe three dimensions, or themes:

1. Disciplinary core ideas
2. Practices
3. Crosscutting Concepts (Bybee, 2014, p. 214; Next Generation Science Standards, 2016; NRC, 2011)

The *"Disciplinary core ideas"* provide a framework to identify "the most important aspects of science", especially those that are common across science and engineering disciplines (ex: energy). The *"Practices"* focus on the behaviors that scientists and engineers engage in as they investigate questions and build models that illustrate their ideas. For example, "scientific inquiry involves the formulation of a question that can be answered through investigation, while engineering design involves the formulation of a problem that can be solved through design." The *"Crosscutting Concepts"* are those elements that have application across science and engineering such as, "patterns, similarity, and diversity; cause and effect; scale, proportion and quantity; systems and system models; energy and matter; structure and function; stability and change." (Next Generation Science Standards, 2016).

With the exception of the disciplinary core ideas, one notices that the other two dimensions largely focus on developing *ways* to approach thinking about science and engineering as opposed to a slew of facts and content themes. This is very much in contrast to the science standards that preceded the NGSS, which were much more fact and concept based. Table 1 gives explicit examples of this shift from fact/concept based

standards towards the skills based standards associated with the NGSS. Notice that this table also includes implications that these shifts have on student learning outcomes. Key phrases such as *developing models* and *using practices of engineering design* speak to the process based nature of the NGSS. Furthermore, The NGSS prescribe,

> *both knowledge outcomes and cognitive abilities for students. They should, for example, know that scientists ask questions about nature, use models, and require evidence as the basis for explanations. In addition, students should develop the cognitive abilities to formulate models, apply mathematics, construct arguments based on evidence, and communicate the results of investigations.(Bybee, 2014, p. 219)*

Asking questions, formulating models, constructing arguments, and communicating results are all very process-centric functions. Similarly, much of the activity that takes place with making and maker education is also grounded in processes.

*Table 1*: Educational shifts based on NGSS and their implications for science teacher education (Source: Bybee, 2014)

| From | To | Implications |
|---|---|---|
| Learning facts (e.g. parts of the cell) | Explaining natural phenomena (e.g. how cell structures relate to cell functions) | Students develop models and make sense of the natural world by using evidence to develop explanations |
| Single dimensions of science (e.g. disciplinary core ideas for physical science) | Interconnections of three dimensions of science (e.g. science and engineering practices, crosscutting concepts, disciplinary core ideas) | Students use the practices to gather data and form explanations using crosscutting concepts and disciplinary core ideas |
| Grade level content (e.g. middle school life science) | Progression of core ideas and practices across K-12 (e.g. coherent horizontal and vertical development of concepts and practices) | Students learn concepts below and above a grade-level |
| Science as a single discipline (e.g. biology) | Science and Engineering (e.g. practices of engineering design incorporated with science) | Students learn and apply the practices of engineering design |
| Science as a body of knowledge (e.g. conceptual structure of a discipline) | Science as a way of knowing (e.g. nature of science as an extension of practices and crosscutting concepts) | Students understand the nature of scientific knowledge |
| Science as a stand-alone discipline (e.g. separate time or course in curriculum) | Science connected with common core (e.g. English language arts and mathematics incorporated with science) | Students' science education program includes experiences that incorporate reading, writing, and mathematics |

Martin articulates that, "points of alignment with [the NGSS and] making are clear, such as the inclusion of 'defining problems' and 'designing solutions' as core engineering practices. Others are more subtle, but equally important." (2015, p. 31). Quinn and Bell (2013) identify that one of the more subtle ways that maker activities uphold the NGSS goals is by promoting "individual agency" in students. This individual agency, "in turn can help support the [NGSS] framework's emphasis on problem solving and sense-making" (Martin, 2015, p. 31).

In summary, making engages students in STEAM subjects in new and dynamic ways which may work to better integrate subjects that have otherwise operated in silos. Furthermore, making relies on processes (problem solving, asking questions, and design

thinking) that are congruent with the goals of the NGSS and CCSS. The following section looks at the emerging literature that begins to articulate "what works" when maker education is brought into K-12 schools, and ultimately how this learning is influencing teacher education.

### Maker Education and Teacher Education

As the Maker Movement becomes more prominent in formal, K-12, education, there is emerging research that looks at how teachers are preparing, and being prepared, to engage in maker education in their own classrooms and schools. A bulk of the research focuses on credentialed teachers implementing maker education in their classroom or school environment (Angello, Chu, & Quek, 2016; Hira et al., 2014; Martin et al., 2014) or on practices of facilitators in makerspace environments (Blikstein & Krannich, 2013; Sheridan et al., 2014b). Beyond the academic research, there are several museum publications that work to try and establish best practices for teachers and institutions that are interested in cultivating maker education (Brahms & Wardrip, 2014; Exploratorium, 2016; IDEO, 2012). There is very little current academic research literature that focuses on pre-service teacher education and maker education, which is the primary focus of this research project. This section will begin by evaluating the contemporary areas of research, followed by exploring the contributions of museum publications, and will conclude by making the case that research on maker education, as it pertains to pre-service teachers, is an area that would benefit from new and continued attention.

Sheridon et al. (2014) conducted an in-depth case study analysis of three different makerspaces (including MAKESHOP among them). This study's analysis revealed practices that were exhibited among teachers or facilitators working in these makerspaces.

Their findings show that teachers and facilitators in these environments participated in practices including creating scaffolds for understanding how to use and leverage different tools and materials, allowed for exploration and creation that worked across disciplinary boundaries, and created an environments that encourage feedback.

Blikstein (2013a) also worked to identify what people do in environments where making is occurring. One practice that seemed to bring success was designing environments that are "conducive to unlikely interdisciplinary projects" (p. 16). An example provided in this study was a music student who used computer controllers and pneumatics to create a robotic flute that played classical music. A second practice was the ability of a teacher or facilitator to be able to "contextualize learning in STEAM" (p. 18), arguing that such an ability helps to bring abstract ideas in to concrete situations. A third practice is the "intellectualization and re-evaluation of familiar practices, rather than the replacement of existing ones" Blikstein (2013a, p. 18). In other words, this practice suggests building an ability within teachers to be able to work with, and build upon, existing ideas that children bring rather than trying to replace those ideas (a practice also identified by Vossoughi, Escudé, Kong, & Hooper, (2013)).

MAKESHOP, a makerspace within Pittsburgh's Children's Museum, has published recommendations for practices based on their own in-house research (Brahms & Wardrip, 2014). These practices include factors such as design of space, design of activities, and design of facilitation. These practices are intended to be applied by any teacher, makerspace facilitator, or any other person engaged in creating and upholding similar types of learning environments.

The Exploratorium, a science exploration museum in San Francisco, has published a framework of "facilitation moves" (Exploratorium, 2016). These facilitation moves are similar in function to those set out by MAKESHOP as they work as guidelines for practitioners wishing to incorporate such practices in their own learning and making spaces. Common among these two museum publications is an underlying belief that, given a resource rich environment that depends on peers as co-thinkers and collaborators, children are capable of identifying, creating, exploring, and modeling their own ideas and problems to be solved.

In addition to identified and recommended practices, as they relate to maker education and teacher education, another common theme in the research literature has to do with how educators might seek to design makerspaces and the associated educational benefits of educators increasing their familiarity with the tools and technologies within these spaces. The Makerspace Handbook (Hlubinka et al., 2013) lays out in fairly explicit terms the ways in which an educator, organizer, or facilitator would want to design and outfit a makerspace– be it in a dedicated space or in a part of a classroom. Beyond the Makerspace Handbook, other researchers also identify the benefits of educators familiarizing themselves with the tools (both digital and analog) and the materials that are common to makerspaces as this will allow them to think more broadly and creatively when supporting student explorations and designs (Exploratorium, 2016; Harris, 2011; Oliver, 2016a; Papert, 1999).

However, some literature cautions that gaining computer and technological skills not just be about *how* to use these tools, but more importantly about developing a sense of *when to use certain tools and not others* (Blikstein, 2013a; Papert, 1980b). Developing a

sense of when to use certain tools and not others comes with practice and experience with tools over time and over a range of different experiences. This suggests the need to develop teachers who have a deeper familiarity with such tools, and who can leverage these tools as creatively as the students whom they are trying to get to do the same.

Currently, there is limited research on the *ways in which educators need to think in such spaces*, and even less about how this would pertain to training pre-service teachers. (Brahms & Wardrip, 2014; Peppler, 2013; Vossoughi & Bevan, 2014). However, the concept of *design thinking* has emerged as a common practice in places where making is happening and it offers a framework for how to approach thinking in such spaces; furthermore, there are instances where design thinking is making its way into formal classroom settings. The following section of the literature review will explore design thinking as it pertains to maker education and teacher education.

## Part 2: Design Thinking and Education

Design thinking is an integral part of the Maker Movement and maker education (Hlubinka et al., 2013; T. Martin et al., 2014; Oliver, 2016c; Vossoughi & Bevan, n.d.). In the literature design thinking is discussed as both a stance as well as a toolset. As a stance, design thinking provides a way to perceive, interpret, and act in the world around us. As a toolset, design thinking provides a set of principles to follow for approaching complex problems. Additionally, there are some who have identified design thinking as one way that educators might begin to address the need to prepare our students for 21st century skills, as suggested by the Next Generation Science Standards (NGSS) (Boesdorfer & Greenhalgh, 2014; Crismond, Gellert, Cain, & Wright, 2013).

This section will first provide a brief overview of design thinking, followed by a look at how design thinking has been researched as it pertains to education and teacher education.

**Design Thinking: A Brief overview**

The literature largely conceptualizes design thinking either as a *stance* that influences how one perceives and operates in the world, or set of *principles* to be followed when approaching a problem.

Conceived of as a set of principles, design thinking currently lacks a unified and operationalized definition of the principles that comprise design thinking (see Table 2). While the steps that define the process vary depending on the source, all agree that the process is largely iterative and should be cycled through as many times as need be in the pursuit of the best solution (Brown, 2009; Carroll, Goldman, & Britos, 2010; IDEO, 2012; Meinel & Leifer, 2011).

*Table 2:* Comparison of design thinking principles by source (own illustration)

| Brown (2009) | Carroll et al (2010) | Meinel & Leifer (2011) | IDEO (2012) |
|---|---|---|---|
| **Inspiration:** *includes understanding the problem, doing research, and organizing information* | **Understand:** *Learn about issues related to the design challenge* | **Define the Problem:** *Design never ends* | **Discovery:** *I have a challenge. How do I approach it?* |
| **Ideation:** *brainstorming, prototyping, testing, and re- designing* | **Observe:** *Watch how people behave and interact. Talk to people about what they are doing, ask questions and reflect on what you see.* | **Needfinding & Benchmarking:** *Understand the users, define the space* | **Interpretation:** *I learned something. How do I interpret it?* |
| **Implementation:** *execution of the solution, with the recognition that implementation leads to new projects or the next iteration of the current one* | **Point of View:** *Takes into account information about user needs and insights.* | **Brainstorm:** *ideate* | **Ideation:** *I see an opportunity. What do I create?* |
| | **Ideate:** *In the ideation phase, quantity is encouraged. Brainstorming ideas is the foundation of this phase.* | **Prototype:** *build* | **Experimentation:** *I have an idea. How do I build it?* |
| | **Prototype:** *A prototype can be a sketch or a two- or three- dimensional low resolution model made out of diverse materials. It is a way to convey an idea quickly;* | **Test:** *learn* | **Evolution:** *I tried something new. How do I evolve it?* |
| | **Test:** *Testing is part of an iterative process that provides feedback. The purpose of testing is to learn what works and what doesn't, and then iterate.* | | |

In addition, while each of these processes imply a neat and tidy cycle, Meinel and Leifer (2011) mention that research on the actual stages that designers follow are not at all neat and tidy and in many cases move fluidly and sporadically among the different stages (see Figure 1).

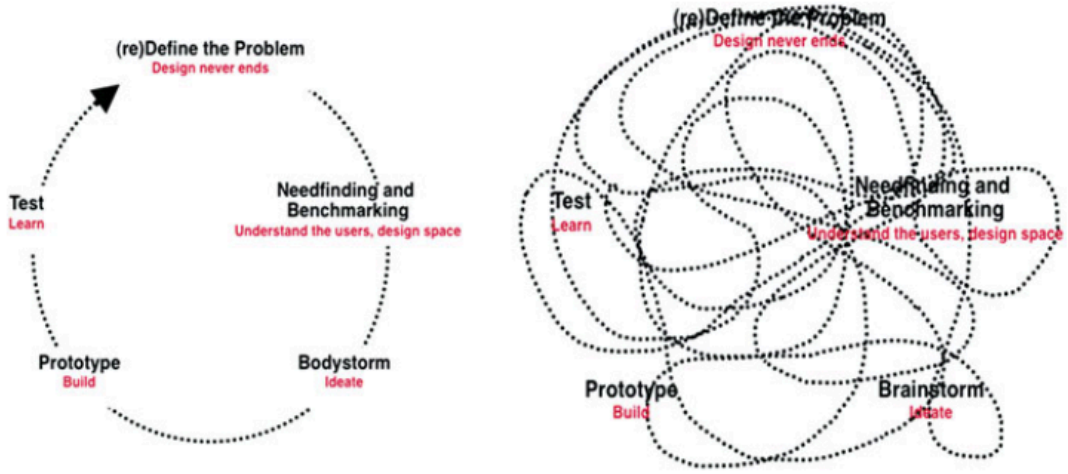



*Figure 1:* The hypothetical path of design thinking in action (left) compared to the more realistic path of design thinking in action (right) (Source: Meinel, & Leifer, 2011)

For the novice, these principles can be taken simply as a set of tools to be applied to a problem. For educators, these principles can be applied as an approach for engaging students in science education, for example. For the committed, these principles can be adopted and integrated into a transformational shift in how one perceives and acts in the world.

In arguing for the case that design thinking can be embraced as a stance, or way of perceiving, Meinel and Liefer explain that, "design thinking is mainly about building innovators who can use the design thinking paradigm to transform ideas into reality, to transform organization, and to transform all aspects of life." (2012, p. 1); in this manner design thinking takes on a holistic approach (Goldman et. al, 2014; Plattner & Meinel, 2012). Shelly Goldman and her colleagues at the Stanford d.School (Stanford Design

School), argue that a design thinking stance can be developed in individuals, calling these shifts towards thinking as a designer: *mindshifts*. A mindshift, "when finally set, is an underlying structure for thinking and acting as a design thinker—it is the deep structure and world-view that is learned in conjunction with, and supports, the development of design skills." (Goldman et al., 2012, p. 29).

Design thinking as a stance implies that a person or organization could potentially adopt design thinking as a fundamental approach to thinking about the world. Alternatively, seen as a set of principles to be applied, it seems possible that a person or organization might simply adopt the principles and apply them in trying to solve a particular problem. However, some researchers and practitioners caution that the real promise of design thinking, as a way to foster creative problem solving, risks breaking down if it is not embraced holistically, as stance instead of a simple set of tools (Brown, 2009; Plattner et al., 2015; Royalty, Oishi, & Roth, 2012)- a warning worth heeding for those intending to bring design thinking into educational environments under the premise of creating learners who are prepared for a very uncertain future.

**Design thinking and education**

Kafai & Resnick (2011) explain that, "theories of design and learning have very different origins. Traditionally, design theorists have been interested primarily in the final product, and in the ways that constraints influence the design of the product. By contrast, learning theorists were interested primarily in process, not product" (2011). As design thinking makes inroads into mainstream education, research continues to emerge on the ways that design thinking is actually much more in line with many aims of current education trends (Kafai & Resnick, 2011; Koh, Chai, Wong, & Hong, 2015).

Some policy makers (NRC, 2011), researchers (Goldman et al., 2012), and educators (Carroll et al., 2010) have begun to embraced design thinking as a way to empower students with the skills for thinking that they will need to navigate an uncertain, but almost certainly more technologically advanced, future. When, "students become design thinkers, they emerge with significant changes in their approaches to problem solving and to new challenges. They start to develop a sense of resiliency that enables them to think 'outside the box.'" (Goldman et al., 2012, p. 14). Design thinking has the potential to shift students' perspectives to favor *empathy* in the search for a good design (Brown, 2009; IDEO, 2012; Meinel, Leifer, & Plattner, 2012; Plattner et al., 2015); it promotes *metacognitive* awareness as designers need to become aware of the ways in which their own biases may be influencing the design, or as they become aware of learning how they learn (Carroll et al., 2010; Goldman et al., 2012; Puntambekar & Kolodner, 2005); and finally design thinking demands others to be involved in the process- be it in the form of a collaboration, or with those who provide feedback and insight on a design- designers do not go it alone (Goldman et al., 2014; Koh et al., 2015; Kwek, 2010). The NGSS explicitly promote the use of design thinking strategies as a way to get students formulating solutions to complex problems, based on an assumption that the future will be complex and will demand skills that can tackle as-yet-unknown problems (Bybee, 2014; Lederman & Lederman, 2014; NGSS, 2016).

In the effort to bring in design thinking in to education, it should be considered that it is coming in to an environment where the scientific method has long stood as the primary means for conducting scientific inquiry in educational settings. However, design thinking should not be perceived as being in competition with the scientific method, but

rather complementary to it. Scientists and design thinking engineers use similar practices, such as:

- developing and using models,
- planning and carrying out investigations,
- analyzing and interpreting data,
- using mathematical and computational thinking,
- engaging in arguments from evidence, and
- obtaining, evaluating, and communicating information (NRC 2012 p. 49),

That said, "[scientists] use these practices to achieve generally different outcomes. Scientists typically work to understand natural phenomena while engineers [and designers] try to design a solution to a problem" (Boesdorfer & Greenhalgh, 2014, p. 51). Given that each has a different purpose, it would make sense that the two can and should exist alongside one another.

As design thinking becomes more relevant for K-12 education, it follows that teachers, and ultimately pre-service teachers, need opportunities for deep and meaningful exposure to design thinking. The following section looks at the ways in which design thinking has been approached in the research literature as it pertains to teacher education.

**Design thinking and Teacher Education**

A review of the literature on design thinking, as it pertains to the development of teachers and pre-service teachers, reveals that there is very little research in this area. Koh et al. (2015) point out that,

> *Even though the conceptual importance of design thinking is gaining recognition, the gap between theory and practice remains wide open, especially in the area of*

> *pre-service teacher education. In particular, there has been little research dedicated to understanding how pre-service teachers' pedagogical awareness and capacity can be developed from the perspective of design thinking. The practical question of how to foster pre-service teachers' design thinking remains a pedagogical challenge. (p. 69)*

That said, a small body of professional development publications are emerging from the making community (in particular museums) that begins to identify theoretical best-practice recommendations for educators working in makerspaces (Brahms & Wardrip, 2014; Exploratorium, 2016; IDEO, 2012). Additionally, there does exist some research that aims to analyze design thinking in action, as practiced by teachers, in K-12 schools. However, as alluded to in the quote above, very little research exists that analyzes design thinking as it applies to developing teachers and pre-service teachers. Looking beyond the specific research on design thinking, as it pertains to teacher education, there is tangential research that seems useful in forming the first understandings of how design thinking may function in teacher education environment.

This section will first explore the growing body of professional development publications that begin to outline best practices for teachers and facilitators working in makerspaces (places that commonly implement design thinking). Next it explores existing research that looks at what design thinking in action currently looks like in K-12 schools, when put in to practice by teachers. Finally, one study will be looked at which is outside the domain of teacher education, but which yields potential pedagogical insights for those looking to bring design thinking in to teacher education institutions.

Gleaned from research and experience in their makerspace facilities, researchers and practitioners from the MAKESHOP and the Tinkering Lab have each published frameworks aimed at helping teachers and facilitators engage students in practices that are

very similar to practices found in design thinking. The MAKESHOP framework (Brahms & Wardrip, 2014) provides insight into the, "considerations for the design of space, design of activity, and design of facilitation" (p. 9) that educators and facilitators may want to consdier when engaging learning in makerspace environments. Additionally, and in coordination with these design considerations, MAKESHOP outlines a series of "Learning Practices" that help orient educators on what to look for when attempting to assess how students are engaging in these activities. These observable learning practices are described as: *inquire, tinker, seek & share resources, hack and repurpose, express intention, develop fluency, and simplify to complexify.* While the Learning Practices themselves are not explicitly described as components of the design thinking process these Learning Practices can arguably be mapped on to Carroll et al.'s (2010) version of the design thinking process (see Table 3).

*Table 3:* Comparison of Carrol et al.'s (2010) Design thinking steps to Brahms & Wardrip's (2014) learning practices

| **Design Thinking Steps Carroll et al (2010)** | **Learning Practices (Brahms & Wardrip, 2014)** |
|---|---|
| **Understand:** *Learn about issues related to the design challenge* | -Inquire |
| **Observe:** *Watch how people behave and interact. Talk to people about what they are doing, ask questions and reflect on what you see.* | -Seek & Share resources |
| **Point of View:** *Takes into account information about user needs and insights.* | -Inquire<br>-Seek & Share resources, |
| **Ideate:** *In the ideation phase, quantity is encouraged. Brainstorming ideas is the foundation of this phase.* | -Tinker |
| **Prototype:** *A prototype can be a sketch or a two- or three-dimensional low resolution model made out of diverse materials. It is a way to convey an idea quickly;* | -Hack & Repurpose,<br>-Tinker<br>-Express Intention, |
| **Test:** *Testing is part of an iterative process that provides feedback. The purpose of testing is to learn what works and what doesn't, and then iterate.* | -Express Intention,<br>-Simplify to Complexify, |

While Brahms and Wardrips's (2014) design considerations and "Learning Practices" bear relation to outcomes proposed by engaging in design thinking, Brahms & Wardrips (2014) do not express an intention to map their practices to any form of the design thinking process; rather, this relationship is one that has been identified within this literature review. There is currently no research-based evidence to support the claim that students engaging in such learning practices are by default engaging in design thinking and the design thinking stance. However, this would be an interesting line of inquiry to pursue, as a positive relationship between these two frameworks would potentially give a set of learning indicators to educators engaging students in design thinking in their classrooms.

Similar to MAKESHOP, the Exploratorium's Tinkering Studio has published a framework of learning indicators and "Facilitation Moves" to help guide those facilitators who are navigating learning in makerspace environments (Exploratorium, 2016; "Learning Dimensions Framework," 2013). As with the Learning Practices and design considerations outlined by MAKESHOP, the Tinkering Studio's framework is not explicitly aligned to design thinking processes; again, these frameworks are extremely helpful to facilitators in makerspace environments, but further research is needed to understand if these frameworks have applicability to design thinking pedagogy and design thinking learning outcomes in K-12 settings.

While there exists an abundance of literature on the education of designers, architects, and engineers in design thinking skills, there is only very limited research that works to describe and analyze the outcomes of design thinking, as implemented by teachers/pre-service teachers in K-12 classrooms. Puntambekar and Kolodner (2005) explored two implementations of Learning by Design (LBD) in a middle school classroom. LBD is now a trademarked method that is more or less a series of design challenges, created to get students to learn science by using design thinking projects. It is rooted in the method of Problem Based Learning (PBL), a case approach to learning that first gained popularity in medical schools (Gertzman & Kolodner, 1996). Puntambekar and Kolodner (2005) investigated the best ways to design scaffolds for teachers to implement in the pursuit of getting students to learn science via LBD. The first study was an attempt,

> *to design support based on our best understanding of the processes involved in learning science by design and what we knew about student difficulties, in order to understand better the kinds of help that students require. Our second study put what we learned in the first study into action and allowed us to focus on how to*

*best integrate tools with different kinds of support into classroom activities. (p. 190)*

The research took place in an 8th grade classroom and the DBL project that was developed for the study (titled, "The Jekyll Island Challenge") was facilitate by the class teacher, who was, "a seasoned PBL [problem-based-learning] facilitator, but this was her first full implementation of the Jekyll Island challenge". The results of their first study revealed that when students are "learning by design," they need more specific prompts (i.e.: to reflect, to redesign, and to evaluate their learning) and multiple forms of support (i.e.: timely answers to critical questions, linking models to scientific concepts, careful sequencing and timing of activities). Their second study showed that when more carefully considered prompts and support were provided, students showed an increased ability to engage more fluidly and independently in LBD. While the results from Puntambekar and Kolodners's (2005) study reveal insights in to what works for students engaging in LBD, it does little to shed light on the role of the teacher and her relationship to design thinking in the deployment of the "The Jekyll Island Challenge". In this manner the study indirectly outlines what a teacher might want to consider when engaging in LBD, but it does not pin it to any sort of methodology or pedagogy for engaging learners in design thinking.

Kwek (2010) carried out a case study of a group of three middle school teachers employing design thinking in their classrooms. Of the three teachers included in this study, two had some level of design thinking training through the Stanford d.School ("Design School"), while the third did not have any explicit design thinking training or education. Kwek's results found that these teachers primarily utilized design thinking the following ways:

1. as a strategy to maximize motivation and increase confidence

2. to ensure particular outcomes (both content and skill based outcomes)
3. as a limited activity (rather than a general stance) that only takes place in STEAM related classes/lessons (Kwek, 2010, p. 21)

While two of the three teachers had at least been familiarized with design thinking to some extent (though the extent to which is not clear in the research paper), it is unsure how much, if any, of the design thinking training was contextualized in any sort of pedagogical context; in other words, it is unclear if the results from the study reflect teachers who had been exposed to design thinking as it applies to education, or simply exposed to design thinking as a practice in its own right. This may be an important difference to articulate as, "the kind of design thinking required in teaching may be defined as cognitive processes that help teachers to produce innovative solutions that adaptively address teaching-related issues and problems in educational settings" (Koh et al., 2015, p. 68). Understanding the nature of their design thinking training would help to make the insights from such a study more applicable to those studying and designing teacher training in this area. For the purposes of this research paper, the specific type of design thinking required in teaching design thinking will be referred to as *design thinking as a pedagogical stance*.

Koh et al. (2015) conducted a quantitative study looking at the effect of *knowledge-building pedagogy* on teachers' design thinking capacity. Koh et al.'s conceptualization and implementation of knowledge-building pedagogy is based on Scardamalia & Bereiter's (1994) original formulation of the concept. Described "as a deeply constructivist approach, knowledge building is defined as a social process focused on continual generation and improvement of ideas valuable to a community" (p.69). Koh et al. (2015) further make the claim that, "analogous to design thinking that highlights a

process of forming, relating, and synthesizing ideas, knowledge-building principles also highlight sustained idea improvement by engaging learners in activities such as idea diversification, elaboration, and reconceptualization" (p. 70). The findings from their research reveal statistically significant relationships between pre-service teachers who were exposed to knowledge-building pedagogy and their time spent engaging in design thinking and constructivist based activities in the classroom. The two case studies (n=30) "demonstrate the possibility of using knowledge-building pedagogy to develop pre-service teachers' design-thinking capacity" (p. 83). Koh et al. (2015) recommend that in order to better understand the relationship between knowledge-building pedagogy and design thinking skills, "more qualitative studies (e.g., in-depth interviews) would help in this regard" (p. 84).

Moving beyond the limited research that specifically looks at educating teachers/pre-service teachers in design thinking, Royalty, Ladenheim and Roth (2015) revealed interesting findings about how design thinking coaches think when engaging business executives in learning design thinking. In particular this research is interesting as it holds insights for a potential pedagogical framework that teacher educators might engage in when educating pre-service teachers in the design thinking stance.

The design thinking "bootcamps" that Royalty, Ladenheim and Roth (2015) look at in their study operate under the assumption that, "design as a competency goes beyond design skills like interviewing and prototyping. The goal is to instill design dispositions so that employees have the ability to behave like designers" (p.74). In attempting to make visible the tacit practices that design coaches used in these bootcamps, Royalty, Ladenheim and

Roth discovered five core "instructional elements" that all design thinking coaches engaged in (see Table 4).

*Table 4:* Instructional Elements and their explanations (Source: Royalty, Ladenheim & Roth (2015)

| Instructional element | Explanation |
|---|---|
| Discomfort | "Design thinking is a new way of working for most of the participants. They are not typically allowed to work in a familiar way during the program, and this can create a lot of anxiety. Coaches utilize discomfort as a marker that indicates their participants are trying something new." |
| Constraints as scaffolds | "This happens when coaches assign certain boundaries or limits to the team or individuals to help them further engage in the design process. Working in a new way can be overwhelming. Limiting materials that the team uses for prototyping or assigning roles to different team members helps simplify the work they are doing." |
| Safety | "Creating a space where participants feel emotionally supported to take risks and try new things makes up this element. This is important because many participants are relying on their creativity more than they have in a very long time. It is a side of them that they may not be used to showing. If they feel unsafe, they are likely to revert back to traditional, and more innately safe ways of working." |
| Momentum | "Momentum refers to the concept of keeping the process moving. It is important for a few reasons. Logistically, there is not much time in the program so the teams have to accomplish a lot in a short period and there is no way to catch up if they fall behind. In terms of working style, design moves quite quickly. They need to repress any instinct to stop and over think the situation. Finally, time constraints can actually increase participants' creativity." |
| Engagement | "Keeping participants interested in the project and process are essential. Beyond providing motivation, an essential part of any learning experience, high engagement allows participants to personally connect with design thinking. This is important because often times learning design thinking is a personally transformative experience." |

In addition to identifying these key instructional elements that are used by design thinking coaches in these environments, their research also revealed the indicators ("student responses") that coaches look for in participants to evaluate if students are engaging in the transformative process of internalizing and using design thinking (see Table 5).

