

UCLA

UCLA Electronic Theses and Dissertations

Title

Increasing STEM Exposure in K-5 Schools Through MakerSpace Use: A Multi-Site Early Success Case Study

Permalink

<https://escholarship.org/uc/item/5j3859cf>

Author

Ortega, Veronica Inez

Publication Date

2017

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA

Los Angeles

Increasing STEM Exposure in K–5 Schools Through MakerSpace Use:

A Multi-Site Early Success Case Study

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Education

by

Veronica Inez Ortega

2017

© Copyright by
Veronica Inez Ortega
2017

ABSTRACT OF THE DISSERTATION

Increasing STEM Exposure in K–5 Schools Through MakerSpace Use:

A Multi-Site Early Success Case Study

by

Veronica Inez Ortega

Doctor of Education

University of California, Los Angeles, 2017

Professor Noel D. Enyedy, Co-Chair

Professor Linda P. Rose, Co-Chair

Using Brinkerhoff’s success case methodology, this multi-site case study examined early models of MakerSpace implementation in K–5 schools in a single district. Specifically, this study examined the early use of MakerSpaces as well as the supports and barriers affecting teacher use of these spaces. The study also examined curricular connections and MakerSpace use as a conduit for purveying instruction in the soon-to-be-implemented Next Generation Science Standards.

The findings of this study are based on three sources of data: a survey of teachers in the district querying current usage and beliefs about MakerSpaces; in-depth interviews of seven district principals of schools with MakerSpaces; and nine observations of MakerSpace lessons in

the district. The data were coded by macro themes such as barriers and affordances, as well as themes related specifically to vision and curricular content.

This study showed that MakerSpace practices in the district are not guided by one specific model and that different models of use have emerged: the dedicated teacher model, the insider capacity builder model, and the collaboration model. Additionally, the study revealed a teacher training gap in using MakerSpaces resulting in missed opportunities for grade level-connected learning. However, the study also found that teachers' use of MakerSpaces provides hands-on experiences for students, which provide early engineering exposure. Many of these experiences are supported by a dedicated person in charge of the MakerSpace. The findings suggest a need for a well-articulated plan prior to MakerSpace implementation that includes professional development opportunities for teachers as well as specific curricular and human capital supports.

The dissertation of Veronica Inez Ortega is approved.

Christina Christie

James Stigler

Noel D. Enyedy, Committee Co-Chair

Linda P. Rose, Committee Co-Chair

University of California, Los Angeles

2017

DEDICATION

I dedicate this manuscript to my family...

Yesenia and Yliana: You have provided me with the inspiration to push forward and persevere every day since the day you were born. The women you are becoming make me proud each day.

Mom and Dad: You both showed me the importance of hard work through your actions and words. Who knew that the boy from Tepito and the girl from El Agua Caliente would accomplish what you have?

Christopher: This would not have been done without you loving, pushing, encouraging, and even prodding me. Thank you for your unrelenting support and belief in me.

TABLE OF CONTENTS

ABSTRACT OF THE DISSERTATION	ii
DEDICATION	v
TABLE OF CONTENTS	vi
LIST OF TABLES AND FIGURES	viii
ACKNOWLEDGMENTS	ix
VITA	x
CHAPTER ONE: OVERVIEW OF THE STUDY	1
MakerSpaces: A Possible Way to Improve STEM Outcomes	2
The Study	4
Research Questions	4
Overview of the Research Methods	5
Significance of the Research	6
Public Engagement.....	6
CHAPTER TWO: LITERATURE REVIEW	8
Constructionism: The Historical Underpinnings of MakerSpaces.....	9
Makers and MakerSpaces.....	11
Next Generation Science Standards	12
The Role of Teachers in MakerSpace Use	13
Elementary Teacher Perceptions about Science.....	13
Teacher Self-Efficacy.....	16
The Role of School Principals in MakerSpace Implementation	17
Principal Effects on Schools.....	17
Leadership Style	19
Diffusion of Innovation.....	20
Conclusion.....	23
CHAPTER THREE: METHODS	25
Research Questions and Design	25
Research Questions	25
Success Case Method	26
Research Site Selection and Access	27
District Site Selection	27
Case Study Site Selection.....	29
Site Access.....	30
Data Collection.....	32
Survey.....	32
Observations	33
Interviews	34
Data Analysis	35
Ethical Considerations.....	37
Role Management.....	37
Credibility.....	37
Validity	38
Positionality.....	38