*Table 5:* Student Responses and their explanations (Source: Royalty, Ladenheim & Roth (2015)

| Student Response | Explanation |
|---|---|
| Optimism | "This is faith in themselves and their creative abilities. It manifests itself in two main ways. First, that they believe they have the capacity to work using design thinking. Second, that this process can lead to a novel and interesting solution. It is important to have this sense of optimism because it is the first time many of them have used design thinking and they have no reference for what a successful process or outcome look like." |
| Confusion | "This is simply not understanding aspects of design thinking. It is a normal part of any learning process. It is up to the coaches to resolve their team's confusion." |
| Surprise | "Surprise in this case is being surprised at ones' own ability to succeed using design thinking. This, fittingly, was the most unexpected element. The previous two participant response elements are a normal part of learning. This encapsulates the experience participants have at the end of a project when they see that their creativity led to a novel and interesting outcome. To be clear, it is less about what they actually made and more about the creative capacity in themselves that came out during the process." |

In synthesizing these findings Royalty, Ladenheim and Roth (2015) hypothesize that the three identified student responses can be connected to the five instructional elements (or coaching tactics), and work together to help design thinking coaches understand how students are progressing on a design project. Figure 2 illustrates how the student responses are hypothesized to map on to the "coaching tactics" (or instructional elements).

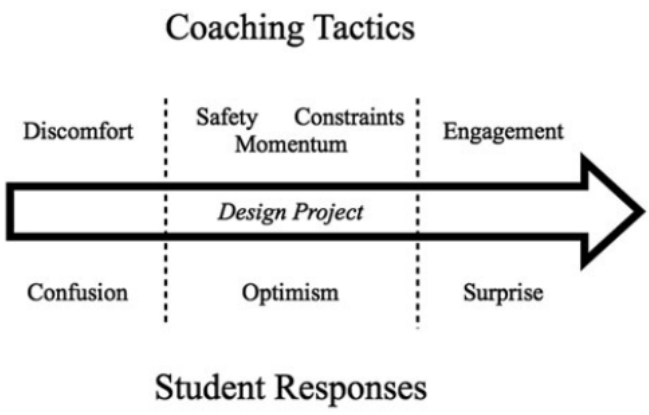



*Figure 2*: A model of Executive Education design thinking instruction (Source: Royalty, Ladenheim, & Roth, 2012)

In conclusion, a review of the design thinking literature reveals that a fair amount is known about the design thinking stance that is found amongst designers, engineers, architects and creative types. There is emerging research on design thinking and its impacts on student learning in K-12 classrooms, as well as on some of the practical actions that educators should take when engaging learners in design thinking. However, there is very little which is known about design thinking as a pedagogical stance and as it pertains to teacher education, and in particular pre-service teacher education.

*Conclusion: Literature Review*

In addition to providing definitions and historical accounts of concepts and ideas pertaining to making, the maker movement, maker education, and design thinking, the literature review also outlined areas in the literature that would benefit from further research contributions– in particular research that focuses on pre-service teacher education as it pertains to design thinking. As making and design thinking are incorporated more and more into formal education environments, we would benefit from gaining a deeper understanding of what it means to prepare teachers for teaching in such spaces. This research project is framed by the following research questions, in the pursuit of contributing in a meaningful way to this growing area of academic research:

- What is the experience of pre-service teachers in a Maker Faire environment?
- How do pre-service teachers interact with children in a Maker Faire?
- How do pre-service teachers display their pedagogical understanding of design thinking, in a Maker Faire environment?

Chapter 3 describes the methodology used in this study when investigating a group of pre-service teachers' experience in a School Maker Faire, and their emergent understandings of design thinking.

# CHAPTER 3: METHODOLOGY

The goal of this research project consists of two parts. The first goal is to understand the nature of experience for pre-service teachers who participated in the School Maker Faire event; the assumption being that this Maker Faire event was likely asking them to act and think in ways they have not been exposed to extensively, making this a potentially rich environment for insights and observation. It is a second goal of this project to understand the ways, and extent to which, the pre-service teachers displayed their understandings of design thinking. In the support of these two goals, the following three questions guided the research:

- What is the experience of pre-service teachers in a Maker Faire environment?
- How do pre-service teachers interact with children in a Maker Faire?
- How do pre-service teachers display their pedagogical understanding of design thinking, in a Maker Faire environment?

This chapter describes the methodology used in attempting to answer these research questions.

## Research Design

Peshkin (1993) describes qualitative analysis as being particularly well suited to instances where description and interpretation are goals of the research. Furthermore, Maxwell (2004) argues that qualitative research is well suited to understand educational phenomenon as an approach that investigates the very contexts which generate these outcomes. Given that this research project aimed to describe and interpret experience and interactions of pre-service teachers in a maker faire context, a qualitative approach was chosen.

## Research Site

The research took place within a Teacher Education Program (TEP) at a large public university in California. Participants for the case study were selected from among the 2015-2016 Multiple-Subject Teaching (MST) cohort of students consisting of 33 pre-service teachers. Data were collected from the School Maker Faire that was designed to be the culminating project for the Elementary Science Methods course.

The primary goals of the Elementary Science Methods course were to introduce pre-service teachers to the Next Generation Science Standards (NGSS) and help them develop strategies and content knowledge that would help them start their teaching careers as well-started beginners in the content area of science. In the 2015-2016 year, the course emphasized maker education. Pre-service teachers were exposed to course content and learning experiences based on research on teacher education and on informal science learning. These experiences included experiences participating in the type of learning activities that they would ultimately be expected to design and conduct with their students, in this case design thinking and Maker education activities. The final project for the course required pre-service teachers to facilitate a School Maker Faire for the local elementary school students in their practicum courses.

The School Maker Fair was designed by the course instructor who has a background in teaching and research pertaining to science and engineering education in for K-12 teachers. The course instructor was assisted by a graduate teaching assistant whose research focus is on STEAM learning and maker education. The course instructor designed the School Maker Faire to be a culminating project where pre-service teachers could come together in teams and design, facilitate, and assess different hands-on learning

activities that they created for students and guests to participate in. Furthermore, the School Maker Fair had the goal to "provide a fun learning environment for local school children and provide resources for local teachers" (Science Methods Course Syllabus, 2015). Guests consisted of students and families invited from the 33 different K-6 practicum classrooms associated with the 33 K-6 pre-service teachers enrolled in the course. In addition to the students and families associated with these classrooms, educators from the local school district were invited, as well as staff and faculty from the education department at the university. Based on the sign-in sheet, it was estimated that over 400 people attended the event.

The School Maker Faire took place in the education building at the university. Given the number of activities being facilitated for the event, and the high number of guests that were expected to show up, the event was spread out among the classrooms on all three floors of the education building. The three hour event took place in the early evening, after school, in hopes of being able to attract as many visitors as possible.

In the weeks leading up to the activity, the course instructor and the teaching assistant supported students in finding and designing fun and engaging activities that were tied to NGSS standards. Teams designed and organized activities such as: *building birdfeeders from recycled materials, building boats and testing their weight holding capacity, making art from recycled materials, learning about 3D printing, building with circuits, using magnets to paint, designing a lunar lander that could land as gently possible, and designing balloon powered rockets.* In addition to helping students chose and develop fun and engaging activities for the School Maker Faire, the course instructor and the graduate assistant helped pre-service teacher teams develop assessments that were

in line with the NGSS standards that their activities were tied to. In the week prior to the School Maker Faire, the different pre-service teacher teams set up their activities in the university classroom in what was called the Mock Maker Faire. This event was created as a chance for teams to try out each other's activities (without guests), with the goal to iron out any unforeseen problems and to improve experience designs.

The primary focus of this study is the pre-service teachers' experience from the School Maker Faire, the nature of their interactions with guests at the Faire, and how they demonstrated their pedagogical understanding design thinking in the School Maker Faire setting.

## Case Study

Miles and Huberman (1994) define the case "as a phenomenon of some sort occurring in a bounded context" (p.25). Defining a particular case, or cases, to study are often informed by the conceptual framework that is framing the study; in other words the conceptual framework works to "bound the context" and also works to define that which will be included for study, and that which will not. Cases can be individuals, roles (example: principals, mothers, teachers), groups, communities, or even nations (Miles & Huberman, 1994).

Cases can be studied in a variety of ways, including the following: *temporally*, as an episode or encounter, as an *event*, or as a process (Miles & Huberman, 1994). Yin (2009) points out that some cases may even have subcases with in them. For example, a case study of a school might include subcases such as classrooms or teachers (Miles & Huberman, 1994).

A case study approach is suitable for contributing to our "knowledge of individual, group, organizational, social, political, and related phenomena" (Yin, 2009, p. 4). Within such areas of knowledge, case studies are a good choice in studies that aim to explore contemporary events, but where predictions about the behaviors of individuals or groups are not sought (as is the case with clinical experiments).

In defining case studies more specifically, Yin (2009) outlines two major components (and their subcomponents) in a case study approach:

1. A case study is an empirical inquiry that
    a. Investigates a contemporary phenomenon in depth and within its real-life context, especially when
    b. The boundaries between phenomenon and context are not clearly evident
2. The case study inquiry
    a. Copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result
    b. Relies on multiple sources of evidence, with data needing to converge in a triangulation fashion, and as another result
    c. Benefits from development of theoretical propositions to guide data collection and analysis

As Yin (2009) points out, case studies benefit from the development of a guiding conceptual framework beforehand as this works to a) define appropriate cases, and b) guide data collection and analysis. For this study, design thinking operates as the conceptual framework and the lens through which themes generated from the data are interpreted.

This study explored the nature of interactions between pre-service teachers and children in a Maker Faire environment, as well as the ways in which the pre-service teachers displayed their understandings of design thinking. The case study method's emphasis on context seemed to lend itself well to studying pre-service teachers' interactions, which were arguably very dependent upon, and influenced by, the context in which they occured. In other words, a teacher's interactions with children are going to not only influence the environment they occur within, but will also be influenced by those same environments. The case study enables the study of real-life phenomenon, in depth, while recognizing the importance of contextual conditions (Yin, 2009).

Likewise, the case study method's reliance on multiple variables of interest and multiple sources of data reflects the present study's "wide net" approach. The present study used the following sources of data[1]:

- Stimulated recall interviews with the selected pre-service teachers
- follow-up interviews with the same pre-service teachers
- Observational notes
- Course syllabus from their Science Methods course
- Interviews with the Science Methods course instructor

This study used a *holistic multiple-case study design* (Yin, 2009). The study looked at multiple cases of pre-service teachers planning, designing, conducting, and assessing activities in the context of a School Maker Faire setting. Each case was looked at holistically in the context of the School Maker Faire, both at the individual case level, as well as across individual cases. According to Yin (2009), "holistic design is advantageous

[1] These data sources are described in more detail later on this chapter.

when no logical subunits can be identified" (p. 50); in the case of pre-service teachers planning, designing, conducting, and assessing activities in the context of a School Maker Faire setting, there is no logical subunit below that of the individual teacher. In looking at each case, the target phenomena of study included the pre-service teacher experiences, the nature of their interactions, and how they displayed their pedagogical understanding of design thinking. Analysis consisted of summarizing how and to what extent the target phenomenon was demonstrated in individual cases, and also the extent of similarity or variation across cases (Yin, 2009). The nature of the cross-case analysis is discussed in more depth in the data analysis section.

## Case Selection & Participants

The pre-service teachers considered for this study were all enrolled in a Multiple Subject Teacher (i.e., elementary school) credential program at a large public university in California, referred to as the Teacher Education Program (TEP). Of the 33 students enrolled, 29 were female and 4 male. All entering students had finished their undergraduate degree. The 13-month program spanned an academic year, including both the summer immediately prior to the academic year and, for those teachers pursuing a Master of Education (M.Ed.) degree, the summer immediately following.

The Elementary Science Methods course was held during the second half of the program. The course met 10 times for three hours each. Students began the Science Methods course having already completed two quarters (Summer and Fall) of coursework and having spent three months student teaching in local elementary school classrooms. The course was taught by a member of the faculty whose research and educational focuses concentrate primarily on science and engineering education for K-12 teachers. The course

instructor was assisted by a graduate teaching assistant whose research focus is on STEAM learning and maker education.

Case selection from among the MST cohort proceeded in two steps. First, potential participants needed to consent to being video recorded during the Maker Faire event. Of the 33 MST pre-service teachers enrolled in the Science Methods course, 12 consented to being video recorded during the Maker Faire. Collectively, these 12 pre-service teachers made up three of the different Maker Faire activity groups (4 pre-service teachers per group). All 12 of these pre-service teachers, and their three corresponding activities, were recorded in a single classroom during the Maker Faire[2].

The second step in case selection was to attempt to get an entire activity group where each group member would consent to two interviews: a stimulated recall interview session, and a follow-up interview. As the different Maker Faire activities were the product of group work, it made sense to try and get an entire group of consenting pre-service teachers as this would allow access to the full range of perspectives that led an individual Maker Faire activity that was ultimately facilitated at the School Maker Faire. Of the 12 pre-service teachers who consented to being video recorded, 5 of them responded that they would be willing to participate in the two interviews as well.

Of these 5 consenting pre-service teachers, 4 of them comprised the entire Balloon Rockets activity group; the fifth participant was from another group (the Lunar Landers) and was therefore not included in the set of cases (but was used as a pilot for the stimulated recall interview). The choice was made to exclude the fifth participant (from the Lunar Lander group) because it seemed most beneficial to focus research efforts on a cohesive

[2] Details pertaining to the specific activities associated with these three groups, as well as the recording setup, will be addressed more explicitly later in this chapter.

group who had worked together in both the planning and execution phases of a particular activity for the School Maker Faire project. This selection process resulted in the four participants included in this case study who comprised the Balloon Rockets activity group (these pre-service teachers are referred to in this study using the pseudonyms: Mary, Amber, Ruth, and Sally).

It should be noted that while the fifth participant did not share a common planning and execution experience with the participants from the Balloon Rocket activity group, this person was exposed to other common features of the course such as the general coursework itself, and the general experience of the Maker Faire. Due to sharing a common experience in this regard, the fifth pre-service teacher (who was omitted from the final set of cases), served as a pilot for the stimulated recall interview session. This proved beneficial in that it allowed an opportunity to test the stimulated recall interview and afforded an opportunity to make adjustments to the questions and the format of the interview, prior to conducting the stimulated recall interviews with the members of the Balloon Rockets activity group. The data from this pilot interview also proved beneficial as it was a place where initial coding schemes could be tested and revised (this will be discussed in more detail in this chapter where Data Analysis is addressed).

## Data Collection Methods

### Audio/Video Recordings

Audio/Video recordings were produced by having multiple cameras (2 GoPro cameras, and one HD handheld camera) placed strategically in the classroom at the Maker Faire; specifically, each of the 3 cameras were trained on each of the 3 activity groups. Given that the Maker Faire was a large event that utilized multiple classrooms throughout

the building, only one classroom was designated for A/V data collection in order to simplify A/V recordings. This consolidation of recordings into one classroom also worked to isolate the research to a single manageable location which was important for purposes of consent. Visitors were notified through the posting of flyers on the classroom doors, and the four interior walls of the classroom, that research and A/V recording was taking place in this classroom. The content on the flyers notified visitors that they could contact the researcher (who was present in the room) if they preferred to have the audio or video turned off while they participated in the activities contained within that particular classroom.

In addition to the three cameras, microphones were placed at each activity table in order to capture more detailed audio that the handheld and GoPro cameras were not able to. A/V recordings were then downloaded to a computer, and each audio source was synced to its corresponding camera data in iMovie in order to create three separate video files, with synced audio, for the three different activity groups that were in the room.

As is discussed in more detail in the following section, this video data was primarily used as a jumping off point for *stimulated recall interviews* with each participant about what they might have been thinking during various moments of the Maker Faire. Since the video recordings were used as a way to *recall* thinking on the part of the pre-service teachers, fine details in the recordings such as gaze, gesture, and high-quality audio were not of primary importance.

**Stimulated Recall Interviews**

This study implemented a method of interviewing known as *stimulated recall.* This approach to interviewing uses audio or video as a *stimulus* to aid interviewees in

*recalling* thinking that may have taken place in the moments that are present in the audio or video recording. Bloom (1953) is often identified as the pioneer of this method. He was the first to try a version of the technique with a group of his college students. Bloom was interested in trying to understand the range of what students were thinking about during class lectures and discussions. Recognizing the challenge in trying to access in-the-moment thinking, he designed an experiment in which audio from lectures and discussions were recorded and later played back to individual students. The goal was to see whether or not hearing the lectures (*stimulation*) could serve as a way to *recall* the thoughts students may have originally been having at various points during the lecture or discussion. Bloom argued that such a method worked well to recall thoughts students were having in class several days before.

Stimulated recall, as it has evolved in education research, is largely a technique where teachers are video recorded and then shown the video at a later time. This viewing of the recording is usually done with an interviewer to try to elicit some of the "behind the scenes" thinking that may have been happening at different points in time during the time that they were being recorded. The video records serve as the "stimulus" for information that is recalled during the interview (Nespor, 1985).

It is argued that stimulated recall works well to recall teachers' thinking back to events and situations that played out in the classroom (Peterson & Clark, 1978; van Es & Sherin, 2002). In this way, its strength seems to be in its ability to prompt reflection back to very specific events and moments in time. Stimulated recall has proven to be an effective strategy for promoting teacher reflection on their practice (Peterson & Clark,

1978; van Es & Sherin, 2002). However, reflections on thinking are not the same as actual thinking that occurred.

Some are skeptical (Nespor, 1985) as to the validity of stimulated recall as a valid means of generating useful data, as the argument that a *report* of thinking is not the same as thinking itself. While this is a valid concern, stimulated recall has potential to be useful in uncovering the beliefs and implicit theories that underlie a person's thinking, rather than exactly *what* they may have been thinking. Framed this way, the problem of getting accurate accounts of *what they were thinking* was less of a concern for this research project:

> *Stimulated recall is not a means of eliciting interactive thought or reflection-in-action, but rather as a means to elicit reflection-on-action. As reflection-on-action, stimulated recall provides access to the ways in which teachers make sense of teaching episodes. It may be an effective way to elicit teachers' implicit theories and beliefs as well as their understandings of the specific patterns of behavior or interaction (Yinger, 1986, p. 273).*

As this research project intended to explore the nature of interaction and experience, including the beliefs about teaching and understandings of design thinking that might be driving pre-service teacher actions and experiences, stimulated recall still seemed appropriate for these research goals– despite the acknowledgment of the limitation that we still ultimately have no way of knowing exactly what a person is, or was, thinking.

Those researchers who have used stimulated recall interviews do not universally describe, nor adhere to, a type of interviewing protocol that is specific to stimulated recall interviews (e.g.: think aloud, grand tour, concept map, etc.). For example, Peterson and Clark (1978) use a set of four structured interview questions which they administer to teachers during stimulated recall sessions. On the other hand, some researchers (Kagan,

Krathwohl, & Miller, 1963; Sherin & Elizabeth, 2005) tend towards a much looser set of interview questions as they are simply seeking pathways to "recall" a teacher's thinking during such sessions.

For this research project, the stimulated recall interview sessions had the goal to generate data for the exploration of the following research questions:

- What is the experience of pre-service teachers in a Maker Faire environment?
- How do pre-service teachers interact with children in a Maker Faire?
- How do pre-service teachers display their pedagogical understanding of design thinking, in a Maker Faire environment?

In conducting the stimulated recall interviews, a semi-structured interview was implemented in accordance with the *interview guide* approach as described by Patton (2002) (see Appendix A: "Stimulated Recall Guide"). This approach had the added flexibility that the predetermined questions could act as a bank of questions to be drawn from and inserted in the interview where relevant, as opposed to systematically asking the questions in a series, one by one (though they may also be used in series). It is important here to remember that the purpose of stimulated recall was to stimulate, through reviewing video, one to recall what they may have been thinking in particular moments. This implies that a certain level of freedom was needed when it came to interview questions, as the goal was to find the right questions that worked to recall accounts of thinking.

The question bank for the semi-structured interview was divided into categories based on the different types of information that is the interest of this study. The first goal in the stimulated recall interviews was to work with the pre-service teacher to locate moments of interaction in the Maker Faire video that "stood out to them"; it was

hypothesized that such moments might be locations to explore richer accounts of experience as such moments were likely memorable for the individual; the logic being if the moment is more memorable to the individual, then there may be more detail available in the recall account. Once a moment was located, then subsequent questions were asked that had the goal of eliciting recall of the types of thinking that *may* have taken place in that particular moment.

Each stimulated recall session was itself audio/video recorded. The camera was positioned so that it could capture only the interview between myself and the pre-service teacher, and not the Maker Faire video footage on the laptop screen. The reason for omitting the Maker Faire footage that was used for recall was because of the complications to consent and lack of anonymity that came with using video data that has images of children and other participants who attended the Maker Faire. These stimulated recall interviews were then transcribed so that they could be analyzed and coded using the MAXQDA analysis software. A high-quality, separate, audio recording was also made for each stimulated recall session as a backup record of the stimulated recall interview.

Stimulated recall interviews took place within 2-3 weeks of the original recording so that the stimulated recall was as fresh as possible. The closer the recall session is to the original event, the higher the quality of data in terms of level of detail provided in the interviewee's account of their thinking (Nespor, 1985). Compressed and conflicting schedules made it impossible to schedule interviews any earlier than two weeks out from the original recording.

Each stimulated recall session occurred in two stages and comprised roughly an hour in total. The first 30 minutes were dedicated to the stimulated recall interview

questions (see Appendix A: "Stimulated Recall Guide"). The second 30 minutes were dedicated to follow-up questions pertaining to information and insights revealed through the stimulated recall interview (see Appendix A: "Stimulated Recall Interview: Deepening Questions Guide"). Having this first round of follow-up questions occur directly after the stimulated recall proved to work well as the recall accounts were fresh and easily accessible for deeper exploration.

**Follow-up Interviews**

Roughly a week after each stimulated recall interviews, an additional follow-up interview was arranged. The follow up interview was scheduled for roughly a week after the stimulated recall interview sessions in order to allow for time to process and complete a first round of analysis of the stimulated recall interview data. The purpose of the follow-up interview was to probe deeper into the origins and background of their thinking, actions, and perceptions that were revealed from stimulated recall interviews.

As with the stimulated recall interviews, an interview guide was used to inform the framework of interview questions with each candidate (see Appendix A: "Follow-up Interview Guide"). One main reason for choosing the interview guide for these interviews was because, "an interview guide is prepared to ensure that the same basic lines of inquiry are pursued with each person interviewed" (Patton, 2002, p. 343). Given that analysis included cross-case comparison, it was important that each pre-service teachers was exposed to the same basic framework of questions so that comparisons could easily and readily be drawn between case study participants.

A second reason for choosing an interview guide over other interview approaches (structured interview, for example), was because the interview guide afforded freedom

during the interview that seemed necessary. For example, if there arose an opportunity to explore a pre-service teacher's belief system (which may reveal information about *why* they chose to interact in a certain manner), there needed to be a level of flexibility to be able to "drill down" into interview responses that presented themselves as potentially revealing. Recall that the main reason for having these follow-up interviews, in addition to the stimulated recall interviews, was that stimulated recall interviews are meant to recall thinking, but they are not meant to probe deeper into the underlying motives or rationale behind such thinking (as it distracts from the recall). These follow up interviews were more exploratory in nature and arguably needed more "space" to explore; the interview guide seemed to provide this space. A third reason for choosing an interview guide, was for the flexibility to be able to introduce artifacts (coursework, images, observation notes) into the interview in order to push discussion or thinking towards potentially fruitful directions.

## Additional Data Sources

### Direct Observation Notes

There was an opportunity to make observational notes on two different occasions. The first was during the Mock Maker Faire, in which the different activity groups could test out their activity with their peers during the Science Methods class. The second opportunity for observation notes was during the Maker Faire itself. As the cameras and the audio recorders recorded automatically once deployed, I was free as the researcher to observe interactions and take observation notes.

### Course syllabus from their Science Methods course

The Science Methods course instructor provided access to the course syllabus. This proved useful in gaining a framework of some of the relevant topics that the instructor intended the pre-service teachers to study through the course of the year. In particular, the syllabus pointed to specific publications that pre-service teachers referred to when designing their activities and their assessments for the School Maker Faire (e.g.: Brahms & Wardrip, 2014; Exploratorium, 2016; Next Generation Science Standards, 2016).

### Interviews with the Science Methods course instructor

The final piece of data was an interview with the Science Methods course instructor and the Teaching Assistant that provided support during the course. This interview had the purpose to gain the instructor's perspectives on the goal of the Maker Faire, as well as to provide some basic insights on some of the concepts that pre-service teachers were exposed to during the Science Methods course. An interview guide was also used for this interview, applying the same lines of logic already outlined in the in the section on *Follow-up Interviews* (see Appendix A: "Science Methods Course Instructor Interview Guide").

## Data Analysis

### Qualitative Content Analysis (QCA)

This project used Qualitative Content Analysis (QCA) for data analysis. As a method, QCA is systematic, theory driven approach for describing the meaning of qualitative data (Mayring, 2000; Schreier, 2012). As a system for approaching qualitative research, QCA follows these steps:

1. Decide on research questions
2. Select material

3. Build coding frame
4. Divide material into units of coding
5. Test coding frame
6. Evaluate and modify coding frame
7. Main analysis
8. Interpretations and findings.

In QCA, the coding frame is informed both by the research questions guiding a study, as well as informed by codes that emerge from the data. The questions guiding this research project are the following:

- What is the experience of pre-service teachers in a Maker Faire environment?
- How do pre-service teachers interact with children in a Maker Faire?
- How do pre-service teachers display their pedagogical understanding of design thinking, in a Maker Faire environment?

According to Mayring (2000), when using QCA, "the level or theme of categories to be developed must be defined previously" (p. 34). Given the set of questions above, the initial coding frame was informed by themes such as experience, interaction, and display of design thinking in a Maker Faire environment.[3] In addition, "with QCA, you can create your coding frame in a data-driven way and you may repeatedly return to include more data and generate additional categories. But some of your categories may also be concept driven, especially main categories" (Schreier, 2012, p10).

QCA was used for this project as it allowed for a systematic way to code and structure the data, which then allowed for an efficient means of comparing findings across cases (for example- *how did the nature of experience at the Maker Faire vary among the different cases?*). Additionally, this method allowed for the data to be approached with an

[3] A more explicit description of the initial code scheme is provided in Chapter 4

existing conceptual framework; in the case of this study, design thinking was the existing framework. Finally, QCA provided the affordance of reducing data by carefully making, "categories sufficiently abstract to allow for comparison and sufficiently concrete so as to preserve as many specifics as possible" (Schreier, 2012, p.8). With this careful attention to how coding schemes were created and refined, QCA limited analysis to the elements that were most relevant to the target research questions.

**Analysis of stimulated recall interviews and pre-service teacher interviews**

Following the method described by QCA, stimulated recall interviews and pre-service teacher interviews were coded and further analyzed following each session. Such analysis included any relevant interview notes, data sources, or memos. Handling the data in this manner worked to develop an ongoing relationship with the data as well as worked to manage and organize data as it grew (Maxwell, 1992). Additionally, this consistent approach allowed for the emergence of themes as new information was folded in to the data set, and new connections were made. Such connections and themes then worked to influence the collection of future data (for example, influencing the interview guide for the second follow-up interview). In addition to working with interview data in such a manner, other data sources (course work and observations notes) were handled similarly.

**Case analysis & Cross-case analysis**

The first step in the individual case analysis process was to thoroughly analyze and apply the initial coding scheme to a *single case;* the data used for this initial round of analysis was that from the pilot stimulated recall interview (the "5$^{th}$" teacher). The initial

coding scheme was simple, yet informed by the research questions and the proposed research problem. Below are the initial codes[4]:

- Relationships
- Teacher's Role
- Design thinking

Subsequent rounds of analysis using this initial code scheme were re-applied to the pilot case, leading to adjustments to the initial coding scheme. Adjustments included actions such as merging sub-codes where logical[5]. Emergent themes that were a by-product of these first rounds of analysis were added as well (such as "preparation"). Starting with such a baseline helped to maintain focus, clarity, and direction during subsequent rounds of analysis with the four cases that were the focus of this study (Miles & Huberman, 1994; Yin, 2009). These multiple rounds of analysis using the pilot case, ultimately led to a revised coding scheme. This revised coding scheme was comprised of codes that were either *emergent*, or *derived from the initial code scheme*. The revised code scheme is listed below[6]:

- **Pre-Maker Faire Preparation** *(emergent theme)*
- **Interaction Drivers** *(derived from the "The teacher's role", "Relationships", "Design thinking")*

[4] A more detailed account of the *initial* coding scheme is provided in Chapter 4: "Individual Case Analysis". This more detailed account also provides insight as to how the initial coding scheme evolved into, and informed, the revised coding scheme.

[5] For example, the sub-code "engaging students" (under Teacher's Role) was collapsed into the sub-code "problem solving". The logic behind collapsing this sub-code was because it was found that pre-service teachers often reported *engaging students* as a means to *solve an identified problem*- such as getting them to iterate designs.

[6] A more detailed account of the *revised* coding scheme is provided in Chapter 4: "Individual Case Analysis". This more detailed account also provides insight as to how the initial coding scheme evolved into, and informed, the revised coding scheme.

- **Assessment** *(derived from "The Teacher's Role")*
- **Parents** *(derived from "Relationships")*

With the development of the revised coding scheme, the second step in analysis was the *individual* analysis of all four cases in the Balloon Rockets group, using the revised coding scheme. As the revised coding scheme was applied to all four cases, the codes were also assessed for suitability as they applied to each individual.

The third step was analysis across cases. Analysis results from individual cases were compared and contrasted across cases. A by-product of the cross case analysis was the emergence of new patterns which ultimately became topics for discussion (Miles & Huberman, 1994).

**Transcription**

Interview transcription is described by Miles & Huberman (1994) as the first step of analysis, where one first immerses themselves in the data. Interview transcription can be divided into two primary categories: *naturalism* and *denaturalism*. Naturalism has the goal of transcribing speech as verbatim as possible, "where utterances are transcribed in as much detail as possible" (D. Oliver, Serovich, & Mason, 2005, p. 1276) with the goal of accurately representing speech (this includes utterances such as pauses, "um", "uh-huh", etc.). Denaturalization also has the goal of transcribing verbatim speech but, "has less to do with depicting accents or involuntary vocalization. Rather, accuracy concerns the substance of the interview, that is, the meanings and perceptions created and shared during a conversation*"* (Oliver et al., 2005, p. 1277).

The transcription process used in this research project followed the guidelines suggested by a denaturalized approach, as this research focused on the perceptions and experience of the individuals, as opposed to the analysis of the speech itself.

**Software used to facilitate and archive coded data**

For this project, all data were coded and archived using coding software. Coding software is recommended when using QCA as it affords considerable flexibility in terms of adjusting codes during the iterative process as well as gives many options for viewing/visualizing relationships which may exist among codes (Mayring, 2000; Schreier, 2012). The specific software used was MAXQDA 11, Release 11.2.0.

The MAXQDA 11 software allowed for the generation of *meta-matrices*. Meta-matrices are describe by Miles and Huberman (1994) as charts designed to help assemble and organize descriptive data in ways that makes the large amounts of data associated with cross-case analysis much more manageable and usable. Finally, as the MAXQDA 11 software also handles the cataloguing of research memos, this software served as the hub where such records were recorded kept for later retrieval.

## Research Steps

The research steps are provided not only for purposes of replicability of this study, but also as a means to increase trustworthiness as a documentation of the research process is an important step in this pursuit (Mayring, 2000):

1. Pre-service teachers were approached, introduced to the research concept and proposed data collection, and solicited for participation
2. Those willing to participate were given Waivers of Consent to sign (see Appendix B)

3. Researcher attended Mock Maker Faire to establish contact with consenting participants and to begin taking field notes as to how pre-service teachers prepared for such an event
4. Those pre-service teachers willing to participate in video data collection were placed in the same classroom during the School Maker Faire to facilitate ease of data collection
5. Upon collecting video data, pre-service teachers were contacted a second time in order to see who would be willing to participate in two interview sessions
6. Results from requesting participation in follow-up interviews yielded one complete group of 4 pre-service teachers that would be willing to do follow-up interviews, plus one additional pre-service teacher from a second group. The four participants comprising the complete group were selected as the target group of this study. The 5th willing participant was used as a pilot interview and for the initial round of analysis.
7. Maker Faire video data was reviewed multiple times by researcher, with at least one targeted review per pre-service teacher as a preparation for the individual stimulated recall interviews
8. Stimulated recall interviews were scheduled, and carried out– each time blocked for a 60 minute time slot per pre-service teacher.
9. The 5th pre-service teacher (the one who was not a member of the Balloon Rockets group) was used as a pilot for testing the interview frame and refining the stimulated recall approach. (This pre-service teacher's interview was also transcribed, coded, and analyzed)

10. Stimulated recall interviews comprised the first 30 minutes of the interview time slot, and the remaining 30 minutes consisted of follow-up interview questions aimed at probing results from the stimulated recall
11. Notes were written following each stimulated recall/follow-up interview session and were used to inform ensuing analysis
12. Interviews were transcribed within a week of conducting each interview
13. Transcripts and video recordings of the stimulated recall interviews were analyzed and coded in terms of the research questions, and emergent themes were recorded.
14. Emergent themes from the first rounds of analysis informed the interview guide for the follow-up interview.
15. The follow-up interviews were scheduled and carried out by phone, and were recorded.
16. Data from the follow-up interview were folded into the existing data and analyzed using the existing frames.
17. The Science Methods course instructor was interviewed and the interview guide was informed by a) the themes that emerged from the data analysis as well as b) the relevance of design thinking in the coursework.
18. Data analysis was written up and discussed.

## Trustworthiness

Although qualitative research might be more flexible and adaptable during the research project than quantitative research, the validity and trustworthiness of a qualitative study increases with the adherence to a set of quality criteria. Mayring summarizes a set of

six quality criteria particular to qualitative research, that are used in this research project (Mayring, 2000, p. 144):

1. **Documentation of procedure**: While for quantitative research it is often enough to refer to the used methods and techniques, as they are standardized, in qualitative research methods are often specifically designed to a particular project. Therefore, a detailed description of the research procedure is required to ensure traceability to others.
2. **Argumentative validation of interpretation:** Interpretations are essential in qualitative research, however since they cannot be proven an argumentative validation is important. This includes the exposition of the preconception as well as a conclusive argumentation. Furthermore, alternative explanations have to be considered and tested constantly.
3. **Rule-based procedure:** As mentioned earlier qualitative research design is flexible, and the iterative process allows ongoing modification. However, a systematic approach is still required. That means that, despite flexibility, the research process should be well-defined and include clear process steps. The same counts for the individual steps, which also should be conducted systematically and be rule-based.
4. **Proximity to the subject of study:** Proximity to the subject of study should be secured through investigations in the real-life context and ideally through matching interests between researcher and the investigated person(s). A relationship on equal terms supports fulfillment of this quality criterion.

5. **Communicative validation:** Validity of results and interpretations can be increased by presenting the findings to and discussing them with the investigated persons. It can be an important argument for backing up the findings if the investigated persons can find themselves within the results and interpretations.
6. **Triangulation:** Triangulation refers to the connection of different approaches during the research process. This refers to different sources of data, different interpreters, as well as different theoretical assumptions and methods used. The goal is to capture the investigated phenomenon from various positions and perspectives and in this way gain additional insights.

Table 6 illustrates the adherence to these trustworthiness criteria in the present study, as well as an example of corresponding evidence for each criteria component.

*Table 6:* Quality criteria adherence across research process (Source: Own illustration based on Mayring, 2000; Schirmer, 2014)

| | **Preparation** | **Data Collection** | **Data Analysis** | **Discussion and conclusion** |
|---|---|---|---|---|
| **1. Documentation of procedure** | -identifying relevant theoretical foundations | -creating "audit trail" of steps taken in data collection including rationale | -creating "audit trail" of steps taken in data analysis including rationale | X |
| **2. Argumentative validation** | X | X | -themes developed using evidence from multiple cases across multiple contexts | -connection of themes to the concept of design thinking made in logical and argumentative manner; alternative explanations considered |

| | | | | |
|---|---|---|---|---|
| **3. Rule-based process** | -developing a system for identifying cases<br><br>-following established processes for multi-case study approach (Miles & Huberman, 1994; Yin, 2009) | -using and implementing interview guide<br><br>-following process of established multi-case study of approach | -rounds of analysis conducted in line with established methodology (Miles & Hubberman, 1994) | X |
| **4. Proximity to the objects of study** | -establishing contact and building rapport at Mock Maker Faire | -carrying out interviews in ways that are respectful participant time constraints and taken place in locations to participants | X | X |
| **5. Communicative validation** | X | -impressions from first round of interviews shared with interviewees prior to start of second follow-up interview to check for agreement | X | X |
| **6. Triangulation** | X | -data collected from multiple sources: *stimulated recall interviews, follow-up interviews, course syllabus, Maker Faire video, stimulated recall interview video recording, interview with course instructor* | -data analyzed *across* multiple sources | -arguments and claims formed in discussion upheld by evidence across multiple sources and contexts |

## Summary

Chapter 3 described the implementation of a qualitative research design where a holistic multiple case study approach was used. Data was largely generated using stimulated recall and follow-up interviews. Qualitative Content Analysis was used to

analyze the data. The following chapter presents the analysis of the data from the four cases, first per individual case, and then across cases.

# CHAPTER 4: ANALYSIS

Before delving into describing each individual's experience with the Maker Faire, the following vignette describes an experience that occurred prior to the Maker Faire that was common to all group members. This experience is important to illustrate beforehand as the interviews reveal that each TC was influenced by what took place in this experience.

It should be noted that in the vignette, none of the pre-service teachers are referred to by their pseudonym, but rather in general terms. This is due to the fact that upon observing this group's experience, I had not yet gathered names of individuals (nor created corresponding pseudonyms). I had just walked up to observe this group when the following events took place, and this vignette is reflective of my field notes. Although this group eventually became the focus of the study, I was not able to backwards map their names to the notes that I jotted down as I observed them because I had not yet realized they would be the focus of my study. Nonetheless, this vignette is meant to describe an event that will serve as a reference point to come back to in the analysis as individual group members reveal their experiences and relationships to the event through the individual interview accounts.

## Vignette: Transitioning from Balloon Cars to Balloon Rockets

A week prior to the Maker Faire event, the course instructor held a Mock Maker Faire in the Science Methods class. This was an opportunity for groups to set up their activities, and have their peers test them out in order to make any last minute adjustments to the activity's design. The course instructor intended for pre-service teachers to take their activity into their student teaching classrooms to test their activity with children. The goal was that activities would be tested twice before the actual Maker Faire, so that necessary

adjustments could be made. In my follow up interview with the course instructor, she reported that though this was her intention, the reality was that many of the groups had not tested the activity in their student teaching classrooms so were only conducting their activity for the first time at the Mock Maker Faire.

The Balloon Rockets group was one such group that had not tested out their activity prior to the Mock Maker Faire. What they had done, as a course assignment, was describe the activity that they would be carrying out for the Maker Faire. The group described an activity titled "Balloon Powered Cars", in which participants would use supplied materials to build a car that uses the air in a balloon as its power source (see Figure 3). They also described providing steps that students at the Maker Faire should follow in order to make such a car. These steps corresponded with prepared materials that the group intended to provide.



*Figure 3*: Sample Balloon Cars

I first observed the Balloon Rockets group on the evening of the Mock Maker Faire in their Science Methods course. The Mock Maker Faire was set in the science classroom where the Science Methods course took place. Tables in the classroom were organized so

that each group could have their own space to set up their activity. I came to the Balloon Rockets table during the period of time that was provided to set up for the Mock Maker Faire (about 30 minutes). The group had a variety of materials including old CD's, straws, cardboard, tape, balloons, paper, and scissors. Though this was a preparation time, the group was not interacting with the materials, but instead talking about various concerns about the teaching program and their teaching placements. In a later interview Amber confirms this observation by recollecting that, "everyone wanted to eat chocolate and talk. No one wanted to do this."

As the time for the Mock Maker Faire approached, the group appeared to spend the majority of this preparation time talking about events unrelated to the Mock Maker Faire; aside from having boxes of supplies at their table, it did not appear that they were ready to have their peers come and test their activity. Once the Mock Maker Faire got underway, the group members stayed put at their table instead of exploring the activities provided by their peers- as was the intention of the Mock Maker Faire. However, after about five minutes into the Mock Maker Faire, the group members shifted their discussion towards the problem at hand: *how to get prepared for their Balloon Powered Cars activity which they had described in their write-up.* Among the first problems they identified as they started engaging in the materials was how to build a car themselves. They were at once trying to build a model car for participants to reference, as well as experience what it was like to build one of these cars themselves.

As the group members attempted to build their own versions of the balloon powered cars they discovered several challenges. The first was that it was challenging get holes in the bottle caps (wheels) for the straws (axles) to go through. With this identified

problem, they collectively came to the solution that they would need to pre-drill holes in all of the caps to a) save time and b) keep the activity safe for kids. The second problem that they identified was that the cardboard (car body) would need to be cut; their collective solution was to pre-cut the cardboard because a) they did not feel it would be safe to have kids using razor blades to cut cardboard and b) it would be too time consuming for each kid to cut their own cardboard.

These challenges were identified within the first five or ten minutes of their preliminary experimentation with the materials and upon finding these two challenges they started to talk about making adjustments to their plan. One of the first reasons they expressed for needing to make an adjustment was due to the amount of time it would take to prepare all of the materials themselves ahead of time; it would be too time consuming and they did not have immediate access to tools such as a drill. The second reason they felt the need to change course with their plan was because they thought that even if the materials were prepared it might be too difficult for kindergarteners and first graders to build (their target age group).

At this point of reevaluating their Balloon Powered Cars, one of the group members remembered that the course instructor had suggested to them earlier in the quarter that balloon rockets (see Figure 4) could be a good activity for the School Maker Faire. Balloon rockets consist of finding a way for a balloon to travel along a length of string as it expels its air (propulsion). This shift in focus led to the group assessing whether they currently had the materials to be able to try to make a balloon rocket for themselves.

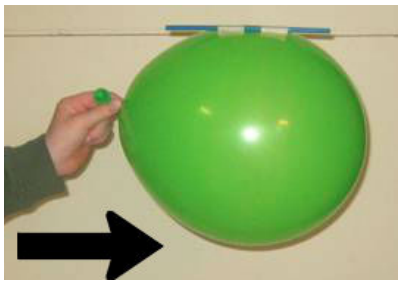


*Figure 4*: Sample Balloon Rocket

Also with this shift in focus came a shift in excitement about the project. The group went from appearing defeated and stuck, to showing signs of excitement and exploration. In the scurry to try out this new idea, one person recognized that they did not have string amongst their materials, so they collected some from another group that had string. Within a matter of minutes they had blown up a balloon, taped a small section of a straw to the outside of it, threaded the string through the straw and they were ready to test out their first rocket design.

The group counted down, and let the rocket go…it travelled forward about 3 inches along the string before it stopped its forward momentum and spun around the axis of the string several times as it expended the remaining air inside. This first test resulted in a lot of excitement with everyone appearing to be quickly engaged in how to adjust the design so that it would travel along the string further.

One person thought that the edges of the straw were rough from being cut, and that the rough edge was causing it to hang up on the fibers of the string. This led to two different design solution ideas: one, try to get rid of the rough edges and two, try to find a string that did not have fibers that the straw could get hung up on (one person had the idea to use fishing line, which they did not have on hand). After playing with the straw and testing it several more times, the group thought that perhaps the problem came from the straw being too narrow, or constricting. This led to a design iteration that used a toilet

paper tube to mount the balloon to instead. With the balloon attached to the toilet paper tube instead of the straw, the balloon rocket travelled almost the entire length of the string (about 8 feet). The group was very excited about this discovery and the ensuing success of their rocket, leading to one of the group members exclaiming, "This is so fun! They [the students] would love this!".

This moment of success and excitement was immediately followed by seemed to be a pivotal moment in the group's trajectory. Having found a design that travelled along the string, and that seemed approachable enough for their target age group to be able to construct, their focus shifted from further iterating their own design to thinking about the activity in terms of how participants would experience it. One person pointed out that "we will have to make them successful or they will be crying" (assuming that crying would be an outcome of having built a rocket that does not travel along the string). At about the point in time this comment was made, the Mock Maker Faire had come to an end and the class session was wrapping up. The timing of all of these things happening at once seemed to place exploration and conversation on hold, as the group's focus shifted toward cleaning up and defining last minute responsibilities so that they would have all the necessary materials for the Maker Faire.

While cleaning up, the group came back to the idea that different types of string might influence the flight of the rockets, so one person agreed to bring fishing line in addition to string in order to test this out at the Maker Faire. Other than that, they had the materials they needed as they could simply re-appropriate the materials they had collected for the Balloon Powered cars.

As they left class, they were now the "Balloon Rockets" group. They had identified that one of the problems they might need to contend with at the Maker Faire is to make kids feel successful; success in this instance had been identified as getting the balloon to travel along a string; and, finally, potential that their students might cry if they could not get this to happen. This parting sentiment revolving around this specific form of success deserves pointing out as it is ultimately had considerable influence on a number of experiences and interactions with students during the course of the Maker Faire itself.

## Individual Case Analysis

In this section, the results from the interview data are presented for each individual pre-service teacher in the Balloon Rockets group. Before launching in to the individual case analysis, the *initial code frame* and the *revised coding frame* are introduced as these code frames ultimately led to the themes used for analysis in this chapter.

This research project began with an initial code list (Mayring, 2000) in order to frame the initial rounds of analysis (see Ch. 3: Methodology, for details). This initial code list was applied to the interview data from the teacher used as the pilot. Below are the *initial codes*, their rationale, and a sample coded segment:

1. **"Relationships":** initial codes of this nature were informed by the fact that two of the three research questions pertained to the nature of interaction and experience of pre-service teachers in the Maker Faire environment. This initial code was generated on the assumption that any segments of the interview that alluded to a relationship might yield insight about interaction and/or experience.
    - **Sample code segment:** "*I think it matters what parents think of their kids teachers. I wouldn't want them to view us as not having prepared*

*for an event that we're putting on for kids. I think that would look very unprofessional"*

2. **"The Teachers Role":** initial codes of this nature were informed by the assumption teachers are products of an "apprenticeship of observation", whereby pre-service teachers arrive in teacher education programs with a pre-existing set of beliefs about what it is that teachers do. This code expected to reveal coded segments that might lead to insights on the types of beliefs about teaching that might work to inform interaction and experience in the Maker Faire environment.
    - **Sample code segment:** *"I don't know. I think it's just the teacher in you. I don't give kids the answers. Just spark their thinking."*
3. **"Design Thinking":** initial codes of this variety were informed by components of the design thinking process itself. This initial code was also informed by the assumption that segments of the interview that alluded to a teacher engaging in any part of the design thinking process would also serve as a point where design thinking was being manifested.
    - **Sample code segment:** *"I want him to maybe ... the creation he makes next maybe he has more intention behind it. Last time I made this design and it didn't really work out, this time I am going to do this because I feel like it's going to make it go faster because of xyz."*

Subsequent rounds of analysis using this initial code scheme were re-applied to the pilot case leading to adjustments to the initial coding scheme. Emergent themes that were a by-product of this first round of analysis were added as well. Below is the revised

coding scheme that was ultimately used across cases as well. This revised scheme indicates codes that were either *emergent*, or *derived from the initial code scheme*.

1. **Pre-Maker Faire Preparation** *(emergent theme)***:** Interviews were coded for this theme when the pre-service teachers mentioned talk about the need for or importance of preparation. The pre-service teachers in the balloon rockets activity group universally described the desire and need to be prepared for the maker faire- a logical motivation considering that the faire ultimately received around 400 visitors. Key words and phrases such as *preparation, prepare, getting ready,* and *before* were used (but not relied upon solely) to search for portions of the transcripts and field notes that might contain talk about preparations for the Maker Faire.
    - **Sample code segment:** "I would want to have a solution for every problem that might come up."
2. **"Interaction Drivers"** *(derived from the "The teachers role", "Relationships", "Design thinking")***:** This theme revealed that factors such as emotions, types of questions, and visions of success all seeming to have a relationship to interactions that played out in the environment. The following key words and phrases were used (but not solely relied upon) in order to search transcripts and field notes for relevant sections to be considered for coding: *words associated with emotion (feel/felt, nervous, surprise, worry, etc.); words associated with questions (ask, how, what, where, why, who); words associated with success (goal, success, succeed, fail, failure).*

- **Sample code segment:** "I was a little nervous that some kids would be upset if it didn't work. I was really trying to focus my reaction on how cool it was."

3. **Assessment** *(derived from "The Teacher's Role")***:** Assessment took on two different forms in the data. The first form was consistent with the type of assessment that is commonly associated with teaching– an assessment of what a student might know, or what they can do. A requirement of the Science Methods course was that teachers developed a frame for assessing learning during the Maker Faire. Accordingly, this theme was present across all group members and seemed to play an important role in a) perception and b) interaction. Key words and phrases such as *assess, assessment, show, learn/learning/learned, able to/had the ability* were used (but not relied upon solely) to search for portions of the transcripts and field notes that might contain talk about the role of assessment for group members during the Maker Faire. The second type of assessment was of the nature of assessing a scene– an assessment of what is happening. This type of assessment served the purpose of informing subsequent actions on the part of the teacher. Key words and phrases such as *looking for, wanted to see, watching, observing* were used (but not relied upon solely) to search for portions of the transcripts and field notes that might contain talk about the role of this particular type of assessment for group members during the Maker Faire.

    - **Sample code segment (assessment of knowledge/ability):** "That shows that there is thinking going on. There is improvement and

learning going on. We are trying to get them to make this connection, when I build it in a certain way it is going to have a certain effect."

- **Sample code segment (assessment of the scene/situation):** "I was constantly circling the table and assessing the situation to see where I was needed."

4. **Parents** *(derived from "Relationships")***:** all group members touched on the role that parent presence played for them during the Maker Faire. Key words such as *parent(s), child(ren), dad, mom* were used (but not relied upon solely) to search for portions of the transcripts and field notes that might contain talk about the role parent presence played for group members during the Maker Faire.

    - **Sample code segment:** "I remember also it's like awkward because his dad was blowing up the balloon and I felt bad because those balloons were like really hard to blow up."

The following section provides the individual case analysis for each group member (Mary, Amber, Ruth, Sally[7]). The findings are presented categorically as they pertain to the revised code scheme outlined above. Each case analysis account begins with a brief overview of each pre-service teacher's relationship to science, either formally (via coursework of profession), or informally (hobbies and interests).

[7] Pseudonyms have been used to protect identities of participants in this study.

**Mary**

Mary was a pre-service teacher who described herself as being comfortable with science, "especially with the Next Generation Science Standards" as they really resonate with her. In terms of her background with science, she is a liberal studies major who took a number of science courses which dealt particularly with how to teach science. Mary explained that this background with science pedagogy allowed her to "feel more comfortable in situations where she may not always know the relevant content", which she elaborated was partially the case for the deeper science behind how balloon rockets work.

***Pre-Maker Faire Preparation***

Having been part of the transition from the balloon cars to the balloon rockets, Mary recounted that she, "did not feel super prepared." As she reflected back to the Mock Maker Faire, she remembered trying to build the balloon car and how, "the materials weren't allowing it, the car was falling apart a bit on us, we didn't have enough of both types of tubes, and it just led us to the rockets." While she explained that in some respects she felt unprepared, she also felt confident during the Mock Maker Faire that her group would get something to "work because it was the engineering design process" that they themselves were using to get prepared for this event. For Mary, she ultimately felt "comfortable not having made a successful model" of a balloon rocket and she attributes this to a confidence in children's ability to take, "modern materials and see if they can make it happen"; to her that was the point of this event, and she didn't think a model of a balloon rocket was necessary to get them exploring (which is in contrast to what Amber believed).

Furthermore, Mary recounted that she herself "didn't have a structured idea of what was going to happen", and that she was particularly comfortable with that. Once they had settled on the balloon rockets as their activity she was curious to "see what they would come up with". Mary specifically remembered thinking during their Mock Maker Fair preparations that she, "didn't want it to be a step-by-step, like 'Let me tape this on here and this is how you have a rocket'". Rather, she wanted to see different types of rockets and she wanted kids comparing and testing their different qualities. She felt that providing a model rocket might prevent a variety of outcomes from occurring as she assumed kids would orient to the model if one was provided.

***Factors that Influenced Interaction***

Mary conveyed a vision of success that involved children successfully getting a balloon to fly along a string. Mary was, "a little nervous that some kids would be upset if it didn't work". This framing of success, as creating a rocket that flies along the string, may have influenced Mary to react in certain ways when rockets did not go as planned. For example, there was one boy who launched his first balloon rocket design and instead of the rocket travelling along the string, it just spun around in circles on the string until the air was exhausted. In the video footage from the Maker Faire, Mary enthusiastically says, "Wow, how did that happen? You made it spin- let's figure that out!" In approaching the unsuccessful launch in this manner, she explained that she was trying to reframe the experience. In other words, she was trying to shift the child's perception of that event from seeing it as a failure, and something he could be upset about, to seeing it as an opportunity to explore what happened and a chance to figure out what to change in the design.

In reviewing the Maker Faire video, Mary was seen in the footage spending a significant amount of the time pulled back from the action where building is happening, in what appears to be a more observational stance. This behavior might be explained partially by the fact that Mary described intentionally trying to be as hands-off as possible:

> *I didn't want it to be a step-by-step, like let me tape this on here and this is how you have a rocket…With all the age groups and all the parents able to help and everything. I wanted it to be less, "Let me teach you how to make a rocket". I wanted to see what they came up with.*

Mary saw her role as being a facilitator who was available when someone needed it, but if kids appeared as though they were on a good path, then she explained that she was likely to step in to the background and just watch.

Mary explained that she tried to gauge individual student emotional states as a way to inform how much, or how little, support that she should provide. One of her strategies to gauge a child's emotional state was to repeat back what students said as illustrated below in an excerpt from the Maker Faire video:

> *Student: "[My rocket] didn't work."*
> *Mary: "It didn't work?"*
> *Student: "I can't fix it."*
> *Mary: "You can't fix it?"*
> *Student: "Well, I need to tape it."*
> *Mary: "Okay, so you just need to tape it."*

When looking the video footage of this excerpt, Mary explained that she remembered that she, "was repeating back and trying to gauge if he was bummed out about it or getting frustrated. Then when he basically told me how to fix it, I was like, okay then." In other words, since he was thinking about how to modify his design, she figured that the best

move for her in that moment was to step out of the way and let him go. In Mary's words she elaborated on her logic:

> *I think their emotional wellbeing determines how I test where they need the scaffolds. Because I don't want them to get frustrated and quit and I don't want them to feel like they can't do it. Emotionally, if that's in concern, then I'll start with higher scaffolds and take them down, down. Ideally, emotionally, if they are ready for it, I start with barely any scaffolds and then bring it up as needed.*

In addition to using her sense of students' emotional states to dictate how she guided interaction, there were moments where she made subtle adjustments to the environment as a way to provide structure for how children might engage in the activity and in design thinking. For example, at one point in the video Mary finds a whiteboard that she brings over to the activity with the intent to use it as a way to inspire kids to want to compare how their balloon might travel on the two different strings they provided (one string was nylon fishing line, the other was white cotton string). Her thinking was that there would be, "one column for the white string and one column for the invisible string [fishing line]", and by putting this in the environment kids might think, "okay, there is something that can be done that got a faster time," ultimately working to push them to experiment in order to get their rocket balloon to travel faster. This indirect move is an interesting example of how she considered the environment as a factor that could be manipulated to provide structure without having to directly tell a child they should try to get a time that is faster than one posted on the board. In this way it seems she was trying to empower the child with the feeling that they were the one making the choices of how to modify the design, instead of the teacher by the types of questions she asked.

Mary seemed to consistently search for ways to help create a space where exploration was encouraged. Whenever she helped to load a rocket on to the string when it

was ready to fly, she allowed the kids to put the balloon on in whatever direction they wanted. While the balloon could only travel one direction on the string setup they had, by intentionally creating a space where instead of telling kids the direction to load their rocket on the string, she let them try their own ideas, it can be argued that she worked to structure an environment of exploration with those she interacted with. During the stimulated recall portion of the interview, there was a moment with a particular child where she remembered thinking that she, "was fully prepared to put it on the string the wrong way and see what happens." To do so would allow her an insight into the child's basic understanding of the cause and effect relationship of propulsion, as well as allow space for the child to try out his own ideas.

Another interesting way that Mary guided thinking and interaction was by using what she called "fabricated curiosity." She describes "fabricated curiosity" as moments where she recognized that there might be more to explore in a certain situation. By saying something like, "Whoa! Why did that happen? We've never seen one spin before!" she used it as a way to guide a student into realizing that, "there might be something interesting here" to explore.

While fabricated curiosity was used as a tool to help students frame how to look at exploration, Mary described a second layer that was important to her in this idea of fabricated curiosity. Mary described fabricated curiosity as also being a way to "spur on or validate the kid's curiosity". She mentioned that she felt that in school children don't always have the time and space to really explore the questions and curiosities they might have. She attributed this to school being a place that children may feel belongs to teachers because it was "the teachers and adults that set up an activity...like, it's our space and they

are in our space they are doing our activity" when they are in the classroom. Whereas in the Maker Faire, she had the intention to try and make it feel more like it was the student's space where "it's okay to investigate all your questions". And to be fair, Mary recognized that it in the case of the Maker Faire, it was also the adults who designed this space and organized these activities. However, she mentioned that she felt like they had an opportunity to be intentional about how the space was arranged so that it felt like a space for kids to explore: "What can you do with these materials?"