CHAPTER FOUR: FINDINGS	40
Success Case Study 1: Internal Capacity Builder	41
Success Case Study 2: The Collaboration Model	42
Counter Case Study 3: Dedicated MakerSpace Teacher.....	43
Finding 1: How Are MakerSpaces Being Used?	45
MakerSpace Use on Success Case Campuses	45
MakerSpace Use on the Counter Case Campus	47
Finding 2: How Do MakerSpaces Enhance Learning?	48
Centrality of Hands-On Activities.....	49
Observed Hands-On Learning.....	50
Finding 3: How Does the MakerSpace Connect to the Broader Curriculum?	54
Observed Connections.....	54
Risk of Repetition.....	55
Lack of Established Curriculum.....	56
Finding 4: How Do Engineering Practices in MakerSpaces Align with the NGSS?	58
Perceived Relevance of Engineering.....	58
Observed Engineering Practices.....	59
Finding 5: What Facilitates MakerSpace Use?	64
Finding 6: What Are the Barriers to MakerSpace Use?.....	66
Unfamiliar Technology	67
Lack of Professional Development	67
Conclusion.....	69
CHAPTER FIVE: DISCUSSION.....	71
Discussion of Key Findings	72
Different Models of Implementation Have Emerged.....	72
Hands-on Learning in MakerSpaces	76
Connections to the Curriculum.....	77
Engineering Practices in MakerSpaces	78
Dedicated Support in MakerSpaces.....	79
Consistency with Diffusion of Innovation Theory.....	80
Recommendations for Practice.....	82
Inform Teachers of the “Why”	82
Develop a District MakerSpace Task Force.....	83
Develop Teacher Capacity	84
Provide Professional Development Prior to and Concurrent With Use	84
Provide STEM-Rich and MakerSpace-Compatible Curricula	85
Maximize Teacher Use of Time	86
Limitations to the Research.....	86
Recommendations for Future Research	87
Conclusion.....	88
APPENDIX A: TEACHER SURVEY AND FORCED RESPONSE RESULTS	89
APPENDIX B: MAKERSPACE OBSERVATION.....	102
APPENDIX C: PRINCIPAL INTERVIEW PROTOCOL.....	107
APPENDIX D: INFORMATION SHEETS FOR STUDY PARTICIPANTS.....	109

REFERENCES	114
LIST OF TABLES AND FIGURES	
Table 1: Teacher Survey Response Rates	33
Table 2: Survey Question 2: I have received staff development in the use of MakerSpaces	104
Table 3: Survey Question 6: I have received staff development in the NGSS	105
Table 4: Survey Question 7: How often do you use your schools MakerSpace?	106
Table 5: Survey Question 8: Are you working with other teachers on MakerSpace implementation?	107
Table 6: Survey Question 9: The supplies I need for my MakerSpace lessons can be found in my school's MakerSpace	108
Table 7: Survey Question 11: MakerSpaces enhance student learning	109
Table 8: Survey Question 12: Using the MakerSpace is	110
Table 9: Survey Question 13: I am given freedom to try new things in my classroom	111
Table 10: Survey Question 14: It is okay to have a lesson that fails	112
Table 11: Survey Question 15: Science instruction in a high priority at my school	113
Figure 1: Students at Hidden Valley School participating in a robot race.....	39
Figure 2: Golden Springs School students work in groups to create compost bin prototypes	50
Figure 3: Cielo Vista School students work together to assemble a guitar	51
Figure 4: A student at Hidden Valley School tests a parachute.....	52
Figure 5: Hidden Valley School students test range, accuracy, and power of their catapults	53
Figure 6: Compost bin activity guidelines at Golden Springs School	59
Figure 7: Self-evaluation rubric for monster activity at Cielo Vista School	60
Figure 8: Description of Peep catapult challenge	61
Figure 9: Accuracy evaluation form for catapult lesson at Hidden Valley School	61
Figure 10: Jack and the Parachute activity sheet at Hidden Valley School.....	62
Figure 11: Poster describing the engineering design process at Hidden Valley School.....	63

ACKNOWLEDGMENTS

This journey and its culmination would not have been possible without the support of many people. To those who supported, encouraged, provided feedback, and believed that I could undertake this task—thank you.

To my co-chairs, Dr. Linda Rose and Dr. Noel Enyedy... Thank you for your support, feedback, and time. Dr. Enyedy, your outside-the-box thinking provided me with needed perspective. Dr. Rose, throughout these last three years your leadership has provided me with an ELP experience that allowed me to grow as a leader and as a scholar.

To my committee members, Dr. Tina Christie and Dr. James Stigler... Your creativity and engagement helped my study develop clarity and focus.

To the principals who gave me the opportunity to learn from them in this project... I am honored to work with you. To the teachers who opened their doors for me to learn from them through this study... Your students are fortunate to have such innovative and caring teachers in their lives.

To the members of Cohort 22, Double Deuce... Thank you for your support and wisdom, and thank you for the memories.

To my family... Thank you, Mom, Dad, Yesenia, and Yliana for the patience you have had throughout this process. I know the demands of this journey took time away from you. You are my biggest inspiration, and I thank God each day for you.

To Christopher... You have been my rock, coming into my life and showing me the meaning of partnership and support. Thank you for being my biggest cheerleader.

To the students who are the future engineers and inventors of our world...

VITA

EDUCATION AND TRAINING

- 2003 Bachelor of Arts in English with a concentration in Education
University of Maryland University College (Adelphi, Maryland)
- 2006 Master of Arts in Education
Azusa Pacific University (Azusa, California)
- 2007 South Coast Writing Project Fellow
University of California, Santa Barbara
- 2014 Units of Writing Institute
Columbia University (New York, New York)

PROFESSIONAL EXPERIENCE

- 2003–2004 Teacher
St. Anthony School (Oxnard, California)
- 2004–2008 Teacher
Monte Vista Middle School (Camarillo, California)
- 2008–2012 Assistant Principal
Las Colinas Middle School (Camarillo, California)
- 2012–2017 Principal
Pleasant Valley School District (Camarillo, California)

CHAPTER ONE:

OVERVIEW OF THE STUDY

The acronym STEM, which stands for science, technology, engineering, mathematics, has become commonplace in the K–12 setting as a result of industry’s call to action to produce a STEM-capable labor force (California Department of Education, 2014; Carnevale, Smith, & Melton, 2011; Olson & Riordan, 2012). At the crux of the issue is the underperformance of American students of all socioeconomic levels in science and mathematics: Among the 34 member countries in the Organisation for Economic Co-operation and Development (OECD), whose students participate in the Programme for International Student Assessment (PISA), American students rank 28th on the Program for International Student Assessment. Even when controlled for socioeconomic factors, the results among non-disadvantaged students are equally daunting (Blank, 2012; Hanushek, Peterson, & Woessmann, 2012). This, coupled with a lack of engagement in STEM, has historically led to fewer students pursuing postsecondary STEM education and careers.

President Obama (2009) decried the need for Americans to not just be consumers of things but to be *makers* of them. With the introduction of House Resolution 1020, the STEM Education Act of 2015, the political levers have further applied pressure on educators to build systems wherein K–12 students receive STEM exposure. The development and implementation of the Next Generation Science Standards (NGSS) was a response to this call for action with the goal of increasing STEM capacity within our schools. Indeed, some have utilized the STEM crisis as a way to develop school programs that coalesce with the highly publicized STEM shortage. The ultimate goal of these efforts is to expose students to STEM-rich educational experiences, thereby increasing future STEM capacity in students.

MakerSpaces: A Possible Way to Improve STEM Outcomes

Some schools have adopted a STEM focus to address the needs outlined above, while others have adopted structural solutions to this problem, such as through the incorporation of school MakerSpaces—physical spaces that emphasize learning by making. These are collaborative spaces where like-minded people come together to make things (Hatch, 2013, as cited in Schön, Ebener, & Kumar, 2014). Heralded as innovation spaces, MakerSpaces are equipped with various tools and technologies that allow people to explore and innovate, thereby creating an intersection of constructionism and creativity. Such spaces are being incorporated into schools and libraries and are viewed as highly compatible with the outcomes described within the Common Core State Standards (CCSS) and the NGSS (Fontichiaro, 2014; Hira, Joslyn, & Hynes, 2014).

The Maker Movement was born from Papert's (Donaldson, 2014) constructionist theory, which espouses that learners construct meaning by engaging with the environment and through hands-on learning experiences (Donaldson, 2014; Schön et al., 2014). Makers create, design, innovate, and explore do-it-yourself projects (Peppler & Bender, 2013). MakerSpaces allow students to explore project-based learning or employ design thinking to make meaning of content. Campuses with MakerSpaces can provide a conduit for meaningful, hands-on, contextualized STEM experiences.

Due to the newness of this idea, however, there is little guidance for school administrators in developing the use of MakerSpaces. The incorporation of these spaces has the potential to articulate with the objectives of the NGSS, provided that school conditions support this alignment. Conversely, if not purposefully planned, MakerSpaces can become arts and craft time in schools, a missed opportunity for STEM articulation; Blikstein (2013) cautioned

educators against this type of simplified educational experience, which can devalue the potential of MakerSpaces.

The relative novelty of MakerSpaces and a lack of defined objectives have resulted in school administrators struggling with their purposeful implementation. Without an established set of best practices or practices worthy of attention, school leaders with newly implemented MakerSpaces face ambiguity ensuring purposeful implementation. This is further compounded by constraints surrounding teacher capacity to utilize these new spaces. The hands-on experiences teachers are expected to provide in MakerSpaces are predicated on an understanding of general engineering practices found in the NGSS. While some schools have provided teachers with professional development that increases their capacity to provide hands-on STEM experiences, others have not; instead, they rely on specialists to provide students with weekly STEM exposure (Sikma & Osborne, 2014).