***The Role of Assessment***

Mary described a variety of ways that she engaged in assessing students and their actions during the Maker Faire. One of the things that she described constantly looking for was evidence of design thinking; as the NGSS standard that her group was focusing on was, "to compare two different designs of an object that was meant to do the same thing". Her assessment included looking for evidence of elements such as iterating designs, evaluating designs, and brainstorming ideas. Very early on in the Maker Faire two brothers came to the table to design and experiment with balloon rockets. When Mary watched footage from the Maker Faire with these boys hard at work with their designs she recalls that during the Maker Faire she was observing them and thinking, "It was, 'Okay let's try one balloon, now let's try two balloons' and they just went for exactly what we had been hoping for. It was like testing and redesign and testing and they were there for a long time. That was cool. They were having fun with it."

In total the boys were at the activity for about 30 minutes and they made many modifications and improvements to their designs. While a couple of Mary's group-mates interacted with these two brothers a number of time through their involvement at the

activity, Mary appears largely pulled back from the scene during this time; Mary describes that,

> *I think that in the moment I'm kind of walking around and looking at … I think I'm cognizant of someone else is handling this and especially if I'm hearing that someone else is already like pushing questions more than I would want to. I don't want to like… so I listen, but I don't want to add more questions because I feel it's already too much questioning. Then I'm also cognizant of a little kid sitting on a stool with one big blue sitting in there and I don't want to be like the second one in there.*

When Mary is referring to being another "big blue sitting in there", she is referring to the fact that all of the pre-service teachers were wearing blue Maker Faire shirts that the course instructor had made for that evening.

While Mary was standing more in the background in the scene, assessing the situation with the little brother who is working with one of the other pre-service teachers, she seems to be assessing a number of things. First she recalled assessing being aware that her group-mate was asking more questions than she would want to in that situation. This sentiment reveales a belief held by Mary that kids may not always need teacher questions and direct teacher involvement in order to move forward in their explorations. Second, in her recollection she mentioned being aware that there was already one "big blue" sitting there, and in Mary's assessment of the situation, she imagined that having more of these blue shirts around might be intimidating for the child. This is an interesting thing that she pointed out noticing, because it reveals here awareness of the influence that *physical presence* that a teacher may have on exploration; and more specifically, when all teachers are wearing the same colors there is a possibility that it compounds the influence of their presence.

Mary's assessment of student understanding was not so much focused around content knowledge gained as it was about *how* they approached thinking about their rockets. In this regard, she felt that there were a variety of forms of evidence that could inform her that children were thinking critically about what they were making:

> *Anything from, oh it goes faster, turns out it goes faster on the plastic string than the other string, if we compare those. I wasn't as concerned with them knowing like friction or anything like that …for the aged kids we are getting especially just noticing, well there is a difference there. "When I put wings on it, it flew sideways, but when I took them off, it flew straight." Just some comparison of … So a lot of times it just came out in, "What can you do to make it go faster?"*

When she saw students testing their rockets on the different strings, adding components to them to see how it influenced flight, or simply making changes to try and get the rockets to go faster, she saw all of these actions as evidence of them engaging in design thinking.

In the previous section on guiding interaction, there is the example describing how she would let children decide which orientation to put the balloon on the string. While this example served as an illustration of how she created a space that accommodated exploration, Mary also describes this moment as being a place where she could assess some basic understandings. If a child put the balloon on the string in the "wrong" direction she would use this a way of knowing that they perhaps did not yet understand something like cause and effect, or how air escaping the balloon one direction will cause it to travel the opposite direction: "That's an important thing to figure out if you are going to make a rocket– got to know what's making it go."

***The Role of Parents***

In general terms, Mary had largely positive things to say about parents at the Maker Faire, and her interactions with them. In reviewing the video footage, she recalled one

child who was approaching the activity without his parents and in that same moment looking over at another child who was working on a balloon with her mom and she remembers thinking to herself, "I should talk to that kid [the one approaching without a parent] because that mom has got it covered over there [with the kid already working]." This recollection is a good summary of how Mary recounts her interactions with parents at the Maker Faire; that is, she viewed them as mostly supportive, and able to ask good questions when engaged with their own children.

Characteristic of the more observational role that Mary took on during much of the Maker Faire, she described enjoying watching the parents because, "the parents were taking on more of the interactions than [she] expected". She recalled observing parents, "asking the questions that [the balloon group members] were trying to ask" such as "'Why do you think it did that?'". She elaborated that one of the reasons she thought these parents asked these types of open ended questions was because, "a lot of them were university people who work at the university bringing their kids". The reality is that of the 400+ participants, probably only a small fraction of them were university employees who brought their kids. The invitation for the Maker Faire went out to the 33 classrooms where pre-service teachers were placed, the parents of those children, and all teachers in the school district; additionally, faculty in the education department were invited. Though there is no hard data to confirm the number of university employees who brought their children, what can be inferred is that Mary appears to be making an assumption that in order for parents to ask such open-ended questions, they likely have some level of higher education that would inform being able to ask such a question.

**Amber**

Amber was a pre-service teacher who had mixed personal experiences with science. She recalled that in elementary school she hated science and that she was "never invested in it". In particular, she did not like "recipe labs" in which science meant following a series of steps in order to arrive at a predictable outcome. Her perspective on science changed in college when she took a course in psychology that required her to assist in doing research on stress levels in the home environment of new parents. In this position she would travel to people's houses and collect saliva samples that would then be analyzed for cortisol levels (a predictor of stress levels). She said that her work in the lab as a research assistant gave her the chance to form hypotheses and collect relevant data. Amber's experience with the lab shifted her perspective on science as it opened up her eyes to the exploratory nature of science. Despite this shift in perspective on what "doing science" might look like, Amber still did not "consider [her]self a science person".

***Pre-Maker Faire Preparation***

Although in retrospect Amber "couldn't believe how well [the Maker Faire] went", she explained that she did not anticipate success in the lead-up to the event itself. Her account of how she felt leading up to the Maker Faire describes a range of experience and emotions. For example, she expressed being terrified because "it took us forever to figure out what we wanted to do" as an activity for the Maker Faire; specifically she is referring to the Mock Maker Faire and her recollection of their planning for the event.

One of the things that caused her the most stress, was the fact that her group changed their course of action during their Mock Maker Faire. She described being nervous that due to their change of activity they did not have a concrete plan, or a model

for kids to follow, and the "idea of parents and kids coming to a science event with no plan was terrifying"; Amber explained that prior to the Maker Faire she thought that in order for kids to explore, "they have to be given something to go from". She attributed this perspective as being reflective of how she would imagine herself as a child of that age, where she did not think that she would just start building something without a model to go off of because, "as a child, if I didn't see things I would have been like, 'What do you mean make a rocket out of this stuff?'"

Amber described herself as a person who, "would want to have a solution for every problem that might come up"; and because she did not have her head totally around how kids might engage in the Balloon Rockets activity, she wondered, "how are we really going to explain this to kids?" Such a statement hints at the idea that Amber may also believe that students need to have things explained to them. Despite her apprehensions going into the Maker Faire, she found the experience to be a very enlightening one as, "there were a lot of kids that got really determined to improve the speed of their rocket"; this realization points at a potential shift in her thinking that kids may need less structure (or perhaps a different type of structure) than she would have assumed.

***Factors that Influenced Interaction***

During the event, Amber recalled being particularly concerned with the idea that kids would not have a model or instructions to get them started. She wondered to herself how kids would be able to just come to a table of materials, then conceptualize, and ultimately construct a balloon rocket. During the stimulated recall interview, Amber was looking at footage from the Maker Faire where she herself was standing, staring at the table of materials while her group-mates and participants were busily building balloon

rockets. She described that in this moment she was thinking, “I was the one trying to assess exactly what was happening. Where are the materials we need? Where are the kids at? Everyone else was good with just like, ‘We'll just help the kids as they come. Whatever.’" In this moment she went on to explain that she was trying to take in the “big-picture” of how this would look to kids when kids arrived, and trying to figure out how they should know to build a balloon rocket.

In what Amber identified as a lack of structure for the participants, she recalled that she started creating a framework for how to interact with kids as they came to the Balloon Rockets activity:

> *It's like step one, okay, they did that. They chose a balloon, that was step two, and step three was how to attach the two, and step four was choose the string. They were given those concrete things to do. I was shocked at the direction that kids were able to take it in without having any visual to refer to. I'm still a little surprised by that, but it's memorable.*

Here, Amber identified ways in which she created a series of steps to implement in order to frame how students might interact with materials and work towards building a rocket. For Amber, providing structure in the form of steps to follow would allow kids to feel successful by enabling them to feel confident that they were engaging in steps that would lead to a rocket. Furthermore, providing such steps allowed her to feel she was fulfilling her role as a teacher:

> *I guess I would be worried that a kid might get lost in the process or frustrated and I wouldn't be able to help them because I don't have a firm understanding of science myself. Not being able to, in my view, to do my job as a teacher and facilitate for every single step in the process.*

The last portion of this excerpt is particularly interesting, because it reveals that Amber may consider that part of a teacher’s role is to facilitate steps in a process- something that

would require a particular type of preparation: namely, defining the necessary steps ahead of time and developing a way to coherently communicate those steps. Also contained within this statement is the suggestion that Amber may feel compelled to create this stepwise structure as a way to somehow compensate for her self-proclaimed lack of science understanding.

During one of our first follow-up interviews, Amber revealed that since the Balloon Rockets activity turned out to be a success, that she would do a version of the activity with her placement class during her one-week takeover (the time in which a pre-service teacher has responsibility over the whole class and its lessons). While her commentary about bringing the Balloon Rockets activity into her classroom goes beyond the Maker Faire experience itself, it is worth noting as it works to provide insight about Amber's beliefs about teaching, learning, and providing guidance for learning:

> *In a perfect world, I would want each [group] collaborating to make the most successful rocket, but they're not going to do that. They're going to disagree. Some kids are going to want it to be huge and complicated and some are going to get upset if their idea gets vetoed. I don't know. I also have one hour to do this project so it's like, should I have tons and tons of materials so that they can test every possible way to make a rocket or will that turn into more of an individual thing and defeat the purpose of being in groups? I don't know. I'm going to talk to the woman who usually teaches science for first graders and see what she would recommend doing to facilitate.*

In this excerpt, Amber seems on the edge of three ways of thinking about learning. First, there are elements here that are more reflective of her pre-Maker Faire mentality; a mentality where she shows a preference for thinking about the ways things could go wrong or astray and consequently she seems to be working to design-in solutions to mitigate these potential deviations. Second, this excerpt reveals that she realizes that with a variety of

materials, these students have the potential to make a variety of different rockets; a perspective that may be reflective of what she experienced during the Maker Faire itself. Third, she brings up the problematic nature of time; more specifically, that she believes that having a limited amount of time might be a hindrance on exploration.

***The Role of Assessment***

While most the other three group members mentioned multiple ways that they assessed learning, understanding, ability, etc., assessment of this nature did not reveal itself as a significant theme coming out of the interviews with Amber. What Amber did allude to is assessment of more logistical factors like materials and organization.

During the stimulated recall interview, I prompted Amber to try and recall what she was thinking in a moment of the footage where she was sitting across the worktable from a kid who was working on a rocket. While she was not talking to the child during that portion of the footage, it looks as if she was paying close attention to him. My prompting was based on my assumption that if she was watching a child work, she might be assessing something. In that moment she recalled thinking, "'Should I intervene at all?' It looks like he is pretty solid making his rocket so I don't want to distract". Amber's assessment was informed by what was visible to her, and in that visible evidence she felt she could gauge the child's progress in the activity by how confidently he was working with the provided materials. Her assessment led to her to ultimately not say anything at all, but just continue casual observation of his progress.

At other times in the stimulated recall interview, Amber remembered assessing things that were of a more logistical/facilitative nature- *whether there were enough materials, are kids being tended to, is someone recording the times for the balloon rocket*

*flights.* While all of these things require an assessment of sorts, they don't seem to be assessments of students and their experience with learning or the design thinking process.

The lack of references to assessment could be in part due to interview questions not working well to trigger her to think about how the role assessment may have played in her thinking. On the other hand this lack of assessment evidence could also be due in part to the fact that among her peers, Amber communicated the most concern for a need to have a plan. It could have been the case that fulfilling this need dominated her thinking during the Maker Faire in a way that prevented her from engaging in deeper assessment of children and their learning experiences, and led her to focus more on logistical concerns.

***The Role of Parents***

Among the Balloon Rocket group members, a theme emerged from the data evolving around the role that parents played for the group members during the Maker Faire. For Amber, parents definitely played a role in her experience at the Maker Faire and interestingly, they did not even need to be present to have an impact on her thinking.

In talking about the preparations leading up to the Maker Faire, Amber described parents playing a role in her thinking and actions. As she told how terrified she felt with the idea of parents and kids coming to a science event where she did not feel properly prepared, it is important to note that she was not talking about parents in real terms, but rather the *idea of parents*; more particularly the idea of parents judging her professionalism as a teacher. Amber went on to justify her concern by stating, "I think it matters what parents think of their kids teachers. I wouldn't want them to view us as not having prepared for an event that we're putting on for kids. I think that would look very unprofessional."

This as-to-yet-be-realized reality where parents are judging her for her professional merits as a teacher, seems to have a relationship with her motivation to make sure she is prepared.

Finally, the word "prepared" had specific meaning for Amber: *having a model to work off of, a series of procedures to follow, and a type of preparation that involves planning for every foreseeable contingency.* When placed next to how parents might perceive her, her version of "prepared" reveals how she thinks parents conceive of teachers.

**Ruth**

Of the four group members in the Balloon Rockets group, Ruth reports having taken the least amount of formal science coursework. She, "didn't take any science classes in college" and the last class was in high school. However, Ruth was quick to say that having a very minimal science background did not feel problematic to her for the Maker Faire event. She attributes this largely to the fact that since the Balloon Rockets activity was aimed, "towards younger kids, you don't have to get too technical with them". What is more, she felt confident in this environment (content-wise) because, "a lot of the stuff you learn with the methods classes and teaching could kind of apply to anything that you are teaching, even if you are not the most versed in [science]. As long as it is exploration based and you are letting the students construct their own learning". In this way, Ruth seems to suggest that a constructivist pedagogy relieves her of needing an extensive, or even moderate, science background. While Ruth expresses that her minimal science background is non-problematic in this environment, she does find it problematic when parents enter the scene. This will be discussed in more detail in the section on *parents.*

***Pre-Maker Faire Preparation***

Like her group-mates, Ruth did not feel totally prepared for the Maker Faire event. She found the original balloon powered cars to be too cumbersome to do for the event because “being prepared would mean we would have had all the pieces prepared with a prescribed list of what to do”, likening the original plan to, “IKEA building instructions”. She expressed that as a group they never really sat down and considered the implications of having to prepare the materials so much and the instruction-like nature of the car activity until the day of the Mock Maker Fair; once she realized they needed to change their direction, this led to a feeling a bit unprepared because, “we were not sure what materials they would want and how they would use them to make a rocket”.

Conversely, she admitted that once they settled on the balloon rockets, it, “just kind of made sense…It ended up being way more interesting for them to just do whatever they wanted to”. This shift in sentiment suggests that Ruth recognized that having a more scripted activity, as they had originally planned with the balloon cars, might not lead to the more open exploration that they were ultimately looking for in the Maker Faire.

Ruth reinforced this perspective shift by recalling that with the change towards balloon rockets, new questions arose such as, “Could the kids figure out how to put [the rockets] together? Could they ask questions about why it was working? Can they just take different kinds of materials and just make that move?". A second realization that came with switching from the cars to the balloon rockets was that it felt much easier to prepare for the balloon rockets because, “we didn't have to have all these materials pre-set out, and done for them”, but rather the kids could come and build in their own way that they saw fit, using the materials that were made available.

In reflection, Ruth could identify the way that the balloon rockets might lead to more exploration, when compared to the potential of the balloon powered cars activity that they had originally planned. Interestingly, when it came to the way Ruth interacted with kids during the Maker Faire, she seemed challenged at times to actually allow for this more open exploration, as her interactions with children occasionally hinted at a desire to guide them through the activity in terms of how to build the balloon rockets themselves.

***Factors that Influence Interaction***

Ruth's interactions, and her recall of her interactions, represent a range of qualities. At some points she described exploring right alongside certain children, totally unsure herself where things would go. At other points, she described how she used leading questions to get kids to do or think in certain ways. Below is an account of the various ways that Ruth guided interaction with children at the Maker Faire:

> *We wanted kids to come to the table. We wanted them to come to the table and we wanted them to try it out. I think that we intervened to bring them in. Introduce them. Let them know it was safe. They could come and they could do whatever they wanted. There was really no wrong or right answer. They could just do whatever they wanted. I think it was really important to us to engage the students. Try to engage them as much as possible.*

Early in the Maker Faire video, two brothers arrive together with their mother. They are relatively quick to jump in to exploring the materials in an attempt to create a rocket that could be powered by a balloon. In the video, you see Ruth approach the brothers who are sitting next to each other. As she begins to engage with them, one of the brothers asks, "Can I have two balloons?". Ruth responds by asking, "Okay, well there's only one string, how are you going to make it work with two balloons?". The boy shows her how he plans to tape a straw between the two balloons, in effect joining them together

to have a rocket that is powered by two balloons. Ruth is heard in the video saying, “You want to try that? That looks like it is really cool! Wow!”.

When Ruth reviewed this section of the Maker Faire footage during our stimulated recall interview, I asked her specifically about the nature of her reaction to his idea because in the video she sounds genuinely excited by it. Ruth recalls that in the moment she was working with the boy, he was “really intent on making it go faster, and it was really exciting when he said he wanted to use two balloons because we haven't even thought of it.” When she says, “we haven’t even thought of it” she is referring to herself and her group-mates, who in preparing for the event, had never considered the idea of powering a rocket with two balloons. She recalls thinking to herself, “Okay, well I don’t want to tell him how to use two balloons, let’s see what he thinks up”. Ruth recalls thinking that she “just wanted to ask him questions, and see where he was going, and what he was thinking, and encourage him to just try and do anything.”

In reflecting on this moment, Ruth tells of two experiences happening very close in time to one another. The first experience is the one reflected above, where she is genuinely excited by this new idea that she and her group never came up with. The second experience, which quickly followed, was that once she had her head around what, “the kids are trying to put it together, it's like ‘I already know the best design that you might want to do.’” Ruth reasons that this happened for her because as an adult, and as a teacher, she had already had more “life experience” that allowed her to sort of “see around the corner”, even when encountering a new design. Ruth explains that once she had her head around what he was trying to do she, fell quickly back into the more informed type lines of questioning.

Ruth's apparent insight is that there may exist moments where she was exploring on an eye to eye level with a child; moments that were defined by neither of them having ever explored this particular idea. But she describes that those moments felt fleeting in nature, because her own "life experience" gave her the ability to place the new idea in her larger context of understanding how things work, and when this happened she no longer felt like she was exploring alongside the child but instead back in a role of the knowing teacher.

This shift away from exploration, and towards those "informed type lines of questioning" is reflected in the things she says to the child shortly after expressing her excitement. For example, in getting him to think deeper about his design, Ruth asks the boy, "What do you think, why would two make it go faster? More air blowing out?". In hearing herself ask these questions during the stimulated recall interview, Ruth recognized that these were leading questions; in other words, she is trying to get him to think about how these rockets are propelled by air blowing out of the balloon, and how doubling the number of balloons should effect how fast it travels. Ruth then asks, "What would make this one go further than your other one?" as she helps him load the rocket on to the string. Again, this question signals to him that she probably already knows that this balloon will go faster than the one he made that only had one balloon powering it- even though he has not even tested his double balloon yet. As a matter of fact, this is likely the very thing this boy is testing for: whether two balloons makes a rocket travel faster than a rocket with only one balloon. Although it was highly unlikely that Ruth was trying on purpose to give him the answer before he tested his double balloon rocket, one could imagine how that might work to unintentionally undermine the exploration that the boy was trying to carry out. Such a question speaks to exactly what Ruth alluded to: her own life experience

allows her to "see around corners" and this influences the things she might say, which may in turn influence thinking and action on the part of the child.

In watching the video together, there were other points where Ruth recognized that her questions were leading in a way that worked to guide interaction towards certain ends, but perhaps not others. For example, there was a moment in the video where a child is beginning to build his balloon rocket, and he starts by blowing up the balloon. Ruth asks the child, "Do you want to blow up the balloon now, or at the end?". He replies by saying/asking, "At the end?", to which she replies, "Yeah, probably at the end". Ruth recalls that she asked this question because in that moment she is thinking to herself, "yeah, you should probably blow it up after you come up with your rocket". But instead of telling him this information directly, she presents it in the form of a question because, "It is the teacher in [me]. I don't give kids the answers. Just spark their thinking."

In this case, she is painting a picture of good intentions, intentions where she wants kids to come to their own answers to their questions. But, this question was not the child's question. It was instead Ruth's question, informed by her experience that it works better to blow up the balloon at the end of the design process instead of the beginning. Furthermore, it very well could be the case that there are times where blowing up the balloon at the beginning of the process might be advantageous or reveal certain insights that could be useful in making a balloon powered rocket. However, it seems fair to say that this child's experiment with blowing the balloon up prior to designing the rocket has likely come to an end, in the light of Ruth's leading question.

Consistent with Ruth's assertion that one of her jobs in this environment is to "spark their thinking", Ruth is seen at one point engaging in some balloon rocket

experimentation of her own. In the Maker Faire video footage, there is a point where Ruth is seen cutting and attaching wings to a balloon rocket that she herself made. When asked about what she might have been thinking in this moment, Ruth explains that by putting wings on a balloon rocket she, "was wondering if the kids would put wings on it". In this moment, Ruth is guiding interaction through *parallel play*- a concept they touched upon in the Science Methods coursework. Parallel play is a way to facilitate exploration by modeling a way that learners might be able to take up materials and being exploring. By engaging in the construction in her own rocket and testing what happens when wings are placed on it, she is working on the assumption that, "when [kids] see something then they want to try it". But to be fair, she also just, "wanted to see if the wings would work", for own curiosity. This moment reflects a second point in the Maker Faire where Ruth talks about being at eye level with the children (in this case by experimenting based on her own curiosity), while also being the teacher who is modeling a certain type of behavior (experimenting with the materials in different ways, with the hopes that a child follows her lead).

Ruth even admits that at some point, her curiosity about the wings took over her initial motivation to model experimenting via parallel-play, and she started making modifications to her design by cutting the wings, because they were, "too floppy". She recalls thinking that, "[the floppy wings] are weighing it down". She tests her new design with the shorter more rigid wings, and like the first, it just spins around and around. It doesn't work as planned, and she laughs about it. What is interesting to note, is that even though Ruth describes herself as being totally devoted to experimenting (and at that point has paused any attempts at facilitating the activity), her actions are still available for others

(children) to observe and be influenced by. This speaks to the fact that all of a teacher's actions, intentional or not, are always available for others to learn from when these things are occurring in the same environment. A child could have watched Ruth and seen her: *experimenting with new materials, testing her ideas, evaluating what is causing it not to work in the way she intended, iterating a design, retesting it, and embracing failure with a positive attitude.* All unintentionally put out there, all in line with the goals of their activity, and available to be learned from.

***The Role of Assessment***

Ruth recounts a couple of ways that she tried to assess student understanding- both in terms of content (how rockets work) and in terms of the design process. She largely describes a version of assessment that relied on her careful observation, as opposed to asking targeted questions.

Ruth explains that assessing a child's personality was a way to assess their comfort with the design process. She recounts that when a child started working at their activity, part of her job was to assess how confident they were with exploring on their own, versus needing more guiding. In her own words it really,

> *comes to the personality of the kids. There was the table and they were not sure if they wanted to walk there. It's like "Come on. Let's get you really excited about this." There's any way you could approach it. There were so many things on the table that I think that most kids, it's kind of intimidating. "What do I do? Is there a right way to do it? A wrong way to do it?"*

A child who is overwhelmed by the materials or the task might need more structure on the front end to be able to get to a place where they could identify problems, create and test potential solutions, and evaluate these solutions. In the context of how Ruth guided interaction, it can be inferred that such assessments may have been the driver for Ruth's

leading questions that are identified in the previous section. In other words, it is possible that she used leading questions as a way to guide initial steps, or directions that a child might want to take as they begin to engage in the design of their own balloon rocket.

There were also students that Ruth assessed as being confident and engaging in the design thinking process; she describes that one boy, "already had an idea of what he wanted to do. I don't think he was so much worried about what he could do at the table as much as just getting what he wanted done." Here, Ruth assessed his confidence level, concluding that his confidence in his design concept seemed to drive his confidence with the materials. The student had a strong vision, and it was a matter of somehow leveraging the available resources in a way to execute that vision. During the stimulated recall, she is sitting across from the boy described above, just watching him work, but not engaging with him directly:

> *His design was really interesting. This is why we were watching him because he really had an idea of what he wanted to do and he was working really diligently on it and trying to make it even and have balance to his rocket. That was really interesting. Watching him work. I think he was a 4th or 5th grader, but he was very confident in what he wanted to do. I think that's why we were just watching him for a while.*

In this account, her decision to simply observe is born from assessing that he seemed confident with his idea and with the materials. Also embedded in this account is her assessment of him tending to important rocket variables such as weight, and balance.

In this way, Ruth used her observations of how students engaged with the materials and the rockets as a way to assess what they might understand about how the rockets work:

> *Yeah because some of the kids like they want bigger balloons; it's funny right, but it's because they're kids. But then also, do you think [size] is going to influence*

*anything? I think that's one of our initial questions, like will students realize that the air inside of the balloons is what's propelling it, because I mean they are five. That's kind of like what we were geared towards- cause and effect. Are they thinking about the fact that the air is coming out and pushing the rocket the other way, and then at some points we did ask them, 'Do you want it facing this way or do you want it facing that way. Do you think it matters? Do you want the air coming out that way if you want the balloon going that way?', and they were very quick with that they were like 'No, that way'.*

What she is reflecting here is her assumption that younger kids will be drawn to inflate larger balloons simply because they are "kids". She further explains that she can assess if a student understands that associated with a larger balloon is that, a) the air inside the balloon is what ultimately propels the rocket, b) the more air in the balloon, the further it may travel and c) the balloon will travel the opposite direction that the air input is facing. Ruth felt that by watching how kids assembled and mounted the balloons on the string, she could gain insights into some of their basic conceptual understandings of cause and effect and the movement of air from areas of high pressure to low- even if this understanding was only happening at an intuitive level.

***The Role of Parents***

Ruth described parents having an influence on her at the Maker Faire in multiple ways. She found some parents to be a bit too intrusive in the experience that was meant to be for their children; specifically in the way of influencing what the children ultimately made. At other times she recalled that some parents seemed impatient with what their child was doing, and she would witness the parent intervening in ways that worked to speed up the process. And sometimes, she found that just the presence of a lingering parent could push her into self-doubt about the things she was saying and doing with a child.

When talking about the ways that parents seemed to over-insert themselves into the experience, Ruth argues that, "parents just made such an impact because they were already kind of pushing them towards certain designs, so then they have that exposure." The exposure that she is referring to here is that where there were parents driving the designs, these kids were exposed to more advanced concepts about how to think about designing a rocket; concepts that they might not necessarily arrive at on their own. She emphasized that, "obviously there were some parents there who already had an idea, and were like 'Put it there.'", meaning that the parent was telling the child how to construct the rocket that the parent had imagined. Ruth found this frustrating at times as she maintains that she and her group-mates, "were trying really hard not to influence the kids, not to get them to do what we wanted but just kind of like oh can you figure it out?" Though she described this ideal of what her group was trying to accomplish, it is interesting that despite her frustration with the parents she herself participated in actions and questions that worked to guide children to do certain things and perhaps not others.

Ruth also described some parents as appearing impatient with the amount of time it sometimes took for their child to assemble parts of the balloon rocket. Ruth attributes these types of parental interactions to the fact that parents, "already know the answer a lot of the time, and so it really takes a lot of patience to let the kids just kind of try and figure it out on their own." She even went so far as to empathize with parents by saying that, "it can be really boring" to watch a child figure out their own design, especially if the parent already has an idea of a design in their mind- "You know, 'Just do this, just put it there.', you know just kind of almost giving the answer just because some kids it could take a longer time to get there and really make those connections on their own". Ruth even went

so far as to extrapolate this frustration to herself as a teacher at times by recognizing, "that even as teachers it's hard sometimes when you're like teaching one plus one, and it's like it's easy to do- just count my fingers" but instead kids need the time to really think about it for themselves. She mentioned children needed time to explore their ideas and, "put a lot of stuff on [their rocket], but then maybe after they've tried it a few times they're like, 'I don't want a lot of stuff on it because it's too heavy'". Ruth felt that she witnessed parents sometimes rushing this process and that was at odds with what she and her group-mates propose that they were trying to get kids to do.