Inherent in the NGSS is a dimension that requires K–12 teachers to teach engineering practices and develop hands-on lab experiences. While teachers have a long history of incorporating projects into their instruction, the specific use of project-based learning to develop content is not widespread. In project-based learning, students conduct investigations to find answers or solutions to inquiries (Barrel, 2007). Since teachers have minimal training in these areas, establishing opportunities to build capacity and self-efficacy will be an important component of this shift. Exploring models of early success in MakerSpace implementation can help school leaders to define, guide, and focus MakerSpace efforts to support stronger STEM and critical thinking outcomes for students

The Study

The use of MakerSpaces in schools, particularly at the elementary level, is emergent. Therefore, capturing the practices of early success sites can provide information for future implementers in similar settings. This information can be ascertained utilizing Brinkerhoff's (2003) success case methodology. In this methodology, early success models are identified, as are cases that have demonstrated challenges in implementing an initiative—referred to as counter cases. The model is predicated on discovering the successes and challenges of the initiative with the underlying assumption that this information can guide future steps, including course correction if needed.

In this study, I have identified these models within a school district that has relatively recently incorporated MakerSpaces on all of its campuses. This model employed a qualitative methodology based on Brinkerhoff's (2003) model. A quantitative study alone cannot inquire deeply enough into the descriptors of practices I sought to identify in the early success models. Merriam (2009) discussed the importance of utilizing thick description, and given the undefined landscape of MakerSpaces in K–5 settings, this required detailed description. The incorporation of school MakerSpaces to support STEM instruction is largely undefined and therefore school leaders can learn from these early success models.

Research Questions

The following research questions guided my study:

1. According to teachers and principals, what are MakerSpaces and how are they being used in schools?

2. According to teachers and principals, what are the conditions (structural and cultural) and affordances that are conducive to teacher use of MakerSpaces to provide NGSS-based instruction?
3. According to teachers and principals, what are the barriers that impede the use of MakerSpaces?
4. What are the observational indicators of hands-on, NGSS-based teaching and learning in early success models of MakerSpace implementation that principals can use to guide next steps?

Overview of the Research Methods

I employed Brinkerhoff's (2003) success case methodology, which focuses on learning from success case models to improve and inform next steps of an initiative through methods including interviews, observations, and surveys. Within the school district under study, early success models had already been identified, and these served as the research sites. A survey of teachers delved into their MakerSpace experiences and provided information about the current use patterns of MakerSpaces.

I also interviewed K–5 principals in the district to gather information about the barriers they perceived as hindering teachers from using MakerSpaces. These interviews also probed into the instructional practices and objectives they perceived as coalescing with the use of MakerSpaces. The interview data were coded into several categories including challenges and successes, conditions present on the campus, and specific leadership actions conducive to MakerSpace use.

Finally, I observed MakerSpace lessons at three school sites. I used an observation protocol that documented the setting, participant actions, tools, explicit and implicit learning

objectives, and NGSS engineering practice within the lessons. I drew on these data to triangulate findings from the survey and interviews of principals.

The district that participated in the research was well positioned for the study, given the allocation of resources toward the creation of the MakerSpaces and the fact that the district superintendent was committed to the approach and expected it to improved STEM outcomes. This commitment was further evidenced through the incorporation of district teachers on special assignment (TOSAs) for both STEM and MakerSpace implementation, as well as the allocation of MakerSpace instructional assistants on all campuses. Finally, teachers were expected to begin implementation of the NGSS district-wide; this provided an additional impetus for conducting this study.

Significance of the Research

My study contributes to the body of research related to improving STEM outcomes for K–5 students and adds to the limited body of literature related to MakerSpace implementation on school campuses. More importantly, as schools seek to provide clear outcomes and programmatic objectives of STEM-oriented schools, this process will inform a consistent standard regarding the use of MakerSpaces throughout the district I studied, particularly in the incorporation of the engineering practices inherent in the NGSS. Further, as many schools will be charged with implementing the NGSS, those outside the studied district that are incorporating MakerSpaces can use information from these early success models for implementation of the new standards within the MakerSpace environment.

Public Engagement

An executive summary of the findings from this study will be disseminated to key stakeholders in the district that I studied. These include the superintendent, the assistant

superintendent of educational services, the director of curriculum and instruction, and all district school principals. Pending approval from the superintendent's office, findings may also be shared with other districts that seek information about MakerSpace implementation and use.

CHAPTER TWO: LITERATURE REVIEW

From Henry Ford's Model T to the launching of Sputnik in the 1950s, STEM has been a topic of a national conversation about the development of a capable and globally competitive workforce. But when compared internationally, U.S. students are not making significant growth in mathematics and science. The 2011 Trends in International Mathematics and Science Study, a test administered internationally every four years, revealed that U.S. students made negligible growth on math measures in Grade 8 and on science measures in Grades 4 and 8, as compared to their international counterparts (Stephens, Landeros, Perkins, & Tang, 2016). Findings from the Program for International Student Assessment show a similar trend, with American students ranking in the lower decile of the 34 tested countries (Blank, 2012; Hanushek, Peterson, & Woessmann, 2012).

These statistics have created political fodder that fuels demands for K–12 education to address the reported underperformance of American students in STEM. Likewise, industry has implored the educational community to develop a solution to the shortage of STEM-qualified workers, as the shortage has led to the recruitment of a STEM-ready labor force beyond our borders (California Department of Education, 2014; Carnevale et al., 2011; Olson & Riordan, 2012). In working toward meeting this need, schools have adopted various approaches, including the incorporation of MakerSpaces to build STEM capacity in students. Within this new landscape, administrators with proposed or newly implemented MakerSpaces are at a critical juncture in defining how to best support their use.

In examining this problem, it is important to provide background from the extant literature that defines and provides the genesis of the Maker Movement and MakerSpaces. First,

I discuss constructionism, the theory that undergirds the Maker Movement. I then explore the term *maker* and discuss MakerSpaces and their connections to constructionism. I also discuss educational practices such as project-based learning that have sought to increase student outcomes through hands-on learning.

In this chapter I also provide background on the Next Generation Science Standards and discuss how they connect to MakerSpaces. I describe the role of teachers and the theory of self-efficacy, applying this background to the use of MakerSpaces as a conduit for NGSS-aligned lessons. I then examine the literature on the crucial role of school principals in leading school change for improved student outcomes, focusing on specific leadership actions and the role of school principals as change agents, particularly through diffusion of innovation theory.

Constructionism: The Historical Underpinnings of MakerSpaces

Learning by doing or *learning by making* are terms found within the literature of constructionism. Constructionism is often confused with constructivism, a related theory developed from the work of Piaget and others such as Dewey, Vygotsky, and Bruner. *Constructivists* assert that learning is an active process in which we construct meaning from our experiences; the concern is with the internal processes by which an individual constructs personal meaning and learning (Ackermann, 2011). *Constructionism* is a theory of learning created by Papert that takes constructivism to a tactile, kinesthetic domain (Papert & Harel, 1991).¹

Papert (1980) promulgated the idea that there is a binary in learning, particularly in schools, where instructivism is preferred over its countertheory, constructionism. Instructivism

¹ Papert was reluctant to ascribe a canned definition to constructionism because he found that doing so was counterintuitive, as each person should construct his or her own definition (Papert & Harel, 1991).

is predicated on the teacher as the purveyor of knowledge to be deposited to students.

Constructionism, on the other hand, proclaims that learning by doing creates true meaning; as a learner actively engages with his or her environment through hands-on, meaningful experiences, learning is contextualized (Papert & Harel, 1991). Referring to its hands-on nature, Ackermann (2011) described the making of meaning through learner interactions with different technologies, tools, and processes. In this way, the learner creates products that convey learning to others. Likewise, Donaldson (2014) described constructionism as bringing “creativity, tinkering, exploring building, and presentation to the forefront of the learning process” (para. 1).

Through several school interventions related to constructionist practices in math, and through the use of technology in educational settings, Papert (1980) explored his theory in learning spaces. For example, former Maine Governor Angus King Jr. commissioned Papert to create the Constructionist Learning Lab (CLL) in an effort to engage a group of adjudicated youth in a Maine juvenile detention center. The CLL employed technology and hands-on innovation and gave its users license to construct and innovate.² Papert’s constructionism and the CLL are perfectly aligned with the ideals of MakerSpaces, which are places where problem- or project-based learning can flourish.

Project-based learning is “an inquiry process that resolves questions, curiosities, doubts, and uncertainties about complex phenomena in life” (Barell, 2007, p. 3). It is an instructional method used to engage students in learning and foster self-motivated inquiry. In turn, students are expected to actively participate and take ownership of their learning. In such a curriculum, students spend time investigating, analyzing, and collaborating to solve an ill-structured problem.

² Over a three-year period, the rate of recidivism for users of the lab was 14%, in comparison to the general population of the youth detention center, which for the same period was 70% (Stager, 2013).

They engage in research and discuss and revise their solution strategies while the teacher facilitates rather than guides the process (Trinter, Moon, & Brighton, 2015, p. 27).

Students can explore solutions to these problems through the utilization of design thinking, which was first developed at Stanford University and has since been adapted by educators. Design thinking is a way for students to create solutions and innovations through hands-on experiences; a scaffold guides students from an understanding of a problem and its affected people to the ideation, creation, and prototyping of a solution (Carroll, et al., 2010). A 2010 ethnographic study by Carroll et al. found that the use of design thinking in middle school classrooms yielded increased engagement and conceptual understanding. MakerSpaces provide an ideal setting to employ these practices.