The third parent influence she described, and likely most impactful to Ruth, was the influence that a parent's mere presence had for her on her self-confidence in the content matter that was being touched on with the balloon rockets. When reviewing the video during the stimulated recall interview, Ruth described a parent who was really giving a lot of input to his child at the activity, but Ruth was also working with this child. She recalled thinking to herself, "What does the parent want me to say? What is he expecting right now? Like is he expecting me to like give a little short engineering lesson?" Ruth justified this concern, or lack of confidence in this situation, by referring to her own limited science background:

> *"It's not like I have an extensive science background, so I don't want to say anything wrong. So it is just kind of being self-conscious of the way you are interacting with someone's kid, what you are saying to them, how you are guiding them, just hoping you don't say anything wrong, or something incorrect."*

It seems that Ruth is fearful of how parents might judge her content expertise, and this fear is may be connected to the minimal science background that she reports. Embedded in her statement is the idea that if she were knowledgeable in this content domain, then she might

not be so concerned that she would say something incorrect, or "wrong" in the eyes of the parent. This excerpt from our interview emphasizes the way in which parents had an influence on Ruth at the Maker Faire:

> *It's low stakes when you are just with the kid and they are constructing their own learning, because you can ask them stuff to prompt learning. And you know, sometimes it's like parents want you to have the answers, whereas kids are kind of okay with where you are going. So say a kid asks me a really difficult question and I didn't know it, I would be like, 'well, let's find out' or 'I don't know, what do you think?'. But if a parent was there I would feel weird, like, 'Oh no… I don't know what you are talking about' and what if a parent knows [the answer] and he is just waiting to hear my response…It just comes down to being a teacher. I do want parents to approve of me teaching their kid, and you don't want them to think that you don't know what you are doing."*

While this statement echoes logic found in the previous statement, it also suggests that an alternative way to solve the problem of not being an expert in a certain content area is to ensure that parents are not ever a part of the learning environment in the first place. The reality is that both of these ideas would be hard, if not impossible to enact. Neither is it reasonable to expect that a teacher becomes an expert in every content area they are responsible for teaching, nor is it reasonable to expect that parents could be kept at bay and never allowed to be a part of these learning environments. What does come through in Ruth's statement is that for her, parent presence in a learning environment can work to undermine the confidence she might otherwise have to co-explore the unknown with children.

**Sally**

Sally's educational background is in developmental psychology, and she explains that at the university she attended in Canada, she was able to design her own degree to an extent. During her time at university in Canada, she worked for three years at a science center as a facilitator to visitors. When describing her relationship to science, Sally described feeling, "very comfortable asking questions" and that she is "good at building interest". She attributes these qualities to her time working as a science facilitator where it was her job to "ask questions, get kids to talk more, and get kids to discuss their thinking".

***Pre-Maker Faire Preparation***

Although Sally was not present the day of the Mock Maker Faire, she shared the same sentiment as her group mates in that she did not feel prepared for the Maker Faire event. In our interview, she was quick to say, "I'm going to be super honest. We all went in with super low expectations. Who is going to show up to this thing? We didn't even know what we were doing". Largely, Sally attributes this lack of being prepared to the fact that she had, "never done a maker faire before, so [she] didn't know what to expect".

Despite not being there for the Mock Maker Faire, she had worked with her group enough to identify that there were some problems to iron out with the balloon powered cars. She told of how prior to the Mock Maker Faire "we tried doing bottle caps. We had to drill holes in bottle caps, which we didn't have the ability to do. We tried CDs, but we didn't have axles wide enough to fit through the CDs. It was too much work." Sally felt that once her group decided to change to the balloon rockets, "they had all the supplies they needed" but that still did not change the fact that even once the Maker Faire began,

she did not feel prepared. She recalled asking herself questions like, "What do we set up? What do we do?"

***Factors that Influence Interaction***

Sally used questions to guide interaction in a number of instances. During the stimulated recall interview, she described a moment where she sees herself going back over to the table to work with a boy who has just flown his rocket. In trying to get him to think about aspects of what makes a rocket fly better, she asked him,

> *Sally: Do you think the size of the balloon matters? What do you think, bigger rockets go further, smaller rockets go further?*
>
> *Child: Probably smaller rockets.*
>
> *Sally: Smaller? Ok, what do you think are the most important things about a rocket?*
>
> *Child: Tape, maybe?*
>
> *Sally: Tape, how well it's put together? What about weight?*
>
> *Child: Yeah, lightness…*
>
> *Sally: Do you think the size of the balloon matters?*
>
> *Child: uhh…*

Sally recalled that in the moment the logic behind these questions was to, "get him to think, 'What can I change to make this better, to get this closer to my goal the next time?' I want him to maybe…the creation he makes next maybe he has more intention."

It is worth unpacking the actual questions she asks the child, and the logic that she claims to have been using in asking those questions. Starting with the logic, she makes a case that "she wanted to guide him towards building with more intention". For Sally, building with intention is synonymous with building with more direction, as opposed to just experimenting without a specific goal.

Coming back to the actual questions that she asked the boy at the Maker Faire, it feels more like she was trying to use questions to actually lead him into realizing that a larger balloon (more air volume) would make the rocket go further, but also the weight of the overall rocket matters- the lighter the better. What she got in return, are a series of responses that are arguably not the ones she was looking for, and are perhaps the very reason that her line of questioning takes a rather circular route. In response to "size of the balloon" question, the boy says smaller rockets would be better. Sally does not probe his logic behind his answer, and I would assume that is because she was imagining he would say bigger balloons go further (i.e., because they have more air volume and therefore more propulsion potential). The reality is that he may have been confused because she first asks about balloon size, and then rocket size. Nonetheless, Sally appeared unsatisfied with this response, so then it seems she tried to get him to think about his rocket in a different way, by asking him what the most important things are in a rocket. The boy responds that "tape" is the most important part of a rocket. Again, this is likely not the response she was expecting and reworks his tape response and frames it by saying, "Tape? So you maybe think structure is important?". When Sally asked him if weight is important, he responded that "lightness" is important. Sally apparently agreed with this and circled back to her original question regarding whether or not the size of the balloon matters for how far it goes.

In breaking down Sally's line of questioning, it is important to be careful here and not paint either her or the student in a poor light. The reality is that the two of them were likely making sense of this situation, on their own terms, but they may have been talking about slightly different things. Sally seemed to want to get the boy to consider that a) the

size of the balloon will influence how far it travels and b) the lighter the balloon, the easier it will travel along the string. The boy may have been talking about both real rockets, and balloon rockets. Specifically, *real rockets* might benefit from being smaller and lighter and therefore go further (maybe a big rocket is hard to imagine flying well or would not be aerodynamic), whereas *balloon rockets* really depended on tape to hold them together well; to be fair, it is hard to tell when the discussion is about real rockets, or balloon rockets that are representations of real rockets. Sally's questions seem to narrow his scope of thinking as the questions push his thinking towards trying to consider his design in terms of weight and volume of air in the balloon– terms that Sally seems to have defined.

At another point in the stimulated recall interview, Sally noticed a child come to the table that she remembered interacting with. Again, she used questions as a way to guide interaction. As the boy approached the table, she began to tell him that at their table he can make balloon rockets, and then asked him, "Do you know anything about rockets?" When the boy replied that he does not, she engages him in the following dialogue:

*Sally: What do you think is going to make these rockets go?*
*Child: Uh, well the helium is pushing it.*
*Sally: Well, we don't have any helium, so what are we going to use to fill our balloons (gestures to materials available at the table)?*
*Child: Air, right?*
*Sally: Yeah, air!*

Sally mentioned that at this point in the video she was thinking, "Okay, so let's have a conversation, what are the basics? What should we be looking at here?" In the video footage Sally went on to ask him what some of the things are that he, "might need to think about- maybe weight, structure?" Of these two variables that she put out for consideration, he says that structure would be important. As Sally hears that structure is important, she

starts to go down the list of items he might want to consider for the body of his rocket, "Okay, first thing, what is the body of the rocket going to be? We got short tubes, we got long tubes. We also have these papers, you can make wings if you want [child points at short tubes]…you want short tubes- go wild!" Sally said that in listing the materials for him like this, she was trying to connect his idea about structure being important to the materials that he might want to consider starting with.

At this point in their conversation in the video, the field seemed to be narrowing in terms of what materials this child might consider using as a body for his rocket. Essentially, the body of his rocket was likely be limited to a short tube (toilet paper tube), a long tube (paper towel tube), or paper, based on his initial interaction with Sally. It is important to note that at the table there are a variety of other materials including CD's, string, tape, and water bottles. What is interesting is that Sally's recollection of what she was thinking at the time does not feel congruent with the ways that she is seen and heard engaging the child in the video footage. She recalls doing things like trying to connect the activity to his thinking, and trying to find a way to engage him in a conversation about rockets. However, their actual dialogue paints a picture where rather than conversing and connecting, she is funneling his thinking towards a vision of a rocket that she might already hold in her mind. The question here is whether the stimulated recall account was inaccurate, or whether her recall of her intentions are simply not manifested in what she recounts.

***The Role of Assessment***

As mentioned in the previous section, Sally attempted to get students to think, design, and work with more intention on the rockets they were designing. For Sally, this

idea of intention was not only a way to guide experience, but she explained that when she saw intentionality happening, "That shows that there is thinking going on. There is improvement and learning going on." To Sally seeing intention in action meant that the child must be thinking about "building in a certain way to have a certain effect." This more focused version of exploration, as opposed to a more free and open version, was a queue to her that a child was engaged in the design thinking process- a hoped for outcome of this Maker Faire.

The design thinking process begins with identifying a problem to be solved, and then moves towards experimentation in order to begin finding solutions for the problem. When Sally saw intentionality, she interpreted that as evidence of working towards solving a specific problem. For example, when she saw that a student was trying to solve for, "lightness and strength, he can actually build towards making that his rocket"; in other words if a kid is trying to solve something, then there must be an identified problem nearby that it relates to.

***The Role of Parents***

Like her group-mates, Sally mentioned parents having a role in her experience of the Maker Faire. Where Amber described a mostly negative experience, and Mary a mostly positive experience, Sally's experience with parents is somewhere in the middle. Sally articulates that she could categorize parents in to three categories: *inactive parents, participatory parents, and watching parents.*

"*Inactive parents"* were described as those who took a very hands off approach, or perhaps did not even accompany their child to the activity at all. She described this type of parent as being unproblematic to how she interacted with kids because, "if they were kind

of like off to the side, or not involved, it was like ok I'll handle this." In other words, without the parent being directly in that space, she felt free to do the things that she knew how to do. In watching the Maker Faire video there is a section where she is working with a student who is in her kindergarten placement class; while the parents start at the table in the beginning she remembers that, "At one point I turn around and they are just gone. They didn't tell me they were leaving so I was just like, oh." Sally explained that for her the fact that they had left was fine, because she felt confident in being able to work with him.

Sally described "*participatory parents"* as those who took an active role in the exploration process alongside their child. Sally mentions, "I just always feel appreciative when parents got in and asked some questions. Not necessarily did it for them or helped them, but just showed that they were trying to keep their interest or were trying to get them thinking." In this way, she found them helpful when they could ask questions that got them engaged in the balloon rockets but were not overbearing.

"*Watching parents"* were those who were definitely in the scene and a part of what was going on, but they did not interact or say much of anything. Sally said that this type of parent made her nervous because sometimes she might even ask them a question and, "only get minimal or monosyllabic responses" back from them. She recalled one moment, when looking back at the video, where she was working with a very young girl (she said that she was 4) and she remembered, "I just felt a little uncomfortable having them just stand here and watch us have these interactions. Like, 'Do you want to be part of this?'– nope, all right. I guess I was just feeling like I was being watched as opposed to having them all be part of the same experience." There was actually a moment where she had just helped a boy launch his rocket that used two balloons for propulsion and, "it didn't have a

very good result and [she] felt bad." When I asked why, she recalled that the parents were just watching the whole time and she, "felt a little bit like [she] was being judged."

## Cross-Case Analysis

In this section, the same four themes used for the individual cases are revisited but now explored in terms of the patterns and variance that existed across the four cases for each individual theme. The purpose of this cross-case analysis is to illuminate patterns and new insights that emerge from comparing the cases; new patterns and insights will be explored more in the discussion chapter (Miles & Huberman, 1994).

### Pre-Maker Faire Preparation

#### *Feeling prepared*

All of the group members expressed a desire to feel prepared for the Maker Faire. However, this desire to feel prepared manifested itself in varied ways among the group members. One point of agreement across the group members had to do with the switch from the balloon powered cars to the balloon rockets during the Mock Maker Faire. In this regard, each group member expressed this change leading to a disruption of how well they felt prepared for the Maker Faire.

Among the four group members, Mary expressed having the easiest time managing this shift in their plan, though she admited that she, "did not feel super prepared". However in moving forward she felt confident because she and her colleagues were applying "the engineering design process" themselves as they explored how to make their new plan work. Furthermore, she felt comfortable not having a working model of a balloon rocket for participants to reference. For Mary, not having a "structured idea of what was going to happen" did not seem particularly problematic.

If Mary was the most comfortable with this shift in their plan and the corresponding need to prepare for a new approach, Amber was at the other end of the spectrum. Amber reflected that the, "idea of parents and kids coming to a science event with no plan was terrifying." For Amber, the level of preparation that they achieved as a group prior to the Maker Faire did not resonate with her own version of preparation; one in which she would, "want to have a solution for every problem that might come up". Additionally Amber's version of preparation included having a model balloon rocket so that students have , "something to go from."

Sally and Ruth fell somewhere between Mary and Amber in their accounts of how prepared they felt. Sally had, "super low expectations about the event" because they, "did not know what they were doing." Despite these low expectations, she did not associate them with a feeling of terror or anxiety but instead a more ambivalent feeling towards the event in that, "they had all the supplies they needed" to build rockets so it was more about waiting to see what would unfold on the day of the Maker Faire. Similarly Ruth recounted not feeling prepared, and not sure of, "what materials the kids would want and how they would use them to make a rocket." However, once Ruth and her group-mates began experimenting themselves during the Mock Maker Faire, "it just kind of made sense" that the kids would enjoy exploring in the manner they had.

While the group members experienced the same Mock Maker Faire preparation experience, and the same shift in plans, they responded to this change in very different ways. Variables such as personality type, comfort with the content, and confidence with the design thinking process may account for this range in response. These ideas, as well as

how being prepared may have a relationship to other codes will be revisited in the discussion section.

## Factors that Influence Interaction

### *Emotions influencing interaction*

Among the Balloon Rocket group members, there were a number of points where their emotions seemed to have a relationship to interactions they engaged in. While emotions are arguably a natural part of the human experience, the prevalence of expressed emotions in regard to the Maker Faire seemed to be something significant to each of the group members. Where a pre-service teacher described an emotion they felt, they could also often describe something they did to either mitigate a negative emotion or accommodate a positive emotion.

Amber expressed a range of emotions in her account of her experience with the School Maker Faire. She explicitly expressed being *terrified, nervous, worried, curious*, and *surprised*. Amber recounted that, "Before that evening, the day of, I was still very nervous. I was like, 'Okay, we have a table of stuff and we're just going to tell them to make a rocket and that's it?' No one had a plan." Paired with her expressed emotion of feeling nervous about not knowing how kids should know what to do when they join the activity table, Amber carried out actions during the Maker Faire that arguably worked to mitigate this emotion. Specifically, she worked toward devising a series of steps for students to follow in order for them to have the structure that she was nervous that they would be lacking:

> *"It's like step one, okay, they did that. They chose a balloon, that was step two, and step three was how to attach the two, and step four was choose the string. They*

*were given those concrete things to do. I was shocked at the direction that kids were able to take it in without having any visual to refer to. I'm still a little surprised by that, but it's memorable."*

In the end, she explains that with these steps her emotions even shifted from nervousness to being surprised by how well these kids could start building balloon rockets without having a model to go off of (not having a model being a cause of worry for Amber).

Mary expressed *nervousness, curiosity, enjoyment*, and *excitement* as her range of emotional experiences with the event. In the stimulated recall, she was watching video of herself watching a child at work on a balloon rocket during the Maker Faire, and she recalled thinking in that moment, "I was curious to see what she would do, it was not about what I would do, [our group] already played with it". Mary's feeling of curiosity translated in to action as she passively observed a child's exploration in order to see what unfolds.

*Excitement* and *curiosity* were hallmarks of Ruth's emotional experience with the Maker Faire. Ruth describes a moment of excitement where, "It was just super cool, because you know they're super creative! They're like 'Can I do two balloons?' and I haven't even thought of that, but sure why not?! 'Go for it!', and they made it work and it was just really cool." In this moment that Ruth describes, she paints a scene where her excitement for a student's discovery (using two balloons) leads to action where she fosters a space that encourages the exploration of this idea.

Among the group members, Sally mentioned very little of emotion being an important part of her experience during the Maker Faire. However, at one point she described a feeling of *discomfort* in feeling like she, "was being judged a little bit by the parents" when she was working with their child on the rocket he was building. While she

recalled the feeling, there is not a specific action that she points to being connected to that feeling, though she did remember in her head feeling sorry towards the parents that she did not succeed in helping their child create a "successful" balloon rocket; that is to say it did not fly along the string well. While this thought in her head is not an explicit action, the thought of being sorry that it did not fly is a bit antithetical to the spirit of design thinking and the maker mindset which would celebrate failure as an opportunity to learn and go back to the drawing board on a design.

Table 7 gives a sample of the range of emotions expressed across the group, as well as evidence of potential actions that may have been associated with these emotions.

*Table 7:* Example group member emotions paired with corresponding action

| Group Member | Emotion | Paired action |
|---|---|---|
| Amber | **Nervous** about not having a model | Developed a series of steps to guide students through in building their rockets |
| Mary | **Curious** about the ideas kids would come up with | Observed children to see what ideas they would come up with |
| Ruth | **Excitement** at a child's discovery | Supporting the exploration of the double balloon idea |
| Sally | **Discomfort** with parents watching as she works with their child | Being sorry that she did not get good results on the rocket that she built with their child. |

### *Use of questions to guide interaction*

Alongside the role that emotion appears to have played in influencing actions and interactions, each of the pre-service teachers' in the Balloon Rockets group used various styles of questions to guide interaction.

***Questions as structure.*** Often times during the stimulated recall interviews, the pre-service teachers explained the logic behind certain lines of questioning that they employed during the Maker Faire. One pattern underlying a number of the lines of

questioning was that some questions worked to provide structure for student thinking and action.

During the stimulated recall interview, Sally pointed out a moment in the video where she was working with a boy on his rocket, and she was "trying to get him to think about the different aspects of aerodynamics." In trying to get him to think about this concept, she asked him, "What do you think is the most important: weight? Do you think it could be heavier or lighter?" Her questions appear to be aimed at getting the child to consider different design elements that might influence flight. Sally reinforced this claim by explaining how she "honed" her questions over time in order to allow herself to, "think of the intention of my questions to allow [the students] to have more intention. I would use specific words, like 'weight' and 'structure' to try to get them thinking about what it was they were focusing on." In this way, her questions worked as a way to guide thinking towards specific variables that *she identified* as being important for flight; variables that when intentionally modified might lead to insights for a child about what effects flight aerodynamics.

"Honing" as Sally described it seemed to have an inverse relation to divergent experience (for children) as more time passes. In other words, at the beginning of the Maker Faire activity Sally had likely not created an informal repertoire of "honed questions". Therefore it could be said that students who came to the table at the beginning of the Maker Faire, may have had more opportunity to experiment in a more exploratory way, as she had not yet honed a list of questions to frame their experience. However, as time went on and questions were honed, students who came to the table later may have been more likely to have been subjected to a repertoire of honed questions, and therefore

would have potentially experienced a more limited version of exploration as their experience would have been more bound by these honed questions[8]. Amber's set of steps that she developed over the course of the Maker Faire worked in a similar fashion; children may have had more freedom of exploration earlier in the Maker Faire as Amber had not yet flushed out these steps that operate as frameworks for action.

At another point in the Maker Faire video Ruth is working with a boy who has just started designing a balloon rocket and the very first thing he does is blow up a balloon, which led Ruth to have the following transaction with the child:

*Ruth: "Do you think you should blow up the balloon first, or wait until you have a design?";*

*Boy: "Wait until I have a design?"*

*Ruth: "Yeah, probably wait, huh?"*

When asked why she asked the boy this question, Ruth explained that, "after blowing up many, many balloons it's like, 'Yeah, you should probably blow it up after you come up with your rocket.'" In other words, she asked him this question as a way to structure how he should approach the activity as a whole: first come up with a design concept, and then begin construction. Incidentally, this is knowledge that she herself gleaned from experiencing a number of balloon rocket constructions during the course of the Maker Faire; something worth pointing out as this is a conclusion a child might arrive at were they to spend enough time iterating designs themselves. Again, similar to Amber and Sally, Ruth's questions seemed to become more leading over time as she gained more

[8] This hypotheses would benefit from a careful and detailed analysis of the nature of dialogue between the pre-service teachers and students, over the course of the Maker Faire. Applying such an analysis was beyond the scope of this project. Potential implications of this claim are approached in the discussion section, though again, these implications are merely conjecture at this point as they would demand careful and detailed analysis in order to have any sort of validity.

experience with the activity– suggesting that as time passed in this environment, the pressure on kids to work towards certain teacher-identified outcomes may have increased.

During our follow-up interview, I asked Ruth why she used such a leading-style question, instead of simply telling the child to make a design first and then blow up the balloon once they have a concept. She explained that, "I think it's just the teacher in you. I don't give kids the answers. Just spark their thinking." Later in our interview, Ruth revealed that a lot of her leading-style questions were informed by knowing what would happen when kids went down certain paths. Such a leading question as the one above represented to her the contradiction between the idea that, "you want them to be successful so if you're thinking that the answer's going to make them successful you just kind of want to give it to them," whereas on the other hand she, "was trying to be conscious of not letting the fact that I already knew or had an idea of what I wanted the students to do, steer them one way or another. Just let them kind of figure it out on their own, which is really hard to do." When these two ways of thinking are at either end of a balance that a teacher is trying to strike, this does seem hard to do. However, when Ruth illustrates that these are the things she is trying to balance, it makes sense that a leading question is one way to solve this predicament. Ruth may be operating under an assumption that such a leading question gives the child a feeling that they are making a choice of their own (should I blow up the balloon *before* or *after*?), while at the same time she is guiding the experience to allow for a set of choices that will hopefully lead to success in the experience.

Similar to Ruth, Mary also found herself using questions to guide a child's experience while at the same time trying to maintain a space where the child felt that they were the one's driving the experiences-- however she used a very different style of

questioning from the leading-style questions that Ruth refers to. Recalling to Mary's individual case analysis, she had the following transaction with a student:

*Student: "[My rocket] didn't work."*
*Mary: "It didn't work?"*
*Student: "I can't fix it."*
*Mary: "You can't fix it?"*
*Student: "Well, I need to tape it."*
*Mary: "Okay, so you just need to tape it."*

While it was pointed out that Mary was trying to gauge his emotional state with this line of "echo-questioning", she explained in the interview that there was a second layer to what might have been motivating her echo-style questions; specifically she, "wanted to support what he was saying and let him know that he was heard but didn't want to tell him what to do next. [She] wanted him to just try something else." Mary also explained that during the flight of his rocket, when it did not work, she had noticed that, "he taped one side of the balloon on, so then when the balloon was let go, it just flipped off of the tube and that's what made it spin". Although the style of question is very different from Ruth's, Mary's goal in her questioning is similar: allow the child to feel that they were figuring something out on their own, while at the same time not revealing the fact that she knew the reason that his balloon was not working- it just needed to be re-taped.

***Questions as assessment.*** The pre-service teachers in the Balloon Rockets group also used questions as a way to assess students' prior knowledge and understanding; the answers to these questions ultimately guided next steps in the ways that the pre-service teachers interacted with children at the Maker Faire. Many of these assessment-style questions came in the form of *direct questions* asked to students. Interestingly, there were also a number of assessment-style questions that some group members reported during the

stimulated recall interview as being *internal questions* that they only asked themselves during the Maker Faire; it seemed that these internal questions worked to frame how they observed the environment for pertinent information. This is important to point out as it illustrates the two different versions of assessment present in this experience. The first version is aimed at assessing what students know, or what they can do. The second version is about assessing the scene– *what is happening here and how might that influence a teacher's next steps?*

Recall that in the stimulated recall interview, Sally pointed out an interaction she remembered with a 4th grade boy who came over to the Balloon Rockets table. In the Maker Faire video she asked him, "Do you know anything about rockets?" For Sally, this question was a way for her to assess what type of knowledge he was bringing to this activity so that she could start talking to him about the, "basics we should be looking for here". Recall that Sally mentioned having honed a set of questions to ask students as they participated in the activity; this particular boy came towards the end of the Maker Faire, after her questions had been relatively well honed. Her assessment-style question about his level of rocket knowledge was likely motivated by her trying to find which honed questions she should start with in order to get him building his own rocket. When the boy responds at one point that "structure is important", it informed her to start asking questions like, "Okay, yeah, what do you think is important about structure?". Sally then guided the conversation towards familiar topics such as the relationship of structure and weight.

Both Mary and Ruth asked students very simple assessment style questions about the intention behind certain decisions that students were making with their balloon rockets. When Ruth was working with a girl who was mounting her rocket balloon on the string,

Ruth asked, “do you want it facing this way or do you want it facing that way. Do you think it matters?” Ruth explained that she, “wanted to see like just a little quick assessment like, do the kids understand how their rockets are working, do they get that the reason the rocket is moving that way is because the air is blowing the opposite, out of the opposite end?” Similarly, Mary talked about a couple of moments where kids would hand the pre-service teacher their balloon to put on the string and she would say, “Oh, so it goes on this way?”. For Mary, seeing a child’s reaction to such a question was a way for her to also gauge basic understandings they might have about the direction a balloon rocket needed to face in order to propel itself.

Amber and Mary reported during the stimulated recall interview that some of their assessment-style questions happened internally- that is, in their own heads, to themselves. For Amber, she asked herself questions such as, “Where are the materials we need? Where are the kids at?”. Such questions were rooted in her identified need to feel prepared, but they also worked to assess the current state of things and inform next steps she took during the Maker Faire itself. The answers to these assessment-style questions depended largely on observational skills, and led to Amber taking actions that looked like, “constantly circling the table and assessing the situation to see where I was needed”. In reviewing the Maker Faire video one sees Amber procuring and organizing materials, and stepping back from the activity in what looks like her assessing which children were engaged with a teacher or in making a rocket, and which children might need her help. For example, at another point in the Maker Faire video Amber is seen watching one child work by themselves, and she recalls during the Maker Faire wondering, "Should I intervene at all?",

and she goes on to explain that her internal assessment revealed that, “it looks like he's pretty solid making his rockets so I don't want to distract.”

Similarly, Mary reported asking herself questions like, “Do I need to take off for a minute?”, which helped her to assess if there were too many teachers working with one child and if that might be uncomfortable for the child. Like Amber, the answer to such a question resulted in actions like taking a step back and observing the situation. Towards the end of the interview with Mary, she even took a moment to reflect on the pulled-back nature of her and Ambers’ interactions during the Maker Faire, where Mary explains that she just likes, “watching what was happening, and yeah, seeing what kids were doing.” This statement emphasizes the role of these internal assessment-style questions and how they may work to shape a more passive version of interaction in the physical space.

***A vision of success guiding interaction***

Recall that Mary described having trusted that the Balloon Rockets activity, “would work because it was the engineering design process to go through”-- a process that is iterative and that takes advantage of failure as an opportunity to improve. However, in moments where a child’s rocket did not go as planned Mary admited that she, “was a little nervous that some kids would be upset if it didn’t work”. Despite this apprehension, Mary seemed to be the most able among her group members to guide interaction in a way that embraced failure as success, and that kept the experience positive for children. As described in the previous section, Mary asked questions that seemed to work to push children to think about what led to a design not working, or that inspired them to go back and try and improve a design that worked. In the interview she shared insights behind her logic and explained that to her, “this activity wasn’t about success, it was about when it

didn't work. That's what we were looking for. Even when it worked, it was about, 'Well how do we make it better?'…That was a success. [In other words,] 'We are not satisfied with this.'"

Amber was also, "nervous to not be able to catch kids in a way if they hit a wall or got frustrated"; like Mary, she had a vision of success that included kids having a positive experience. However they differed by the fact that Amber mitigated this feeling of nervousness much differently, and she did not share the same belief as Mary that failure could also be a form of success in this environment. Remember that Amber was the group member who wanted to have a plan for every problem that might arise. This becomes evident when she talks about students experiencing failure in this activity, where she explains, "I want to be able to show [students] how to do that. I'm thinking if we don't know how to do that, are we setting people up for a bad experience or failure? I don't know." Amber expressed that she felt she could soften the blow of failure by telling kids what to do in order to get a balloon rocket that could propel itself. This is backed up by the fact that she described a series of steps that she developed to help walk kids through how to make a balloon rocket. In reviewing the Maker Faire video, Amber pointed out a scene where two brothers are each working on their own design; it is interesting to note which brother she describes as successful:

> *His brother was getting really complicated with lots of straws for the body which needed lots of tape to hold it together. It was so heavy on the string. The one in the orange is the younger one. He had success pretty quickly. Yeah, there it is. He had that simple design with just the tube and the balloon.*

Not surprisingly, she described the successful balloon as the one that coincides with her vision of "what works". Recall her simplified series of steps that she developed for

making a rocket: “Choose your body first. Choose your balloon color and how you want to tape it onto the body, and then choose a string.” If a student follows these steps, they should end up with exactly the type of balloon that the “successful” brother ended up with: a straw taped to a balloon. By making and design thinking standards, it is arguable that the boy with the more complicated design was experiencing more success as he was taking risks and “complexifying” his design-- something that designers and makers seek to do in order to push concepts and thinking to new places.

Ruth grappled with her version of success which on the one hand meant, “that the answer is going to make them successful so you just kind of want to give it to them”; whereas on the other hand, she was pushing herself towards a view of success as getting, “the students to manufacture their own thinking and learn through exploration”. In the moments of the Maker Faire where Ruth’s interaction was guided by providing the answers so they could be successful, she utilized leading questions to this end-- and she pointed this out herself when reviewing the video. However, in the moments where she empowered the students to “manufacture their own thinking”, she really became a co-explorer with them. For example, Ruth described a moment during the Maker Faire when two children decided to experiment with a rocket that used two balloons:

> *A couple of the kids decided to put two balloons together. That was really cool because it was so original. It could be as simple as just taping a straw onto a balloon, but then if they wanted to put two balloons together they had to figure out the balance, and how to make it. Some of them just spun around in circles, and the kids really started talking to themselves, like "Oh it needs to be even, it's not going to work. I need to bridge these two balloons together." It was just super cool, because you know they're super creative. They're like "Can I do two balloons?" I*

*haven't even thought of that but sure why not? Go for it, and they made it work and it was just really cool.*

When watching this scene play out in the Maker Faire video, Ruth was visibly excited by this new direction that the two children took. As the boy is showing her how he intends to connect the two balloons in a way that they could still be mounted on the string, she was heard saying, "You want to try that?! That looks like it's really cool! Wow!" During the stimulated recall interview, she recalled thinking in this moment:

*Okay well I don't want to tell him how to use two balloons, let's see what he thinks up. I was like, "Do you want to tape both of them together?" Then he was kind of like "No.", like sticking with the straw design and with the straw. I just thought it was really interesting. I kind of just wanted to ask him questions, and see where he was going, and what he was thinking, and encourage him to just try and do anything. That was really exciting.*

It appears that in this moment, Ruth was really trying to create a space where success is when children explore their own ideas, even though it seems that in the moment she could not completely visualize where it is they were going with the concept; she seemed to be experimenting herself with the idea that she may not always need to know the outcome of what students are doing in order for good learning to happen.

Like Mary, Ruth seemed to want to push herself during the Maker Faire in ways that upheld a version of success that was defined by experimenting and using failure as an opportunity to improve an idea. In articulating how moving to this version of success was challenging for her, she talked about how,

*"The schooling that we grew up with is more geared toward just finding the answer… Whereas now, with this past year of school and everything [referring to the Teacher Education Program], it's no. The point isn't the answer. It's the exploration. It's the inquiry that the kids are doing. It's the fact that they're sitting*

> *there thinking, "Will this balloon make this rocket move?" Not, "Yes. I made it move."*

She went on to back this up by explaining that for her, success had been redefined as the students,

> *trying and trying over and over again. Some of them didn't make [the rockets] move and couldn't figure it out at first, but they would go back to the drawing board and come up with something else and maybe take something off. Add something else. That is what we're going for.*

What Ruth described is a very iterative process, and one that very much reflects a design thinking approach to learning and exploring.

**Assessment**

In terms of assessment, it seemed to be present in two different forms. The first form of assessment is what most would conventionally be associated with teaching: *an assessment of what students know, what they can do, or what they learned.* This first form of assessment informed actions such as asking students questions to see what they knew already or if they understood what might be have been taking place with their balloon rocket. The second form of assessment can be described as an assessment of the scene, or *what was happening*. This second form of assessment often informed choices the pre-service teacher made and actions they took in the environment: *"Should I reorganize the supplies at the table?", "Are there already too many students working with that child?"*

In terms of the first form of assessment, going into the Maker Faire a requirement of the Science Methods course was that all pre-service teachers needed to be engaged in somehow assessing the learning that was taking place at the Maker Faire. Largely, the assessment was informed by a relevant NGSS standard that was attached to their particular

activity. In the case of the Balloon Rockets group, their assessment was guided by the following NGSS standards:

- K-2-ETS1-3: Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.
- DCI: ETS1.C Optimizing the Design Solution

Translated to the Balloon Rockets activity itself, it would be expected that children would be iteratively testing their rockets in order to compare different design features and observing how those features affect either the speed or distance of travel of the rocket.

While the Maker Faire itself was not so conducive to directly instructing children on the design thinking process (due to the transient nature of participants), the group members found numerous ways to try to bring in and model this style of thinking with the students they worked with. Ruth encouraged exploring new ideas and also modeled the design process herself as she experimented with putting wings on a design of her own. Mary's fabricated curiosity was meant to spark thinking to look deeper at the range of what might be causing certain effects on a design. Sally pushed children to be specific about the changes that they were making to their balloon rocket so that they could be confident about which variable led to different outcomes. And Amber focused on providing space for students to feel safe to explore their ideas. These attempts to leverage their interactions with children as a means to expose them to the design thinking process, also then worked to create an environment where they could assess the extent to which children were picking up these queues that the group members were putting out into the environment. For example, Sally expressed using questions to try to get kids to think concretely about the different variables that might be affecting the flight of their rocket balloon. In turn her

accounts of assessment point towards looking for evidence of intentionality in the children's actions and designs.

In terms of the second form of assessment, as mentioned previously Amber's versions of assessment relied heavily on tending to the environment and observing the ways that students were interacting with the materials and the space. Amber mentions moving around the area to assess what was needed, and in the stimulated recall interview she points to a child that she remembers assessing as being, "pretty solid making his rockets so I don't want to distract." While she did not describe what it is specifically that she sees as evidence of the child being "pretty solid making his rockets", this comment does point to some form of assessment that she felt she could carry out from an observational role. Amber attributed part of her tendency towards observation in this environment (rather than direct interaction) to feeling, "so disconnected from science. It's not my area at all." In elaborating, Amber explained that she was, "so much more comfortable with writing, and reading, and language that I feel like I would be able to come up with things on the spot to spark discussions", if the environment were focused on these areas of knowledge instead. But perhaps because she described herself as being disconnected from science as a knowledge domain, she was nervous to put herself into situations that might reveal that lack of knowledge. If this were the case, taking a more observational assessment role during the Maker Faire would seem to make sense (in particular one that focused on assessing logistical concerns).

Interestingly, Mary was also observed in the Maker Faire video as a group member who appeared to take a more observational stance as opposed to a more direct, interactional approach (when compared to Ruth and Sally). However Mary described

herself as feeling confident in science and with the design thinking process itself. This points to the idea that though Mary is observed as participating in similar behaviors as Amber, Mary may have been assessing very different things than Amber. In a follow up interview with Mary, she seemed distinctly aware of the NGSS standard that was informing how and what they should have been assessing during the Maker Faire:

> *Our standard was to compare two different designs of an object that was meant to do the same thing. A lot of our questions were focused on, "Do they know why it's working?", like, "What makes it go?". Then, can they compare two different models or designs to see which one works better?*

Armed with this particular frame for assessment Mary was looking for a range of evidence during the Maker Faire:

> *Anything from, oh it goes faster, turns out it goes faster on the plastic string than the other string, if we compare those. I wasn't as concerned with them knowing like friction, but just for the aged kids we are getting especially just noticing, "Well there is a difference there- when I put wings on it, it flew sideways, but when I took them off, it flew straight."*

Mary was specifically looking for those moments when kids experimented with changing their design or when they perhaps paused to try and figure out what caused a certain outcome. This type of assessment also corresponds well with her "fabricated curiosity", which for Mary worked to get kids to look harder at points that she thought might be interesting or that might reveal why something worked (or didn't work) a certain way. While from the outside Amber and Mary display similar observable behaviors (stepping back, moving around the space, observing), it appears that internally they were looking at the scene quite differently and therefore looking for different types of information that could inform their assessments.

Ruth's version of assessment in this environment was a mix of many of those mentioned above. Ruth actively modeled the design thinking process, as well as utilized lines of questioning to get children to engage in thinking about how to iterate and improve their design. At one point in the Maker Faire video, Ruth was seen constructing her own balloon rocket. This was an endeavor that she described as first being motivated by trying to inspire children at the table to be more experimental with their designs and so she, "was wondering if the kids would put wings on it" if they saw her doing it-- because, "kids are like, when they see something then they want to try it." In line with her modeling this type of exploration, she then turned to assessing whether there was subsequent evidence that illustrated any of the kids adopting the behavior and process that she modeled. During the stimulated recall video, Ruth guided me to a point in the Maker Fair where she and Sally were sitting together and excitedly watching a boy across the table who was begin to fashion wings to attach to his balloon. Ruth is heard saying to Sally, "What's he doing there? Looks like he's cutting some wings!". Ruth explains that aside from this being evidence that the boy has picked up the idea that she modeled, there was more to assess than that. For example, "he was very confident in what he wanted to do… He was measuring. He was making sure his two wings were the same size." This goes back to the idea of intentionality being something that the group members were looking for in this environment as that seemed to be a strong signal that there was a concrete vision that was being aimed towards.

What seems evident is that each of the Balloon Rockets group members engaged in assessment of some sort during the Maker Faire. The different forms of assessment

seemed to have a relationship to the ways in which each group member attempted to model or communicate what it means to participate in design thinking.

**Parents**

A common theme that emerged from the data was the role that parents played in influencing this Maker Faire environment. The group members had mixed feelings on parents, ranging from describing them as problematic, to feeling appreciative of their presence.

Amber seemed the most negatively impacted by the presence of parents. She was the only one who mentions taking parents into consideration prior to the event itself: "To walk into a situation with parents and kids coming to put on a science event with no plan was terrifying to me. We had barely spent an hour figuring this out ourselves." Amber partially attributed her "terror" to the fact that she did not, "consider [her]self a science person." She adds that, "Knowing that day that I wouldn't really know what to do if something went wrong, it was very unsettling to me especially with parents being there." One example of how her negative perception of parents may have influenced her interactions goes back to the more observational role that Amber took in the Maker Faire itself. Her concern about how she might be perceived in the eyes of parents may have also had an influence on her decision to take a more backseat role for a large part of the time. To Amber, "it matters what parents think of their kids teachers". Among the group, Amber seems to have the least positive relationship to science as a content domain; something that she directly attributes to influencing how she perceived parents at the Maker Faire.

Sally, with her extensive science background and science museum experience, seemed to have the most confident relationship to science as a content domain. Despite Sally's positive relationship with science, she shared Amber's sentiment that parents were occasionally problematic to her in this environment as well. Sally pointed to moments when she, "felt uncomfortable having them just stand here and watch us have these interactions… I guess I was just feeling like I was being watched as opposed to be having them all be part of the same experience." On the other hand. Sally expressed that she found it helpful, "when parents got in and asked some questions, not necessarily did it for them or helped them, but just showed that they were trying to keep their interest or were trying to get them thinking." To Sally, the role of parents seemed to come down to whether they were supportive and involved, or if she perceived them to be withdrawn and judgmental.

Ruth also expressed parents as being a detractor to the Maker Faire environment, but for slightly different reasons. She found them distracting to what she and her group members were trying to accomplish, as she explains that she had a number of instances where parents tried to push their children too hard towards creating a certain design. She explained that she and her group members, "were trying really hard not to influence the kids, not to get them to do what we wanted but just kind of like, 'Oh, can you figure it out?'" In particular she described one parent who,

> *seemed like he really wanted his kid to come up with like, he had the end result in mind where he wanted the student to go. Where I was kind of more like, well I don't know, like where do you want to go? It was a lot different because it was a lot more pressure to just be like well what does the parent want me to say, what is he expecting right now, like is he expecting me to give a little short engineering lesson*

*on, you know? Because you can already kind of see them going that way so that definitely was something.*

In a way the concern she illustrates here is somewhat reflective of Amber's concern; Ruth is making the case that parents may have imposed an unwanted pressure that compelled her to feel the need to demonstrate specific content knowledge- in this case engineering content knowledge. Ruth described that she had zero science background, but she did not feel uncomfortable with this fact because, "students construct their own learning". However, this perspective breaks down quickly when parents arrive on the scene as Ruth explains that "parents want you to have answers", because they think that the "role of being a teacher is you must know content". Reconciling her own belief about learning, with her perception of how parents conceptualize teachers, seems to be a point of tension. At this point in her role as a teacher, a parent's presence seemed to have a big influence on Ruth as she seemed more inclined to adjust her behavior towards what she believed to be their perception, as opposed to upholding her own philosophy of learning.

In contrast to her group members, Mary expressed only appreciation for the presence of parents in the environment. She recalled being surprised by the fact that, "the parents were taking on more of the interactions than [she] had expected." In particular, she contrasted the involvement of parents at the Maker Faire to her own experience with parents at her placement school, "where it's a lot of parents that don't have educational background or aren't sure how to extend the education at home." When warranting the high level of parent involvement that she reports witnessing during the Maker Faire, Mary explains that it, "makes sense when I realized that a lot of them were university people who work at the university bringing their kids." (As mentioned, earlier in this paper, Mary's claim is inaccurate. Of the 400+ participants, it is likely that only a fraction of

them were university employees who brought their children. The invitation for the Maker Faire went out to the 33 classrooms where pre-service were placed in their practicums, the parents of those children, and all teachers in the school district; additionally, faculty in the education department were invited.) Mary also articulated that she found that parents were in general very helpful at facilitating exploration and also good at asking question to get kids to think more critically about their design.

While each of the Balloon Rocket group members described a different relationship to parents at the Maker Faire, the common thread was that each of them was basing their account on *perceptions that are largely unsubstantiated by any sort of direct or empirical evidence.* That is to say, none of the group members could know with certainty what the parents were really thinking in that environment, nor what may have been motivating the parents; what they can speak to with confidence, is how parents made them feel.

**Summary**

The cross-case analysis of the stimulated recall interviews and the follow-up interviews reveals that the shift in project focus during the Mock Maker Faire (from balloon cars to balloon rockets) played an important role in framing how the group members came into the Maker Faire. Specifically, this change of plans had an impact on how prepared the pre-service teachers felt they were for the event. It was found that emotions, specific styles of questioning, and varying visions of student success may be related to actions and interactions that took place during the faire itself. Evidence also shows a potential relationship between ways that the different group members modeled design thinking during the Maker Faire, and the corresponding types of evidence that they looked for when assessing learning; revealing that not all group members modeled the

same thing, in the same way, and accordingly, they did not all assess for the same things. Finally, all group members expressed that parents were influential factors in their experience at the Maker Faire, though their accounts of the role of parents is based almost strictly on assumption and very little on fact.

The following chapter discusses the results of the analysis, outlines recommendations for future research based on these findings, and closes with concluding comments.

# CHAPTER 5: DISCUSISON, RECOMMENDATIONS, AND CONCLUSION

This qualitative research project applies a case study approach to investigating the nature of experience and interactions of four pre-service teachers who took part in facilitating an activity for a School Maker Faire. Additionally, the research looks for evidence of design thinking as a pedagogical practice manifested in this environment. This research contributes to the growing literature on maker education and design thinking as it applies to teacher education- an area identified as lacking research and one that is identified as benefiting from a qualitative approach (Koh et al., 2015). Data was collected in the form of stimulated recall interviews and follow-up interviews. Analysis of the data revealed the following four themes as important influencers of experience:

1. Pre-Maker Faire preparation
2. Factors that influenced interaction
3. The role of assessment
4. The role of parents

The following discussion section uses design thinking as framework for looking at the four themes. The discussion reveals that among the group members, Mary's experience seems to show the most evidence of having embraced design thinking whereas Amber seemed to show the least. Ruth and Sally's experience seem to fall somewhere in between Mary and Amber, and are interesting because they seem to show evidence of grappling with the idea of embracing design thinking as a stance.

## Theme 1: Pre-Maker Faire preparation as it relates to design thinking

The findings reveal that preparation for the Maker Faire was an important component for the pre-service teachers. They provided evidence that they felt the need to

prepare both materially (supplies, arranging the space, creating a model), as well as cognitively (assembling a range of questions and problems children might have and being prepared to demonstrate content knowledge to parents). Furthermore, it appears there may be a relationship between a pre-service teachers confidence and familiarity with the design thinking process and what being prepared looked and felt like.

Amber wanted a model of a balloon rocket for kids to build from and she wanted, "to have a solution for every problem that might come up". Mary expressed being comfortable with not having a "structured idea of what was going to happen". Mary attributed her comfort with their level of preparation to the fact that she seemed to put significant trust, "that something would work because it was the engineering design process". Amber expressed apprehension with the fact that she did not have the content knowledge to support the balloon rockets activity (namely physics content knowledge) and this made her nervous because she did not know how she would be able to field specific questions that children or parents might have.

One explanation for why Amber and Mary felt so differently in terms of preparation might be related to the extent to which each of them showed evidence of embracing design thinking; in other words, there may be a relationship between their level of adoption of design thinking as a stance in this environment and the extent to which they felt prepared. On a spectrum, Mary showed evidence of being the most comfortable engaging in design thinking as a stance when compared to her group members, whereas Amber displayed evidence of being the least comfortable with it. Mary gives examples of encouraging experimentation, risk taking, and re-design. Amber guided children through a series of steps that would get them a version of a balloon rocket that that approximated the

style of balloon that she had success with herself (a section of straw taped to a balloon). Where Mary trusted the design process and seemed to embraced the lack of material preparation, Amber seemed unnerved by it. Accordingly, Mary was the least concerned about their level of preparation, whereas Amber demonstrated the most concern.

Ruth and Sally were somewhere in between Amber and Mary in terms of how prepared they felt. While each expressed that they did not feel prepared for the Maker Faire, they expressed a more neutral level of concern about this fact; Sally had, "super low expectations about the event" because they, "did not know what they were doing and Ruth was more curious about, "the materials the kids would want and how they would use them to make a rocket". The quality of these comments point towards at least an open mindedness to a version of preparation where outcomes were uncertain. Accordingly, during the Maker Faire itself Ruth and Sally showed moments where they engaged in the design thinking process by fostering, and in the case of Ruth even participating in, exploration and iteration of ideas. Interestingly, these two also showed evidence of using leading questions at times in order to guide rocket designs towards certain outcomes; arguably pointing towards evidence of moments where they disengaged from design thinking as a stance towards interaction.

Preparation for environments that aim to be conducive to design thinking (such as makerspaces and maker faires) likely look very different than preparation for learning in more formal learning environments, such as a traditional classroom. As Brahms and Wardrip (2014) articulate, *spaces* designed for making and design thinking focus on access to diverse materials, flexibility of the space to accommodate varied use and new ideas, and minimal instructional signage as to maintain a space that is open to unexpected outcomes.

Design of *activity* in such spaces focuses on developing competence with materials and tools particular to the activity, encourages risk taking, and is process oriented (design thinking being an orienting process) (Brahms & Wardrip, 2014). Preparation for environments as those suggested by Brahms and Wardrip are focused on *process* and *divergent thinking,* as opposed to a focus on *product* and *convergent thinking* that one might find more commonly in traditional classroom settings.

Bringing this back to the Maker Faire, on the one extreme Amber seemed to be heavily motivated by a version of preparation that gave her a strong sense of what the end product would be. Her discomfort with not having a model for children to go off of was prime evidence of this. Mary was influenced by a version of preparation that seemed to embrace not knowing what outcomes would look like and she even eschewed the idea of having a model for children because she felt that might stifle a child's exploration:

> *I felt comfortable not having made a super successful model because I think that that's the point, is if you get modern materials and see if they can make it happen. I didn't feel really prepared. I knew we were going to make it work whatever it was but it didn't feel I had a structured idea of what was going to happen. I tend to be more comfortable with flexible teaching than some of my colleagues.*

The potential relationship between how preparation is conceptualized and the degree to which a pre-service teacher has adopted design thinking as a stance is interesting and worth exploring, both for researchers and for practitioners. If design thinking is present, then it may manifest itself in the ways that a teacher or facilitator prepares an environment for this mode of thinking and learning. For teacher educators who foster design thinking in their pre-service teacher population, looking at how teachers prepare seems like a great point of assessment.

**Recommendations for practitioners and future research**

**Researchers.** The relationship between design thinking as a stance, and how this might manifest in the way a pre-service teacher prepares, is worth deeper and more extensive investigation. How a teacher thinks about preparing such a space for learning might also point to the stance that they are using as the foundation or lens to conceive of that space.

Outstanding questions:

- *What are best practices for educating pre-service teachers on preparing and designing makerspaces and environments that foster design thinking?*
- *How do instructors of design thinking (in design schools) prepare themselves for teaching design thinking? Can their modes of preparation be translated into a template for how teacher educators may want to go about teaching design thinking to pre-service teachers?.*

**Practitioners**. One of the main points of tension in preparing for the Maker Faire resulted from those pre-service teachers who were trying to solve the problem of how to create an activity that would get kids making successful balloon rockets. Such an identified problem likely points to a product-oriented stance, where the pre-service teachers were then the ones ultimately solving the balloon rocket design problem instead of the children. For teacher educators teaching design thinking to pre-service teachers, a focus on the nature of design thinking as being process-oriented may be beneficial. As Ruth points out, our current wave of incoming pre-service teachers are largely products of education that has primarily focused on product over process. This implies that teachers may default to a focus on product in the absence of a different and explicit model. Additionally, for teacher educators evaluating pre-service teachers, witnessing evidence of

a focus on product may help teacher educators in identifying pre-service teachers who are still working towards a design thinking stance.

**Theme 2: Factors influencing interaction and how they relate to design thinking**

***Design thinking and emotions***

Across the board, the pre-service teachers in the Balloon Rockets group expressed multiple ways in which a) emotion was a significant part of their experience and b) those emotions connected to actions and interactions. At the surface level emotions of fear, nervousness, excitement, and surprise seem logical given that these four pre-service teachers were organizing, facilitating, and participating in a learning environment that was likely very new to them: the School Maker Faire. Additionally, regardless of their emotional state going into and during the faire, by the end of it each group member reported (in the second follow-up interview) that the Maker Faire was a big success and that they would organize or participate in an event like this again. Simply put, they seemed to have some concerns at the onset, but by the end, those concerns were transformed into surprise, appreciation, and excitement for how it all turned out.

Throughout the Maker Faire experience, from preparation all the way until the end, Mary expressed mainly positive emotions towards the event, demonstrating very little range in emotion as compared to her group mates. In talking about the preparation going in to the Maker Faire, recall from the previous section that despite not feeling prepared, Mary explains that her trust in the design thinking process gave her confidence going into the event. In reflecting back on how the event went over all, Mary mentioned, "I had a lot of fun! I really enjoyed it–I had such a good time. I felt like we were busy the whole time, we had, I just felt like we had a good stream of kids and I liked watching the parents."

In contrast, Amber expressed the widest range of emotions throughout the experience expressing that, “the day of [the Maker Faire], I was still very nervous. I was like, ‘Okay, we have a table of stuff and we’re just going to tell them to make a rocket and that’s it?’”. However, in reflecting back on the Maker Faire, Amber reports that, “I think, for all of us, we couldn't believe how well it went…It worked, yeah. We were very pleased with how it went”. Reinforcing these positive feelings that she expressed after the Maker Faire, Amber mentioned that she would definitely participate in, or even help to organize, another event like the Maker Faire.

Ruth and Sally fell somewhere in between Mary and Amber in terms of the range of their emotional experience. While Sally did not express as much confidence as Mary before the Maker Faire, she also did not express the degree of negative emotions that Amber expressed. Rather Ruth,

> *went in with super low expectations. Who is going to show up to this thing? What do we set up? What do we do? And then kids started coming in and showing interest. We were like, "Oh, okay." As they started trickling in, we started handing out questions more. At the end of the day, a really wonderful experience. We all walked away, saying "That was so awesome that we got to be a part of that."*

Ruth reported that from start to finish the Maker Faire was, “good and I didn't think it was going to be but it was”.

While it can be argued that these range of emotions are tied with experiencing something they have not done before, when looked at through the lens of design thinking, the overall shift in emotions might be indicative of something deeper at play– specifically a shift in their stance taking place. After my analysis was complete, I came across a research paper by Royalty, Ladenheim & Roth (2015) of the Stanford d.School (“Design School”). Their study struck me as particularly interesting because a portion of their

results seemed to map very closely to the emotion findings that I was seeing in my case study.

Royalty, Ladenheim and Roth (2015) conducted a qualitative study aimed at understanding the implicit theories and practices that design thinking "coaches" employed during a workshop series they led on teaching design thinking to business executives; the intention of these workshops for these executives being that they could then bring their new understanding of design thinking practices back in to the culture of their respective workplaces. In other words, "this means that employees who receive training at the d.School head back into a workplace with a fairly entrenched working culture." A formidable challenge, and one that closely approximates the challenge of introducing design thinking into the fairly entrenched culture of our current school system.

In their study, Royalty, Ladenheim and Roth (2015) revealed that the design thinking coaches,

> *challenge participants by first making them uncomfortable. They create a safe space where it is all right to be uncomfortable, perhaps because everyone on a team is more or less equally uncomfortable. From there, coaches help participants move forward in two ways. The first is by offering constraints as a scaffold to work in a design thinking manner. The second is to build and maintain momentum that ensures they stay on track. Finally the coach keeps the level of engagement high throughout the program as a way of connecting the participants personally to the design process.*

The emotions that the pre-service teachers expressed prior to, and occasionally during, the Maker Faire seem parallel to feelings of discomfort that the design thinking coaches tried to cultivate in the executives during the workshops. Going into the Maker Faire, both Ruth and Amber did not have a lot of confidence that it would go well, which might be

interpreted as uncomfortable to them. Continuing the parallels with the actions of the design thinking coaches, the Science Methods Instructor scaffolded the School Maker Faire concept to be a safe place to try out their new understandings about science education and design thinking pedagogy. Furthermore, the course instructor provided design constraints and built momentum in the form of the assignment frame itself for the Maker Faire which involved a specific type of planning, a space to test ideas (the Mock Maker Faire), and the requirement that they define an NGSS standard to assess during the Maker Faire– serving as a design constraint.

According to Royalty, Ladenheim and Roths's (2015) findings, as the coaches guided the executives through the process of embracing design thinking, their research reveals that coaches were looking for specific emotions (discomfort, safety/constraints/momentum, and engagement) from the executives as signs that their stance was shifting towards embracing design thinking (see Figure 5):

> *The discomfort created from coaches immediately forcing participants to jump in to the new design thinking process leads to confusion. The safety, constraints, and momentum that carry teams through the process help instill a sense of optimism. In the end, being personally engaged opens the participants up to be surprised in their own creative abilities.*

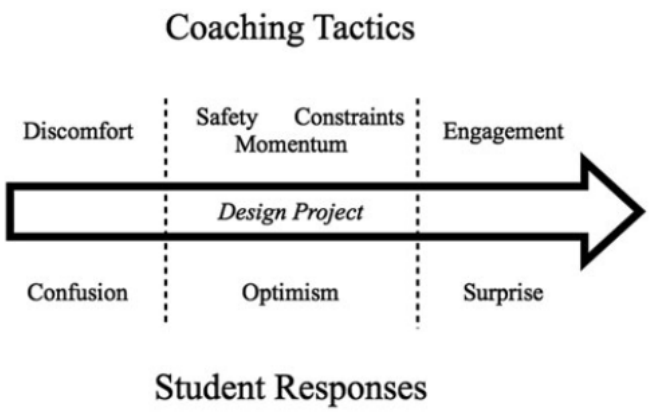



*Figure 5:* A model of Executive Education design thinking instruction (Source: Royalty, Ladenheim, & Roth, 2012)

Figure 5 above illustrates the tactics that coaches implement, and the student responses that they look for as student engage in design thinking over the course of the design process.

Royalty, Ladenheim and Roths's (2015) findings raise questions that seem applicable to some of the pre-service teacher experiences in the School Maker Faire:

- What if the report of pre-service teachers' emotions are more than an account of their experience, but at a deeper level these emotions are evidence of them actively working on a shift in their thinking?
- What if their transition from uncertainty and worry towards a feeling of surprise in how well it all went is also evidence of a shift happening in their thinking? In particular, this shift in their emotions might represent a sign of a shift from their existing understandings of teaching and learning, towards one where design thinking is at the core.