Makers and MakerSpaces

Although the literature on the concept of hands-on learning is not limited, the literature on MakerSpaces currently is. Martin (2015), Dougherty (2013), Blikstein (2013), and Schön et al. (2014) agree that makers are people who value tinkering, creating, do-it-yourself processes, and problem solving through hands-on experiential learning. The term maker was coined by the readers of *Make*: magazine, created by Dale Dougherty in 2005. The magazine highlights various do-it-yourself endeavors and has become a community of sorts for tinkerers. Maker Faires that showcase and share opportunities for makers have emerged nationwide; in 2014, the White House hosted its first Maker Faire. The MakerSpace movement grew from these efforts as communities created collaborative spaces for maker activities.

While the term MakerSpace is relatively new, similar concepts have been in existence for some time. The Fab Lab at the Massachusetts Institute of Technology was created with the premise that if individuals had access to a space that contained the right tools, they would create

amazing products (Blikstein, 2013; Dougherty, 2013). The CLL, described above, is similar in concept (Hira et al., 2014).

MakerSpaces are sometimes housed in public libraries as well as in school settings. Steele (2015) described the transformation of libraries into MakerSpaces, in part to revitalize the school library, which has experienced a decline in use. Across the nation many libraries within and outside of schools are following suit. These spaces are equipped with a variety of tools and technology that users can employ in creating or designing products. Martin (2015) described a collaborative setting in which people use traditional hand tools as well as digital tools such as 3D printers and computer numerically controlled (CNC) machines. Such spaces are now growing in use. Between 2006 and 2016 the amount of MakerSpaces in the United States grew by fourteen times (Lou & Peek, 2016).

Next Generation Science Standards

In 2011, the National Research Council developed the *Framework for Science K–12 Education: Practices, Cross Cutting Concepts, and Core Ideas* as a response to the continued call for improved science outcomes. The framework became the foundation for the NGSS, which were developed by a consortium of 26 states (NGSS Lead States, 2013). Because of the access to tools and technology, the MakerSpace environment is highly conducive to instruction of the NGSS (Hira et al., 2014).

The standards are organized into three dimensions that culminate in specific performance expectations. The first dimension is *practices*, which draws on the specific skills and processes that scientists engage in when conducting scientific inquiry and investigations. The second, *cross cutting concepts*, is centered on the overarching concepts that can increase student understanding of content. In the NGSS, these are specifically defined as patterns; cause and

effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change. The third dimension, *disciplinary core ideas*, defines the content within the specific scientific domain of study (life science, earth and space science, physical science, engineering, technology, and application of science). While life science, earth and space science, and physical science have long been a part of the K–12 science curriculum, the arrangement of these scientific strands has changed with the NGSS.

Previously in secondary grades (Grades 6–12), a course of study occurred in a particular grade level. The organization of the domains is now integrative and recursive, with each grade level covering the different domains each year building upon the last. New to the progression is the interpolation of the engineering and technology domain. It is precisely the learning expectations in the latter domain that MakerSpaces are well equipped to address. But without the content to make these connections, MakerSpaces could become a missed opportunity for contextualized learning. I discuss this and related issues in the sections that follow.

The Role of Teachers in MakerSpace Use

Elementary Teacher Perceptions about Science

The NGSS framework was released in 2015. Many districts are moving towards gradual implementation, and the standards will be fully adopted in California in the 2018–2019 school year. Teachers who were not trained in purveying hands-on science, particularly at the elementary level, will need support to increase their capacity in teaching these standards. A 2014 study by Sikma and Osborne documented the transformation of a traditional K–5 campus to a STEM-focused campus. They found that teachers self-reported apprehension involving STEM content, particularly that which involved engineering practices.

Teacher preparation programs will be charged with the redesign of science methods courses to meet the NGSS, and Bybee (2014) postulated that professional development aimed at current teachers will be necessary to bridge conceptual gaps in science instruction. Fulp (2002) described the results of the 2000 National Survey of Science and Math Education (NSSME), elucidating that 72% of teachers self-reported the need to increase or deepen their own science content knowledge and 84% wanted to learn how to use technology in science instruction. The 2012 NSSME revealed that only 39% of elementary teachers felt prepared to teach science, in stark contrast to roughly twice as many who felt they were prepared to teach math (77%) and reading (81%) (Banilower, et al., (2013).