Viewed from such a perspective, Royalty, Ladenheim and Roths's (2015) research might provide one explanation for why Mary did not experience a significant range of emotions (i.e.: from negative to positive), where Amber did. If Mary truly was embracing the design thinking stance before the Maker Faire even began (as she expressed), then

Mary would not have experienced the range of emotions that Royalty, Ladenheim and Roths's (2015) research would predict with a shift in stance; in other words this evidence would suggest that perhaps Mary was already operating with a design thinking stance. On the other hand, Amber's range of emotions (and to an extent Ruth and Sallys' as well) map well on to the progression of emotions identified in the d.School study, implying that these teachers' emotions might be representative of a shift taking place in their stance.

The connection from the results of my own study, to the results of the study by Royalty, Ladenheim and Roths's (2015) are provocative. The emotions described by the participants in my study may have nothing to do with a shift in their thinking and might only be a by-product of the stress that comes with the teaching program, they are participating in and a feeling of satisfaction in having made it through the Maker Faire event relatively unscathed. However, given the similarity of the content (design thinking) and the context (teaching design thinking to others), the Royalty, Ladenheim and Roths's (2015) research provides a compelling perspective for trying to understand why emotion was such a significant part of the experience for these pre-service teachers. As designers at IDEO (2012) point out, "stepping out of your comfort zone=learning", and to be sure, the Maker Faire brought its fair share of discomfort to the members of the Balloon Rockets group.

Royalty, Ladenheim and Roths's (2015) study suggests an interesting conceptualization for how teacher educators might approach teaching design thinking to pre-service teachers. Additionally, it suggests possible indicators (in the form of emotions) that might work as a beginning framework for evaluating the extent to which design thinking is being embraced. Granted, development of such a model of instruction and

assessment would require significant research as it is also contingent on a few assumptions that themselves require more fleshing out. The first being that design thinking can operate as a stance. Second, that these emotions are accurate indicators associated with a shift in one's stance. Third, that people can accurately assess and ascribe labels to the emotions of others.

### *Design thinking and the relationship to different types of questions*

The analysis reveals that each of the pre-service teachers' interactions were likely influenced by the nature of questions that they asked. Furthermore, the results show that the types of questions that they asked fell into two major categories:

1. questions that work to *shape* experience,
2. questions that work to *assess* experience (these types of questions will be addressed in the next section on Assessment)

Within these lines of questioning are clues that may point to a relationship towards the presence or absence of design thinking.

**Questions as guidance.** Mary described her fabricated curiosity as a way to guide a child's attention towards an element of their design that she thought might be worth exploring further. For example, at one point in the Maker Faire video Mary was seen having just launched a balloon rocket with a child. The rocket only travelled a small distance, and mostly just spins around the string. Mary exclaimed, "Whoa! We've never seen one spin before! What made it spin?!". Mary described this as a moment of fabricated curiosity where although she has seen other balloons spin, and she has ideas of

what might be causing it (thus the fabricated nature), her question about spinning is aimed at,

> *trying to play up and show that I'm curious of what's going to happen then they'll feed off of it. They'll feel like it's okay because sometimes it's okay to investigate all your questions and in a kid's life a lot of times it's: "No. Not right now", or "It's time you stop asking."*

What Mary describes is an attempt to use her own "fabricated curiosity" to model that this is a space and activity where a child should feel free to explore their own ideas. Additionally, this points to Mary demonstrating an emphasis on the *process* of exploration and design iteration, rather than an emphasis on *product* in the form of a successful balloon, as in, "it made it. Here you go, that's great, take your rocket." Mary asked children other question such as, "What happened? Why do you think so? What are you going to do now?". This focus on asking questions that model a process for *how* to think is exactly what Kafai and Resnick (2011) describe as what distinguishes design thinking in an educational context from design thinking in professional contexts such as industrial design, architecture, or engineering where product has equal importance to process; while children usually create a product when they apply design thinking in an educational setting, the focus is generally on the process of design thinking, with the assumption that the process of design thinking is a tool that the child can then begin to apply on their own to many other problems and situations.

In the follow-up interview Ruth talked specifically about how some of her questions during the Maker Faire were leading questions, and she provided the rationale behind her partial reliance on such questions. In particular, she pointed to the identified problem that, "the schooling that we grew up with is more geared toward just finding the

answer." She went on to explain that as a product of that experience, when she "knows the answer" for how a child might solve a problem, she finds it very easy to fall back on using leading questions to help get them to the solution or answer easier. In the instance where she was co-exploring the double balloon concept with a child, she points to the moment in the Maker Faire video where she switched from exploring with him, to knowing what he should do next. She explained that at first she was thinking, "'I hadn't thought of that!', but as soon as you think of [how it works] and the kids are trying to put it together, it becomes 'I already know the best design that you might want to do.'" She described a shift from being shoulder-to-shoulder with the child, not knowing where it was all going, to then understanding his concept and being able to "see around the corner" as to what might work best going forward. She elaborated that, "I think it's really hard to catch yourself but I think that a lot of the questions we asked, [our group] had discussed: 'How can we get them to think about this, how can we get them to think about that?'" Ruth is suggesting that at this point in her experience as a pre-service teacher, what she knows can be problematic to a child's exploration if she is not able to catch herself using her own content knowledge to inform leading questions. She concluded by pointing out that, "throughout most of this thing I was trying to be conscious of not letting the fact that I already knew or had an idea of what I wanted the students to do, steer them one way or another."

Ruth's experiences at the Maker Faire illustrate moments where she was exploring in uncharted waters and these moments led to collaboration with a child on their idea (ex: with the double balloon, and with wings on a rocket). Furthermore, although the window of time that reflects this collaboration is small in the context of the Maker Faire, it contains

evidence of lines of questioning that were genuine in the sense that she was asking questions as a *co-learner*: one who is trying to understand the other's idea and work with it (Brahms & Wardrip, 2014). Though fleeting, her actions in that moment model the collaborative element of design thinking that demands others to be a part of the process, as designers don't go it alone (Goldman et al., 2014; Kwek, 2010); she was asking real questions, as opposed to leading questions.

Going back to the issue of what a teacher knows being potentially problematic to exploration, Sally struggled with something similar. Sally's "honed questions" are another version of leading questions that worked to structure experience for participants. For Sally, the *honing* referred to a process of narrowing down a set of questions that would work to efficiently get kids to think about some of the main variables that would influence the flight of their rockets (weight, size, structure). Additionally, Sally pointed out that given the limited amount of materials, her honed questions worked to guide children towards using a combination of materials that would be the most likely to yield a successful rocket (i.e.: one that flies the length of string). Similar to Ruth, Sally's knowledge of "what works" seemed to have had an influence on the types of questions she asked, which ultimately worked to structure the experience for the child in a very targeted way.

Several of Ruth and Sally's interactions with students during the Maker Faire demonstrated the power imbalance that might occur when their knowledge of how balloon rockets work is manifested in the types of leading questions they asked. Questions informed by such knowledge worked to reduce the number of possible solutions a child might come up with for how to build a balloon powered rocket that travels along a string.

However, interesting things happened when "ignorance" came into the scene, as it did for Ruth when the child started exploring the double balloon concept. In the moment that the child began to explore the two-balloon approach, he brought Ruth's thinking into an area that she had not planned for, or that she was ignorant of. The distribution of power was arguably more equal in that moment as they were both trying to think about the design shoulder-to-shoulder. Yet, when she tells of the moment when she could begin to "see around the corner", she explains that she reverted back to leading questions, and the distribution of power seemed to shift in her favor again as her questions made it apparent that she knows something the child did not. Ruth's experience is reflects Estes (2004) argument, "that teacher-centered facilitation is problematic in experiential education and justifies increasing the use of student-centered facilitation practices". Estes assertion points to the problem that in such an environment, a teachers goals (whether conscious or not) may work to muddy the waters as the child is put in a position of trying to balance their own exploration against guessing what it is the teacher is wanting them to do.

The French philosopher, Jaques Rancière (1991) tackles the potentially problematic nature of what a teacher knows in his book, The Ignorant Schoolmaster. Rancière's argument is based on the account of Joseph Jacotot, a French professor who was exiled in the early 1800's to Belgium (which at the time was still a part of the Netherlands) and who, "by the generosity of the King of the Netherlands obtained a position as professor at half-pay." While Jacotot spoke French and no Flemish, he held class with a group of college students who spoke Flemish but no French,

> *Yet he wanted to respond to their wishes. To do so, the minimal link of a thing in common had to be established between himself and them. At that time, a bilingual edition of the Télémaque was being published in Brussels. The thing in common*

> *had been found, and the Telemachus made his way into the life of Joseph Jacotot. He had the book delivered to the students and asked them, through an interpreter, to learn the French text with the help of the translation. When they had made it through the first half of the book, he had them repeat what they had learned over and over, and then told them to read through the rest of the book until they could recite it…the experiment had exceeded his expectations. Such was the revolution that this chance experiment unleashed in his mind. Until then, he had believed what all conscientious professors believe: that the important business of the master is to transmit his knowledge to his students so as to bring them, by degrees, to his own level of expertise.*

Rancière uses Jacotot's experience to make a case that a teacher's knowledge is problematic to the extent that it creates an unproductive differential of power between those who have the knowledge (teachers), and those who need to become knowledgeable (students). He further argues that this imbalance of power can be reconciled by embracing the assumption that it is human nature to be able to learn and acquire knowledge on one's own– without needing a "master" to transmit that knowledge. However, Rancière is careful to point out the fact that those Flemish students who learned French *depended* upon Jacotot, not because of what he taught them (for he did not teach them French), but because of what he provided for them: *a process and a structure to think and learn within.*

Though Rancière's ideas remain controversial in France, and are even further away from the current educational conversation in America, the vision of learning that he proposes seems to parallel what design thinking in an educational setting attempts to do. Design thinking is described as process for identifying unique problems and creating unique solutions. By its nature, the outcomes of design thinking are relatively unpredictable, but at the same time design thinking depends on structure (Puntambekar & Kolodner, 2005). Teachers who are engaging students in design thinking activities and

projects have a crucial role, and that is to provide a *process* and *structure* for how to problem solve, and for learning how to learn (Carroll et al., 2010; Goldman et al., 2012; Puntambekar & Kolodner, 2005)– and providing process and structure is much different then meeting content objectives, which has been the norm in American schooling for a number of decades now. Similar to Jacotot, this implies that teachers in design thinking environments have a responsibility for setting the parameters for exploration and creation, but not necessarily for defining and disseminating knowledge. For those wondering how content knowledge should ever be acquired, Carroll et al. (2010) point out, in many cases, "STEM content is still an outcome of engaging in designing", though it is not necessarily the objective. One way that a teacher in a design thinking environment can begin to model the design thinking process and provide structure, is in the questions that they ask.

**Design thinking and the relationship to various visions of success**

Common to most of the Balloon Rockets group members was some sort of vision of success that seemed to guide their interactions. In most cases, all four group members described a version of success that included getting kids to build a rocket that could fly along the length of a string. Mary was the only group member to also describe a vision of success that focused on the process, rather than the product; with such a focus this is in line with the argument that, of the group members, Mary seems to be the one most comfortable with embracing the elements of design thinking.

In moments where a child's rocket did not go as planned Mary admited that she, "was a little nervous that some kids would be upset if it didn't work." Her nervousness might point towards the fact that engaging in, and trusting, the design process is newer territory for her. However, despite being nervous she tried to, "focus [her] reaction on how

cool it was" that something didn't work; evidence that she seemed able to apply her vision of success by helping children to frame failure as a positive experience and an important part of the design thinking process. Though Amber shared a similar vision to Mary about success being synonymous with a successful rocket balloon flight, her actions looked very different than Mary's.

Instead of leveraging the design thinking process in iterating towards a successful rocket, Amber ensured success by creating a series of steps that children could follow in order to arrive at a very simple balloon rocket that was almost sure to fly along the length of a string on the first try. Amber's reliance on these steps, as opposed to relying on the process of design thinking illustrates two things. One, she is focused on a version of success that is geared towards a specific product, instead of success being synonymous with promoting a process. Second, by to trying lead all students to a common product, it illustrates that it is likely that Amber has not yet embraced, or may not fully understand, the design thinking process. Her actions also suggest an underlying assumption that kids might not be capable, either in terms of patience or resilience, of going back to the drawing board and re-designing. Whereas Mary's actions reveal an underlying assumption that with proper encouragement and guidance (or scaffolding as she calls it), children are potentially patient and resilient enough to give their ideas another round of re-design.

Both making and design thinking embrace taking risks and failure as something positive, as risk pushes thinking into new areas and failure provides an opportunity to learn and improve a design or concept (Plattner et al., 2011; Royalty et al., 2012). Design thinking in an educational context suggests a version of success that is described by the sum of learning that results from a series of risks and failures; this implies that in the

extreme, perhaps a person does not even need to arrive at a working model to have achieved success–the process itself is where success and discovery lies. As Plattner, Meinel, and Leifer articulate,

> *there is no chance for "chance discovery" if the box is closed tightly, the constraints enumerated excessively, and the fear of failure is always at hand. Innovation demands experimentation at the limits of our knowledge, at the limits of our ability to control events, and with freedom to see things differently" (p. 15)*

Teachers who can foster an environment where success is measured by the risks taken in the process of evolving a design or idea, also create a space where children can begin to experience true discovery. Or as Elanor Duckworth (1972) puts it,

*"The more we can help children to have their own wonderful ideas, and feel good about themselves for having them, the more likely it is that they will someday happen upon ideas that nobody also has happened upon before." (p. 231)*

**Recommendations for practitioners and future research**

**Researchers**. The findings related to emotion as it applies to the pre-service teachers' experience is particularly interesting. In part because mitigating these emotions seems to have a relationship to actions and interactions, particularly when the emotions are negative in nature. These emotions are also interesting as Royalty, Ladenheim and Roths's (2015) research suggests that in an environment where design thinking is being learned, there may be a relationship between emotions and a person's transition towards adopting a design thinking stance; this is an intriguing relationship that might warrant further research.

Also addressed in this section is the idea that scaffolding learning for design thinking may look quite different than scaffolding learning in conventional classroom

learning spaces; one of the main reasons being that design thinking in educational environments suggests a focus on process over product. As scaffolding is a common pedagogical element addressed in teacher education programs, research that builds on Puntambekar and Kolodners's (2005) findings on the importance and nature of scaffolding learning when engaging children in design thinking would be beneficial.

This section of the discussion also raises the question of whether or not a teacher's content knowledge is problematic to student exploration; primarily because it seems challenging for the pre-service teachers in this study to keep their own content knowledge from influencing their scaffolds in ways that work to limit the possible range of exploration. This finding poses a challenge to conventional wisdom and research that stipulates that content expertise in teachers leads to better teaching.

Outstanding questions:

- *Is there a relationship between expressed emotions and the process of adopting design thinking?*
- *Can emotions be leveraged as a) a tool for teacher educators developing design thinking in pre-service teachers and, b) a way to assess adoption of design thinking?*
- *How important is content knowledge in teachers who facilitate design thinking in makerspaces and in maker education? Are there cases where it is even problematic to have more content knowledge in these spaces?*
- *Does teacher content knowledge actually impede child exploration in design thinking environments?*

**Practitioners**. The fact that the pre-service teachers used a variety of means to provide structure and guide interaction is not surprising. In fact, makerspaces and design thinking thrive on structure and constraints. Practitioners who are engaging pre-service teachers in design thinking pedagogy may benefit from explicitly exploring the components that define productive structure in maker education and design thinking environments, and how these structures differ from conventional ones often found in K-12 classrooms.

## Theme 3: Assessment and design thinking

As assessment was a requirement for pre-service teachers participating in the Maker Faire, it is no surprise that it was evident as a theme across group member accounts. What is surprising is the different forms of assessment and what may have driven these forms. Findings reveal that the pre-service teachers demonstrated assessing for evidence that was reflective of the elements of design thinking they themselves had modeled. They used questions to assess student understanding the effect of design variables on flight behavior. They also used observation to assess learning and the context in which learning was taking place.

### Assessing the effect of modeling design thinking

As mentioned in the analysis section, the different forms of assessment that the group members implemented could often be traced back to the ways that they modeled thinking and learning; some of this thinking and learning that was modeled was arguably in line with design thinking. Ruth *sparked thinking* of new ideas and also modeled the design process herself as she experimented with putting wings on a design of her own. Recall that Mary's fabricated curiosity was meant to *promote exploration* to look deeper at

the range of what might be causing certain effects on a design. Sally *pushed children to be intentional* about the changes that they were making to their balloon rocket so that they could be confident about which variable led to different outcomes. And Amber focused on *providing an environment for students to feel comfortable* to explore their ideas.

Each of these actions illustrated above corresponds with "Design of Facilitation" suggested by Brahms and Wardrip (2014) of Pittsburgh Museum's MAKESHOP, as well as with the "Facilitation Moves" described by San Francisco's Tinkering Studio in the Exploratorium, (2016). The fact that each of the pre-service teachers display (at least at times) actions that correspond with these frameworks is likely due to their exposure to these frameworks in the Science Methods course. While each group member modeled much more than what is outlined above (some of which even at odds with design thinking), these examples are representative of slices of their experience where design thinking as pedagogy seemed to live; that is to say that they were engaging in design thinking as a way to promote learning design thinking. Correspondingly, their assessments seemed to show that they were often looking for evidence that children were picking up the modeling that they were putting in to the environment.

When Ruth said to Sarah in the Maker Faire video, "What's he doing there? Looks like he's cutting some wings!" it illustrates that she is assessing a student's design to see if her wing experiment *sparked thinking* in any of the children. When Mary observed children going back to the drawing board on a design, it was a form of assessment that informed her that her fabricated curiosity might have worked to *promote exploration*. When Sally recalls herself thinking in the Maker Faire, "See now that he has lightness and strength he can actually build towards making that his rocket", she is pointing to evidence

that she is assessing whether her questions aimed at fostering *intentionality* may have paid off. When Amber reports assessing "What are the materials we need, Where are the kids at?", this assessment could be interpreted as making sure that environment is *conducive for students to be able to work productively and safely*. (Note: though this last example for Amber is not necessarily representative of an action directly intended as modeling for students, per se, it is still an example of assessment that still upholds a space that is conducive to design thinking.)

**Questions as assessment**

While some types of questions worked to guide and shape experience, there were other types of questions that worked to assess both what a student might know (or what they can do), as well as questions which worked to assess what was happening in a given scene.

Mary would often repeat back to a child what they just said, but in the form of question which she called "echo-questions" (recall: CHILD: I can't fix it/MARY: You can't fix it?). She explains that these echo-questions were meant to first let the child know that they were heard, but also to gauge the child's emotional state as they were grappling with working on a design. When referring to working with the boy who says, "I can't fix it.", Mary explains that her choice to use an echo-question was because she didn't,

> *want to impose his emotion on him. If he's like, "I can't do it," I don't want to jump in with, "Oh are you like upset about it or you are sad about it?" I want to know what he's [feeling] … So I wanted to just, that's my go-to with the kids is like okay, repeat back. You know I hear you and I understand you and then seeing where he goes from that. Does that turn into go to mom and want to leave or like "I can't fix it", it's done, or crying, or what's going to happen next?*

Mary's echo-questions, aimed at assessing emotional states of children as they work, are very similar to the tacit strategies that design thinking coaches in the Royalty, Ladenheim and Roth (2015) study were shown to use with executives in the design thinking workshops. By asking this type of question she is getting important feedback information about how well this child is handling being pushed in the design thinking process,

> *because I don't want them to get frustrated and quit and I don't want them to feel like they can't do it. Emotionally, if that's in concern, then I'll start with higher scaffolds and take them down, down. Ideally, emotionally if they are ready for it, I will start with barely any scaffolds and then bring it up as needed.*

In her simple echo-questions, Mary claimed to be able to assess whether she needed to make the decision to either help the child by adding more structure, or by pulling back and letting them explore as independently as possible. Figure 6 represents a model of the logic that Mary reported.

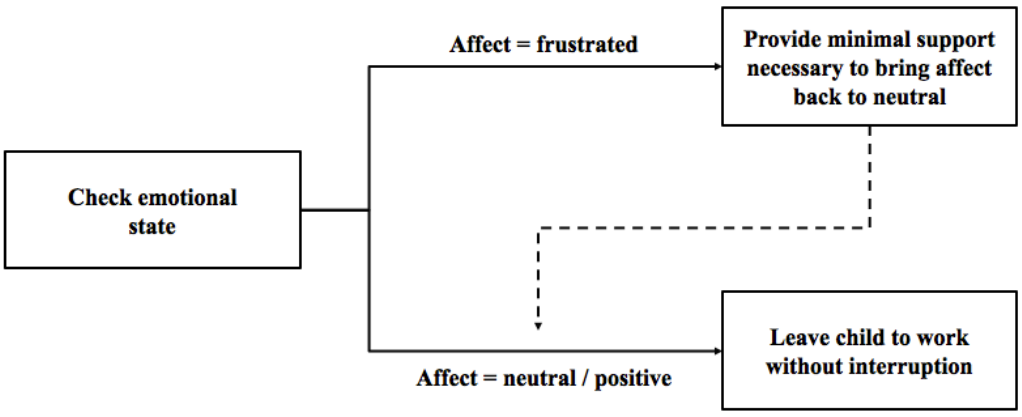



*Figure 6:* Flow chart depicting Mary's decision making process on amount of support to provide a student (own illustration)

By using this assessment logic, Mary is enabling the child to be constantly exploring as freely as possible, with their emotional state being the key determinant in the level of input on her part. This version of assessment mentions nothing of a predetermined product as a

standard for assessment, nor a focus on content knowledge. When reviewing the Maker Faire video, Mary directs me to a scene where she is working with a four year old towards the end of the Maker Faire, in that scene she reports how she had assessed that emotionally,

> *he was confident enough that I felt I could let him fail a little bit. I kind of based that on his confidence where I was like, "He's got it if I let him just fail"… If I give [the tape] to him first then he drops it then like, no, okay, let me help you tape and that's the scaffold I can provide."*

In describing her thinking in this scene Mary connected the dots between her assessment of his emotional state (confident), and the minimal level of support that she needed to provide in order to keep him in charge of exploring (helping him tape). Her assessment revealed nothing suggesting that she had a vision of what he should make, or how he should make it; rather, her assessment revealed that a kid of that age, and perhaps with his level of motor skills, might lose confidence if tearing pieces of tape from a dispenser and applying them to his rocket becomes a barrier for his exploration. Such a version of assessment arguably works to keep authorship in the hands of the child, focuses on process over product, and therefore arguably maintains a space that fosters design thinking.

Mary's group members also used questions to inform assessment, and these questions often served to inform the pre-service teacher about the connection a child was making between an element of design and how that might affect performance. It is worth pointing out that the NGSS standard that corresponded with their activity not only suggested an assessment of *how well* children were able to apply the design thinking process, but also assess evidence of whether they could connect design elements to outcomes they were seeing in their test flights (Ex: How does the size of the balloon

correlate with distance travelled?). To recall, here are the NGSS standards that informed their assessment:

K-2-ETS1-3: Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

DCI: ETS1.C Optimizing the Design Solution

When Ruth asked a child who was loading their rocket on the string, "do you want it facing this way or do you want it facing that way. Do you think it matters?", she claims to be assessing the child's understanding of the connection between the orientation of the balloon and the direction that it will travel. She reports that the child's response helped her to understand the extent to which they were making that connection. Interestingly, while Ruth reports this as a form of assessment, it is arguable that this is also leading question. In analyzing the the multiple layers behind what Ruth identified as an assessment question, Ruth's question:

- Interrupted the child moving forward with their idea while they had to consider the question that she posed,
- Led the child to pause and consider the path that they were already on, as opposed to letting them figure it out for themselves through experience
- Potentially put the child in a situation where they were trying to figure out a) *why is the teacher asking me this?* and b) *is there a right answer I should be looking for?*

While Mary also used the direction that a child loaded the balloon on the string as a way to assess some basic understandings, recall that Mary reported simply watching how a

child would load a rocket on the string. Mary's passive observation, and Ruth's active questioning may have different influences on the action a child takes. In Mary's case, she was:

- creating a space for the child to decide how load the balloon on the string
- creating space for failure, and therefore possibly learning
- allowing an opportunity to assess his understanding by observing his action
- allowing him to move forward with his idea with minimal input on her part

Similar to Ruth, Sally also points to the moment towards the end of the Maker Faire video when a boy is approaching the Balloon Rockets table and she breaks the ice by asking him, "'Do you know anything about rockets?". Sally rationalizes that this question has two intentions. First it, "it was a way for me to just to get him interested." Secondly, it was a form of assessing what he knew about rockets, "for him, it was like, 'No I don't.' Okay so let's have a conversation: What are basics? What should we be looking for here?" While Sally describes an intention to gauge his pre-existing knowledge of rockets, her questions (and subsequent conversation prompts) potentially communicate much more to the child:

- *Perhaps you should know about rockets*
- *Knowledge of rockets will be helpful in engaging in this activity*
- *There are basics to be considered and certain things to be looking at (and not other things)*

Of course, Sally does not describe that she considered what else may have been conveyed in her question; those are my interpretations of potential messages her questions

might have also sent to a child. At face value her intentions were good and she was merely trying to bring him into the activity and find a starting place to begin from.

What this all points to is that the group members likely held a belief that questions are a good form of assessing what children know. Each pre-service teacher had the good intention to assess understanding in some manner, but many may not have even noticed that embedded in a number of their assessment questions were leading questions; questions that by their nature work to frame subsequent action or response in a bounded, and likely unintended, sort of way. This implies that while the motivation to assess in these environments is present, the ability to ask questions that get at what is known without asking leading questions (or imposing assumptions) may be challenging and something that needs to be learned explicitly. However, even a seemingly benign question such as "What were you thinking when you did that?" presupposes conscious thinking in the first place, and sends a message to the receiver that perhaps they should be consciously be thinking about what they are doing. This alludes to raising the larger questions:

- *What is the role of teacher questions in design thinking environments*?
- *Are there questions that can exist in these spaces that work to assess understanding without influencing subsequent thinking and action on the part of the receiver?*
- *If questions-as-assessment are ill-suited for design thinking spaces, then what? What kinds of strategies help teachers know how and what students are learning in these environments?*

**Observation as assessment**

Compared to Sally and Ruth, Amber and Mary both spent a significantly larger portion of the Maker Faire observing what was taking place, not always necessarily directly engaged with a child making or testing a balloon rocket. From an outsider perspective, in such moments Mary and Ambers' behavior appeared similar: both were standing back away from the table, walking around, and watching what was happening. Each of them report that while their action was passive in nature, some of that time was spent actively asking themselves assessment-style questions in their mind as they watched the situation at hand. While they both report having assessment-style questions in their minds during these moments, what they reported assessing was quite different nature. Mary recalls wondering to herself if sometimes there were too many teachers around a child, potentially making the child uneasy. She also remembers having a curiosity about what children were doing as she watched them experiment. Amber recalls questions that worked to assess the environment and materials, "Where are the materials we need? Where are the kids at?" One way to explain why their assessments took on different forms is through the concept of attention and noticing.

Mason (2011) writes that, "attention is both observation and the medium through which observation takes place" (p. 45). Mason, further points out that to notice something, requires attention to it in the first place. He is suggesting both a connection between attention and noticing, as well as an order. Levin, et al. (2009) references a study by Simons and Chabris (1999),

> *which showed research participants various video clips to demonstrate phenomena of "sustained inattentional blindness." In one clip, six students dressed in white or black play with two basketballs, and participants are asked to count the number of*

> *times a student in white passes the ball to another student in white. More than half the participants watching the video, with their attention directed on the passes, fail to notice that a person walks into the center of the action wearing a gorilla suit, stands and beats his chest, and walks off. Certainly everyone watching has the ability to see gorillas; they fail to see them because their attention is directed elsewhere. Framing the task as "counting passes," they do not notice the gorilla. (p. 151)*

The study by Simons and Chabris (1999), is a great illustration of the nature of attention, as it applies to noticing. Think of attention as a filter or lens through which we can perceive the environment at large (wide angle lens). Noticing, is what happens when our attention is narrowed (narrow lens) to particular phenomenon, as viewed through a particular filter of attention. In the gorilla experiment above, the attentional (wide) filter was a white one; only students who were wearing white needed to be attended to, and within this set, only passes between those wearing white needed to be noticed. This white filter, arguably worked to "tune-out" that which was not white, including a person in a dark gorilla suit. As pointed out by Levin et al. (2009), it was not that participants had the *inability* to perceive a person in a gorilla suit, but instead that their attention was framed to perceive something different all together.

Noticing and attention, as described above, assume a sort of mental frame or lens that influences perception. Coming back to Amber's and Mary's reports of what they attended to when they were observing action unfold at the Maker Faire, they may have assessed different types of things because their attention was framed to notice different things altogether. Mary claims to have paid particular attention to evidence of children experimenting with changing their design, or of them trying to figure out why a rocket did not work as planned. She also paid attention to students who were already receiving too

much help from teachers, assessing the situation as to whether or not there was already too much adult interaction, "I didn't want it to be too guided. I don't want them to feel our presence but not". Amber claims to have attended to things that were of a more logistical nature such as maintaining materials and ensuring children were had something to work on. Amber explained that part of her motivation to attend to these logistical things is because she felt, "so disconnected from science. It's not my area at all."

If what a teacher attends to and notices (and ultimately assesses), is a function of the "filter" they apply for perceiving the environment, then a logical question to ask is, *What is the nature of the filter that influenced Amber and Mary's perception?* Design thinking, as a stance and therefore filter, may offer one explanation for what they attended to, and ultimately what each of them assessed as they took on their observational roles.

I would argue that Mary's attention and assessment was influenced by a design thinking stance as she attended to observable phenomena such as child exploration, evidence of iteration, and active problem solving. It is a bit more challenging to say whether or not Amber's attention was influenced by a presence of design thinking as a filter for assessing activity. On the one hand, it can be argued that an attention to the state of materials that are available for children is in line with design thinking. As ensuring, "elements such as activities, furniture, materials and tools are constructed and positioned in ways that allow for flexible and varied use" is very much in support of design thinking (Brahms & Wardrip, 2014, p. 9). On the other hand, Amber reveals that part of her reasoning for taking a more observational stance had a connection to her lack of confidence in science content knowledge. Viewed from this angle, I would argue that design thinking was not at play as a filter for what drove assessment as this evidence

would suggest that her *anxiety* was more likely what was driving her choice to take an observational stance in the first place; the fact that she often defaulted to stepping away from direct interaction with children and instead towards tending to materials is only incidentally related to design thinking actions. Also, if the nature of Amber's assessment is looked at in the larger context of her overall experience at the Maker Faire, of the group members she is argued to have demonstrated the least amount of evidence of using design thinking to inform her thinking and action–making it more likely that her observational assessment has more to do with being uncomfortable in this space than it had to do with upholding principles of design thinking.

From the analysis it seems clear that each of the Balloon Rockets group members engaged in assessment of some sort during the Maker Faire. Evidence also suggests that the different forms of assessment may have a relationship with the ways in which each group member attempted to model or communicate what it means to participate in design thinking. The degree to which a pre-service teacher demonstrated a form of assessment that was in line with design thinking varies depending both on the situation and the individual. The next section explores ways in which the presence of parents in this environment may have influenced interaction.

**Recommendations for practitioners and future research**

**Researchers**. The findings and discussion in this section suggest a relationship between *how* and *what* a teacher assesses, and the degree to which they embody the design thinking stance. Research in this area would benefit from developing best practice models for assessing learning in making environments. While MAKESHOP and the Exploratorium have research-generated guidelines for designing and facilitating learning in

makerspaces, these guidelines need further development to ensure applicability in the K-12 landscape as well as to ensure that that they are applicable across various environments. These two frameworks may serve as a good starting point for building a conceptual framework for how teachers should assess maker education in K-12 classrooms.

Outstanding questions:

- *To what extent can the MAKESHOP and Exploratorium frameworks be developed as tools to assess what students are learning in these types of environments?*
- *Are there ways to operationalize these frameworks to make observation protocols that are useful in the context of K-12 classrooms?*
- *What is the relationship of noticing to assessment in makerspaces and maker education environments?*

**Practitioners**. As a researcher, educator, and teacher educator I found myself falling into the common trappings of teacher assessment when I was reviewing the Maker Faire video. In preparation for the interviews, I reviewed the video multiple times before each stimulated recall interview so that I was familiar enough to be able to navigate quickly to points that stood out to each individual interviewee. In preparing for my interview with Mary, I braced myself for an interview that seemed unlikely to yield very much in the way of usable or interesting results. I based this assumption on my observation that so much of Mary's experience (from my outside perspective) seemed to involve very little interaction with students, as she appeared to be pulled back from the action and appeared to mill about a lot. I could not have been more wrong. Mary's stimulated recall interview revealed some of the richest insights about how a person might

interpret actions and activity in a Maker Faire environment. Furthermore, in her observational stance she provides evidence that she was deeply engaged in trying to understand and uphold the learning that was taking place in the Maker Faire.

All of this is to illustrate that to the outside observer, teachers engaging in design thinking pedagogy may look at times as if they are "disengaged". For those who are used to assessing teachers in traditional classroom settings, a significant part of the assessment is in the different ways that one observes teachers directly engaging students. In an educational space designed for making, teacher-student interaction can (and should) look very different. In part, this may likely be due to the fact that if a teacher has designed the space well, children can and do work with a significant amount of autonomy and minimal adult input in an environment designed to foster student driven design thinking. All of this is to say that for those with the responsibility to assess teachers and pre-service teachers in making environments, who are themselves engaging children in the design thinking process, a re-formulation of what teacher assessment looks like may be in order as the traditional indicators of engagement (direct teacher-student interaction) may be largely absent.

**Theme 4: Parents in design thinking spaces**

As we reviewed the Maker Faire video together, during the various stimulated recall interviews, each pre-service teacher pointed out a moment or two in their experience where parents played an influential role– sometimes to the extent that it influenced their actions and interactions. The findings also revealed that each group member's rationalization of parent actions or motives were largely unsubstantiated by concrete evidence. For example, Sally expressed feeling that some parents judged her, though there

is no concrete evidence to support this in her account or in the video; it appears to only be a feeling. This theme was significant in the data, though among the themes it seems to have the weakest relationship to design thinking. That being said, the evidence does point towards some interesting things to consider.

Mary's reports of her overall experience from the Maker Faire demonstrate the most evidence of embracing and employing a design thinking stance. In addition, Mary was the only group member to report that parents played a positive role for her experience, citing multiple instances where parents were helpful in facilitating exploration and design iteration. It is tempting to pair these two elements of her experience and draw a positive relationship between design thinking and perceiving parents in a positive manner. However, this relationship seems weak when looking at Ruth's case.

Ruth was a pre-service teacher who demonstrated a number of qualities associated with design thinking, but who also had negative things to say about how she felt about parents at the Maker Faire. She expressed mainly negative feelings associated with parents at the Maker Faire, mentioning that she felt self-conscious because she felt that, "parents want you to know the answer", and she was unappreciative that parents often pushed their children towards certain designs. In terms of design thinking, Ruth was a group member who demonstrated a number of qualities related to design thinking, such as role modeling exploration and co-learning (Brahms & Wardrip, 2014), all though she also relied on leading questions on a number of occasions. She explicitly mentioned trying to be conscious of not asking leading questions (though that was challenging) which might be an indicator that she was at least aware of, and trying to uphold, a design thinking stance at

times. In sum, Ruth shows evidence of embracing design thinking on a number of occasions, but holds parents in a negative light, which is contrary to Mary's experience.

Like Ruth, Amber conceptualized parents negatively as they imposed a perceived stress on her in that she, "wouldn't want them to view us as not having prepared for an event that we're putting on for kids. I think that would look very unprofessional." This perception, paired with the fact that she, "felt totally unprepared" left Amber with a feeling that parents were a stressful element at the Maker Faire. Additionally, Amber was a group member who illustrated the least amount of evidence of design thinking. In sum, Amber perceived parents negatively and she demonstrates minimal evidence of a design thinking stance.

Sally lies somewhere in between the others. She expressed mixed emotions pertaining to parents, outlining that she identified three types of parent interaction:

- *Participatory Parents* (positive association): parents who took an active role in supporting their child in the exploration process; they were viewed as supportive to what Sally was trying to accomplish
- *Inactive parents* (neutral association): parents who had a hands-off approach, or even left their child unattended; these parents gave her space to do what she was trying to accomplish
- *Watching Parents* (negative association): parents who were actively watching her interact with their child, but were not engaging in any part of the process; these parents felt to Sally like they were judging her and expecting certain outcomes from her interactions with their child

In addition Sally was a group member who at times demonstrated actions that upheld a design thinking stance (promoted intentionality in design iterations), but she also relied on "honed questions" to get children to a successful balloon rocket more efficiently. In a way, Sally's mixed emotions about parents parallel the mixed evidence of her a harboring a design thinking stance.

This potential positive relationship between how parents are perceived in such an environment, and the extent to which an individual demonstrates evidence of design thinking needs a lot more exploration. An alternative explanation might be that that in an environment where the pre-service teachers are engaged in a form of learning that is not the norm for our current educational system, there exists a tension as they feel that what they are engaged in with children is not what parents conventionally expect from teachers. That is, it may be that the pre-service teachers have a vision of parents who characterize the teacher as the knowledge provider, and they may feel compelled to fulfill this vision. However, the Maker Faire environment and design thinking are asking the pre-service teachers to be *facilitators to learning and exploration instead of content knowledge providers*. This discrepancy between what they feel they are "supposed to do" in the eyes of parents, and what design thinking demands of them in such an environment, might have a relationship to the quality of their experience when parents are present.

**Recommendations for practitioners and future research:**

**Researchers.** This research project only investigated the pre-service teachers experience. As mentioned, their feelings about parents were largely unsubstantiated. The finding that suggests there may exist a relationship between a teacher's level of comfort and ability with design thinking, and how they perceive parents, is weak and would benefit

from further research. In particular, research in a maker education environments that is focused on both the teacher's perspective, and the perspectives of parents, would help to uncover any relationship. Uncovering parent's beliefs about the role of teachers in such environments would be particularly valuable.

Outstanding questions:

- *How do parents experience maker environments and what are their perceptions of the role of the teacher in these spaces?*
- *What do parents expect for their children when they are participating in maker education?*
- *Are there ways to help teachers reframe common perceptions of parents and how might that influence quality of interaction?*

**Practitioners**. Understanding that the path to becoming a teacher is challenging and stressful at times, this research recognizes that parents may play a significant role on experience for teachers in such an environment. Instruction that explicitly looks at the possible roles that parents can actively take on in maker education environments may help to give new teachers more strategies for how to positively and constructively leverage their relationships with parents, as opposed to perceiving parents as a burden.

## Limitations of Research

Despite the findings, implications, and contributions of the present study, the study suffers significant limitations. These limitations pertain to the methodology, the participants, and the findings.

**Methodology**

While a qualitative approach can produce insightful findings, the limited number of cases in this study leads to results which cannot be considered universally and generally valid (Miles & Huberman, 1994). Additionally, as qualitative research depends on human interpretation on the part of the researcher, it is possible that my bias played a role in the interpretation of the data, despite the quality criteria for trustworthiness that were applied in this project.

The stimulated recall approach for attempting to approximate or access previous thinking is still a controversial methodology. Some are skeptical (Nespor, 1985) as to its validity, as the argument that a *report* of thinking is not the same as thinking itself. While I agree with this concern, stimulated recall has potential to be useful in uncovering the beliefs and implicit theories that *underlie* a person's thinking, rather than exactly *what* they may have been thinking. Framed this way, then the accuracy of *what* they were thinking might be of secondary concern for this research study:

> *To the extent that this is true, stimulated recall is not a means of eliciting interactive thought or reflection-in-action, but rather as a means to elicit reflection-on-action. As reflection-on-action, stimulated recall provides access to the ways in which teachers make sense of teaching episodes. It may be an effective way to elicit teachers' implicit theories and beliefs as well as their understandings of the specific patterns of behavior or interaction (Yinger, 1986, p. 273).*

This suggests that stimulated recall may be a productive methodology for illuminating implicit beliefs and theories. Framed as such, it alleviates some of the burden having to do with the fact that we still can never truly know what a person is thinking or was thinking previously. There were also some inconsistencies between pre-service teachers accounts and the observable facts. These inconsistencies became evident when a pre-service teacher

was narrating a scene in the video, in particular moments when they were outlining what was about to happen as the video unfolded. The inconsistency had to do with a discrepancy between what they were predicting would happen, and the content of what actually transpired, pointing to potential moments of inaccurate recall. For example, as one teacher candidate was watching video of a scene in the Maker Faire unfold she comments, "Yeah, look her rocket is going to fail", however as the scene progresses the rocket actually succeeds, leading to the pre-service teacher saying, "Oh, I guess it worked." This occasional error in predicting events is an identified phenomenon associated with stimulated recall (Yinger, 1986). However, despite these moments of discrepancy, there were many other instances where pre-service teachers were accurate in their predictions of what was about to unfold, making a case for accuracy in terms of the recall.

In terms of data, the audio quality in the Maker Faire video recordings was poor, despite having multiple mics located around the room. Given the nature of the event, and number of different people to record, lapel mics were not a feasible option. Though overall the audio is usable, there are a number of instances where a complete, clear, and accurate audio account for certain pre-service teachers is not available. This means that in some cases, comparison of a teacher's recall to the things they actually said during the Maker Faire was not always an option.

In a similar manner, the video was recorded using 2 GoPro camera (and an HD handheld camera) placed strategically throughout the room. While these cameras are good at capturing coarse grain events, they are less able to capture the finer details of subtle interactions such as facial expressions. Similar to the limitations with the audio, this limitation with the video led to some instances where comparison of a teacher's recall to

the things they or children actually did during the Maker Faire was not always an option as the video does not show enough detail.

Finally, it should be noted that Qualitative Content Analysis (QCA) did pose potential limitations for this project. First, the concept driven research questions created a lens for collecting and viewing the data. The pre-design of such lenses may have prevented me from seeing other important and relevant themes as the pre-existing framework that is a hallmark of QCA, may have also acted as a filter for some information, but perhaps not other. Despite measures to bolster trustworthiness in this regard, the strength of QCA is also its limitation.

**Participants**

This study only considered the perspectives of the pre-service teachers of a particular activity group. Because of this fact, it is not possible to say if these findings apply to the experience of the 29 other pre-service teachers who participated in the School Maker Faire. While the study also included the perspectives of the Science Methods course instructor, it excludes the perspectives of parents, students, and other pre-service teachers. These perspectives would be helpful in rounding out factors that influence, and are a product of, interaction in this complex and dynamic environment.

Additionally, the data from this research depends on the accuracy of the accounts from the participants. While questions of validity relating to the stimulated recall process have been addressed above, it should also be considered that the follow-up interviews were dependent on the accuracy of interpreting pre-service teacher thoughts, beliefs, motives, and interactions. Though measures dealing with building rapport and triangulating data

were taken to try and mitigate this dilemma, the accuracy of human accounts remains a considerable limitation to consider.

### Findings

The emergent themes that came from the data may very well be influenced by both researcher bias and the use of QCA which suggest approaching data with a initial conceptual framework. These pre-existing lenses may lead to interpretations of the data that favor certain findings, while missing others.

Pertaining to the research context, this research used a school maker faire, connected with a science methods course in a teacher education program. These factors add up to a significant amount of "static" that may lead to a space that is quite unique in nature, making insights from this context more challenging to apply to other maker faires. Continuing with this logic, school maker faires share similar values to a makerspaces, however they are much more limited in scope and depth of what students and participants will do and engage in. This should be considered when looking at these results. Future research would benefit from replicating this study in a dedicated makerspace or in a classroom which had a dedicated makerspace.

## Conclusion

This qualitative research project applied a case study approach in order to investigate the nature of experience and interactions of four pre-service teachers who took part in planning and facilitating an activity for a School Maker Faire. Additionally, the research aimed to look for evidence of design thinking, as a pedagogical practice, manifested by pre-service teachers in this environment. Data was collected in the form of

stimulated recall interviews and follow-up interviews. Analysis of the data was guided by the following three questions:

- *What is the experience of pre-service teachers in a Maker Faire environment?*
- *How do pre-service teachers interact with children in a Maker Faire?*
- *How do pre-service teachers display their pedagogical understanding of design thinking, in a Maker Faire environment?*

Findings revealed the following four themes as being important influencers of interaction and experience:

5. Pre-Maker Faire preparation
6. Factors that influenced interaction
7. The role of assessment
8. The role of parents

Additionally, evidence illustrates that in some cases there may exist relationships between these themes and a pre-service teacher's level of adopting design thinking. For example, teachers who demonstrated a higher adoption of design thinking as a stance, seemed to use fewer leading questions as a tool for guiding learning and framing interaction. Limitations of this research study suggest that further research would be necessary in order to substantiate these findings to a degree of applicability for practitioners. This research study contributes to the growing literature on maker education and design thinking, as it applies to teacher education.

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## APPENDIX A: INTERVIEW GUIDES

### Stimulated Recall Interview Guide

Developed Feb 2016

Questions aimed at getting a pre-service teacher to take me to moments in the Maker Faire video that stand out:

- Are there any moments that stand out to you? If so, can you help guide me to one of these moments?

- What about what is happening here_____? *(referring to a scene that I had pre-selected as being potentially interesting)*

### Questions aimed at stimulating recall:

- What were is going through your mind in this moment?

- What were you feeling in this moment?

- How were your thinking about this parent/child/teacher?

**Stimulated Recall Interview: Deepening Questions Guide**

Developed Feb 2016

*Questions in this interview are informed by notes taken during the stimulated recall and are aimed to probe reported thinking. All questions can be probed further where needed.*

-What was the Maker Faire like for you? *(aimed at getting a general account of the experience that can then be probed further)*

-What made that particular moment stand out to you? *("that" refers to a scene or interaction that was used as stimulus during the recall interview)*

-Help me relate _____ and _____.
*(use keywords/emotions/phrases to populate the fields for this question)*

**Follow-up Interview Guide**
Developed Feb 2016

*Preliminary rounds of analysis and emergent themes inform questions/prompts in this interview. All questions can be probed further where needed.*

-I noticed that preparation was important for you. Can you tell me more about how preparation for the Maker Faire played a role on your experience?

-Can you tell me a bit about your relationship to science? This can be either formally (coursework/jobs) or informally (interests).

-I noticed that parents were an important part of this experience. Can you tell me more about the role that parents played in your experience at the Maker Faire?

-You mentioned some emotions that came up for you throughout this experience. Can you tell me more about feeling _____? *(Revisit a version of this question for each identified emotion that came from the stimulated recall interview session)*

*-probe these answers to try and uncover where they might come from*

**Science Methods Instructor Interview Frame**
(including teaching assistant input)

Research Questions:

1. *What is the experience of Teacher Candidates in a Maker Faire environment?*
2. *How do teacher candidates interact with students in a Maker Faire?*
3. *How do teachers display their understanding of design thinking pedagogy, in a Maker Faire?*

| Research Question | Interview Question |
|---|---|
| *Q2: How do teacher candidates interact with students in a Maker Faire?* | What are ways that you would hope/expect teachers to interact with participants in this environment? |
| | What would those types of interactions tell you? |
| | What was the range of interactions you observed? |
| | |
| *Q3: How do teachers display their understanding of design thinking, in a Maker Faire?* | So, what was the purpose of the Maker Faire, for you? |
| | How did the Science Methods course work to prepare students for this event? |
| | What were some of the specific strategies, assignments, or activities that TC's engaged in to prepare? |
| | In what ways did the Science Methods course tackle the idea of design thinking? |
| | Did you have any tools that you used to assess their experience at the Maker Faire, either formally or informally? If so, what were these? |

## APPENDIX B: INFORMED CONSENT DOCUMENTS

### Research consent form - Coursework Data

PURPOSE:
You are being asked to participate in a research study. The purpose of the research project is to explore and trace the trajectory of pre-service teacher learning over the course of your involvement in the Teacher Education Program and M.Ed. inquiry.

PROCEDURES:
If you decide to participate, data will be collected from classes and conversations in which you are already expected to participate as required for successful completion of the year long credential program and MEd work. This data will include writings you are asked to do as part of coursework, supervision, or group meeting assignments. These writings might include informal journals and electronic postings, as well as more formal writings from your M.Ed. reports. Data will also include any audio and video recordings of group work and conversations you are asked to do as part of your coursework. You have the right to withhold consent for research and to withdraw from research at any time. Participation in the research will not affect your grades, will have no bearing on your success in the program, and data will not be shared with anyone outside of the research team. Consent forms will be distributed, collected, and recorded by a researcher who is not a current course instructor. No information about consent and no data will be shared with instructors until after grades are submitted. If you elect not to participate you will not be included in any research data. If a non-participant does appear in a recording produced by a research participant, that recording will be excluded from the research.

RISKS:
There are no perceived risks to your participation in this study.

BENEFITS:
The study of teacher learning will benefit the field of teacher education specifically and studies of learning more generally. The hope is this will ultimately benefit the children we aim to educate. The benefits to you personally will not be immediate, as we are not asking you to do anything in addition to what is already required for completion of your credential and MEd work. There is possible benefit to you later, however, when our analysis and findings take shape and can be shared.

CONFIDENTIALITY:
The data from this study (video and audio recordings and texts) will be used to inform our own instruction as well as generate publishable research-related texts, such as articles and books. While names of subjects will be changed in any presentation of the data, absolute confidentiality cannot be guaranteed, since research documents are not protected from subpoena. The data will be used to better understand how teacher candidates learn about teaching and learning. Recordings will be stored on a password-protected hard drive and in

a locked, secure location. When the research has concluded (within the next 10 years), the recordings will be securely destroyed.

RIGHT TO REFUSE OR WITHDRAW:
You may refuse to participate and still receive any benefits you would receive if you were not in the study. Participation is not mandatory and there will be no penalty for not participating in the study. Participation in this research (or decision not to participate) will have no bearing on your success or participation in the Teacher Education Program. You may change your mind about being in the study and quit after the study has started. Additionally, researchers have the right to terminate the your participation in the study at any time.

QUESTIONS:
If you have any questions regarding this research please contact any of the following:

Eva Oxelson: eoxelson@education.ucsb.edu
Jason Duque: jason@education.ucsb.edu
Sean O'Brien sobrien@education.ucsb.edu

If you have any questions regarding your rights and participation as a research subject, please contact the Human Subjects Committee at (805) 893-3807 or hsc@research.ucsb.edu. Or write to the University of California, Human Subjects Committee, Office of Research, Santa Barbara, CA 93106-2050

PARTICIPATION IN RESEARCH IS VOLUNTARY. YOUR SIGNATURE BELOW WILL INDICATE THAT YOU HAVE DECIDED TO PARTICIPATE AS A RESEARCH SUBJECT IN THE STUDY DESCRIBED ABOVE. YOU WILL BE GIVEN A SIGNED AND DATED COPY OF THIS FORM TO KEEP.

Print Name of Participant or Legal Representative:_____

Signature of Participant or Legal Representative:_____

Date:_____ Time:_____

*16-0092*
*Approved by the UCSB Human Subjects Committee for use thru: 2/18/2017.*

**Research consent form - Interviews**

PURPOSE: You are being asked to participate in a research study. The purpose of the research project is to explore and trace the trajectory of pre-service teacher learning over the course of your involvement in the Teacher Education Program and M.Ed. inquiry.

PROCEDURES: If you decide to participate, we will be asking for your participation in 1-3 interview sessions which will take place between now and your graduation from the Teacher Education Program. These interviews will range from 30-45 minutes in duration and will seek to further explore the type of thinking you may have engaged in when making teaching decisions. The person conducting the interview will be a graduate student of Gevirtz Graduate School of Education. In being asked to participate in these interviews, your participation will be purely voluntary. Furthermore, if at the conclusion of an interview (or any point thereafter) you prefer that the data from the interview not be used, you may request its omission and the destruction of any associated data (audio recording, video recording, notes). Should you ask for the omission of interview data, you will not be asked to justify your reasoning.

RISKS: There is a risk that your participation in interviews may ask of you to reflect upon and analyze your teaching decisions in ways that may be uncomfortable to you. You will always have the right not to answer any interview questions, and you further have the right to ask that any/all data collected from any interviews be omitted and destroyed at any point following the interview. Should you ask for the omission of interview data, you will not be asked to justify your reasoning. Also, it is understood that the TEP at UCSB is an intense program that is demanding of your time. Your participation in any interviews will likely be beyond the scope of time where you are asked to be present on campus for coursework. Accordingly, interviews will be kept as brief as possible, be limited in number, and when possible scheduled near times you are already on campus. You will always have the right to decline taking part in any or all interviews.

BENEFITS: The study of teacher learning will benefit the field of teacher education specifically and studies of learning more generally. The hope is this will ultimately benefit the children we aim to educate. The benefits to you personally will be a focused reflection upon your teaching practice. There is also a possible benefit to you later, when our analysis and findings take shape and can be shared.

CONFIDENTIALITY:

The data from this study (which may included: video recordings, audio recordings, and transcripts) will be used to generate publishable research-related texts, such as articles and books. While names of subjects will be changed in any presentation of the data, absolute confidentiality cannot be guaranteed, since research documents are not protected from subpoena. Recordings will be stored on a password-protected hard drive and in a locked, secure location. When the research has concluded (within the next 10 years), the recordings will be securely destroyed.

RIGHT TO REFUSE OR WITHDRAW:
You may refuse to participate and still receive any benefits you would receive if you were not in the study. Participation is not mandatory and there will be no penalty for not participating in the study. Participation in this research (or decision not to participate) will have no bearing on your success or participation in the Teacher Education Program. You may change your mind about being in the study and quit after the study has started. Additionally, researchers have the right to terminate the your participation in the study at any time.

QUESTIONS:
If you have any questions regarding this research please contact any of the following:

Eva Oxelson: eoxelson@education.ucsb.edu
Jason Duque: jason@education.ucsb.edu
Sean O'Brien: sobrien@education.ucsb.edu

If you have any questions regarding your rights and participation as a research subject, please contact the Human Subjects Committee at (805) 893-3807 or hsc@research.ucsb.edu. Or write to the University of California, Human Subjects Committee, Office of Research, Santa Barbara, CA 93106-2050

PARTICIPATION IN RESEARCH IS VOLUNTARY. YOUR SIGNATURE BELOW WILL INDICATE THAT YOU HAVE DECIDED TO PARTICIPATE AS A RESEARCH SUBJECT IN THE STUDY DESCRIBED ABOVE. YOU WILL BE GIVEN A SIGNED AND DATED COPY OF THIS FORM TO KEEP.

Print Name of Participant or Legal Representative:_____

Signature of Participant or Legal Representative:_____

Date:_____ Time:_____

*Approved by the UCSB Human Subjects Committee for use thru: 2/18/2017.*

*16-0092*

**Research consent form - Instructor Consent**

PURPOSE:
You are being asked to participate in a research study. The purpose of the research project is to explore and trace the trajectory of pre-service teacher learning over the course of their involvement in the Teacher Education Program and M.Ed. inquiry.

PROCEDURES: If you decide to participate, data will be collected from classes and conversations in which the teacher candidates are already expected to participate as required for successful completion of the year long credential program and MEd work. This data will include writing they are asked to do as part of coursework, supervision, or group meeting assignments. These writings might include informal journals and electronic postings, as well as more formal writings from their M.Ed. reports. Data will also include any audio and video recordings of group work and conversations they are asked to do as part of their coursework. You have the right to withhold consent for research and to withdraw from research at any time. The teacher candidate consent forms will be distributed, collected, and recorded by a researcher. No information about consent and no data will be shared with you until after grades are submitted.

If you elect not to participate you will not be included in any research data. If a non-participant does appear in a recording produced by a research participant, that recording will be excluded from the research.

RISKS:
There are no anticipated risks of your participation in this study. The data will not be used for evaluation of student learning or teacher effectiveness.

BENEFITS:
The study of teacher learning will benefit the field of teacher education specifically and studies of learning more generally. The hope is this will ultimately benefit the children we aim to educate. The benefits to you personally will not be immediate, as we are not asking you to do anything in addition to what you already do as an instructor. There is possible benefit to you later, however, when our analysis and findings take shape and can be shared.

CONFIDENTIALITY:
The data from this study (video and audio recordings and texts) will be used to inform our own instruction as well as generate publishable research-related texts, such as articles and books. No part of this research will be used for evaluation of student learning or teacher effectiveness. While names of subjects will be changed in any presentation of the data, absolute confidentiality cannot be guaranteed, since research documents are not protected from subpoena. The data will be used to better understand how teacher candidates learn about teaching and learning. Recordings will be stored on a password-protected hard drive and in a locked, secure location. When the research has concluded (within the next 10 years), the recordings will be securely destroyed.

RIGHT TO REFUSE OR WITHDRAW:
You may refuse to participate and still receive any benefits you would receive if you were not in the study. Participation is not mandatory and there will be no penalty for not participating in the study. You may change your mind about being in the study and quit after the study has started. Additionally, researchers have the right to terminate the your participation in the study at any time.

QUESTIONS:
If you have any questions about this research project or if you think you may have been injured as a result of your participation, please contact:

Eva Oxelson eoxelson@education.ucsb.edu
Jason Duque jason@education.ucsb.edu
Sean O'Brien sobrien@education.ucsb.edu

If you have any questions regarding your rights and participation as a research subject, please contact the Human Subjects Committee at (805) 893-3807 or hsc@research.ucsb.edu. Or write to the University of California, Human Subjects Committee, Office of Research, Santa Barbara, CA 93106-2050

PARTICIPATION IN RESEARCH IS VOLUNTARY. YOUR SIGNATURE BELOW WILL INDICATE THAT YOU HAVE DECIDED TO PARTICIPATE AS A RESEARCH SUBJECT IN THE STUDY DESCRIBED ABOVE. YOU WILL BE GIVEN A SIGNED AND DATED COPY OF THIS FORM TO KEEP.

Print Name of Participant or Legal Representative:_____

Signature of Participant or Legal Representative:_____

Date:_____ Time:_____

*Approved by the UCSB Human Subjects Committee for use thru: 2/18/2017.*
*16-0092*