With the implementation of the NGSS, these needs will continue, becoming more punctuated by the increased rigor of these standards. Increasing elementary teacher self-efficacy in science content will be an important step. Deniz and Akerson (2013) found in their exploration of elementary teachers' self-efficacy in nature of science inquiry (NOSI) that NOSI increased when teachers were exposed to a professional development program that linked their capacity in language arts, a familiar domain, with instruction with NOSI. In their 2012 study on elementary teacher capacity in science instruction, Heller, Daehler, Wong, Shinohara, and Miratrix found that when teachers with limited conceptual knowledge on the topic of circuitry were exposed to a robust intervention on this content, the effect on student outcomes measuring this content was significant ($p < 0.001$). In other words, the link between increased teacher content knowledge in science and student outcomes is strong.

As school leaders work towards the implementation of the NGSS and address the expectation that teachers will incorporate engineering practices at the K–12 level, they will need to find ways to support teachers. While, as noted above, 39% of teachers said they felt prepared

to teach science, when broken down by science disciplinary core idea, elementary teachers reported feeling more prepared to teach earth and life science. While physical science was not a clear area of self-reported strength, elementary teachers reported feeling least prepared to teach engineering—73% said they were not adequately prepared to do so (NSSME, 2012, p. 24).

With the NGSS significantly altering previous performance expectations in science for K–12 students, professional development for teachers to stay current is critical. However, the NSSME (2012) revealed that, in the previous three years, 65% of elementary teachers reported less than six total hours of professional development related to science instruction. This mirrors the frequency with which they instructed science in their classrooms, with 41% of K–3 teachers reporting that they did not teach science every week, and 32% of Grade 4–6 teachers reporting the same.

Another interesting finding from this national survey demonstrates the reliance on instructional materials by elementary teachers. When asked if they used the textbook/module to guide the overall structure and content emphasis of the unit, 77% of elementary respondents stated they did, compared with 64% of high school teachers. Similarly, 65% of elementary respondents stated they followed the textbook/module to guide the detailed structure and content emphasis of the unit, compared to 45% of high school teachers (NSSME, 2012). Without the content knowledge to guide curricular design, teachers are more likely to rely on curriculum to compensate for lapses in content knowledge. The role of robust instruction in science content, both in teacher preparation programs and through continued staff development for veteran teachers, cannot be overemphasized. Increasing teacher sense of self-efficacy in science instruction is a critical step in the improvement of STEM student outcomes. I turn to this next.

Teacher Self-Efficacy

Albert Bandura's (1977) theory of self-efficacy is concerned with people's beliefs about their capacity to perform at certain levels. Bandura proposed that there are specific factors that influence whether a person believes that he or she can undertake a challenge: performance accomplishments, vicarious experience, verbal persuasion, and physiological states. Within the scope of MakerSpace implementation on K-5 campuses, mastery is something that will take time, as the objectives and parameters surrounding MakerSpaces as a conduit towards NGSS instruction are not truly defined. That said, if teachers are provided with opportunities to develop lessons within this domain and those lessons are successful (performance accomplishments), it is plausible that they will feel more capable (Ross, Cousin, & Gandalla, 1996).

Bandura (1977) further proposed the influence of social models (vicarious experiences) as a conduit for self-efficacy. Bandura posited that when people see others (models) similar to themselves succeed at a given endeavor, the sense of being able to accomplish the same endeavor is increased. Within the scope of MakerSpace implementation, allowing teachers to observe other teachers' lessons may validate this assumption. Principals can provide teachers with time to observe and collaborate with one another as they seek to incorporate the use of MakerSpaces.

According to Bandura (1977), persuasion is also influential in building self-efficacy, and self-doubt can easily undermine it. Thus, in designing MakerSpace experiences, it is essential for principals to provide entry-point activities at which teachers can succeed so as to create positive perceptions of their capacity within the MakerSpace. If several teachers feel successful in the activities they facilitate, the degree of social persuasion that other teachers can also

experience success is likely to be greater; those who have experienced the success will positively encourage their peers that they too can do it. Conversely, if very few teachers experience success in MakerSpace lessons, it may build the idea that outliers are the only ones who will be successful in the new endeavor.

Finally, Bandura (1977) theorized that the emotional (physiological) state of a person has a direct influence on whether they believe they can be successful at a task. In his meta-analytical study of classroom technology use since 1920, Cuban (1986) discussed lack of teacher technical skills as an obstacle to the use of technology in the classroom. By reducing obstacles such as this—and by making initial expectations connected to MakerSpace implementation attainable—school principals can help to counteract feelings of stress connected to MakerSpace use for teachers.

The Role of School Principals in MakerSpace Implementation

Principal Effects on Schools

The influence of the school principal on student achievement resonates throughout the literature on school leadership (Leithwood & Jantzi, 1999; Waters, Marzano & McNulty, 2003; Griffith, 2004). Second only to classroom instruction, the role of the principal is a critical driver toward student achievement (Sheppard, 2013; Leithwood, Seashore Louis, Anderson, & Wahlstrom, 2004). The principal's role has become bifurcated, however, with a need for instructional leadership and site management. Administrators are charged with accomplishing both tasks with the ultimate goal of improving student outcomes.

A 1999 study conducted by Leithwood and Jantzi found “transformational leadership had strong direct effects on school conditions (.80) which, in turn, had strong direct effects on classroom conditions (.62)” (p. 467). Griffith (2004) pointed to the indirect effect of principals

on student achievement as caused by the direct effect principals have over working conditions. In his study of 117 schools located in the suburbs of a large metropolitan area, he analyzed the path between transformational principal behavior and student performance and staff turnover. He concentrated on three components that he ascribed to transformational leadership: charisma and inspiration; individual consideration of staff needs; and intellectual stimulation of staff through growth opportunities.

The three components that Griffith (2004) highlighted are critical to an examination of school conditions related to MakerSpace implementation. To move the vision of MakerSpaces forward, the principal needs to *inspire* staff towards the vision. Moreover, the success of MakerSpace implementation is largely predicated on meeting the *professional needs* of the instructional staff. An analysis of teachers querying areas of needed support will yield important data for principals to plan support for teachers in MakerSpace implementation and use. Additionally, professional development targeted towards meeting teachers' individual growth needs will provide the *intellectual stimulation* espoused by Griffith as an important dimension.

Like Griffith (2004), Waters, Marzano, and McNulty (2003) highlighted the connection between intellectual stimulation of staff and positive student outcomes, with an effect size of .32. Among the 21 attributes they found to directly influence student outcomes were order and curricular knowledge, with effect sizes of .26 and .24, respectively. They defined order as structural conditions including procedures and routines.

While Waters et al. (2003) cited curricular knowledge among principals as important, this area has not been extensively discussed within the literature. Fink and Resnick (2001) noted the dearth of professional development focused on principals. They pointed to the job demands of managerial and administrative tasks required of principals as obstacle in obtaining professional

development in instructional leadership. They described a multi-faceted professional development district program designed for site leaders to increase instructional leadership. Spillane, Diamond, Walker, Halverson, and Jita (2001) explored the importance of increasing human capital in elementary science leadership through principal staff development. They discussed the inculcation of a district culture of learning wherein the principal is also considered a learner. Further, they promulgated the importance of school leaders understanding district initiatives in order to effectively guide teachers in programmatic implementation.

Leadership Style

The leadership style of a principal is also highly relevant to the success of any new initiative. Cuban (1986) discussed several unsuccessful attempts at classroom innovations that were implemented “top down” without input from teachers. He proposed that by making innovations relevant to teacher practice and ensuring that they are “reliable, durable and versatile” (p. 66), leaders can lay groundwork that is more conducive to teacher adoption of an innovation.

Relatedly, the specific actions of principals are also important in student success initiatives. In their 2008 study, Gerard, Bowyer, and Linn investigated the importance of principal leadership in the implementation of curricular initiatives. Specifically, their study examined the use of a technology-based science curriculum, which a group of principals worked collectively to learn and implement at their sites. Over the course of three years they met as a study group to share ideas and discuss specific leadership actions related to the implementation of the curriculum. The researchers found that principal understanding of the new curriculum improved and that their science content knowledge increased. As a result, the principals became more capable instructional leaders working to support teacher practice.

Gerard et al. (2008) further discovered the principals shifted from a managerial focus—for example, observation of staff in the implementation of the curriculum—to a collaborative role in which they shared ideas and instructional techniques with the science teachers in the classrooms they observed. The paradigm shifted their leadership practices, in that the principals aligned their priorities to support the science innovation they observed in classrooms. They became the fulcrum balancing the needs of staff and students in the adoption and implementation of the new curriculum.

The importance of professional development for principals—not only to increase individual capacity but also to serve as a conduit for increasing the instructional capacity of teachers—was a key finding in a study by Gerard, Bowyer, and Linn (2010). They found that “Principals are eager for the opportunity to develop their capacity as leaders for technology and to focus attention on improving science instruction” (p. 174). The effectiveness of principals to navigate new initiatives together was an important finding of their work.

The success of an innovation is largely predicated on the culture that the principal helps to create. The principal, as the lead learner, models this process and helps to “create a culture of innovation will only work fully and effectively if the initiative is able to claim commitment from the top of the organization” (Robinson, 2011, as cited in Fleming, 2015, p. 58). As I discuss in the next section, Rogers’s (1962, 2003) diffusion of innovation theory reveals the path for adoption of an initiative in an organization.

Diffusion of Innovation

In developing his theory that would come to be known as diffusion of innovation, Rogers (1962, 2003) proclaimed that, “In spite of Americans’ generally favorable attitude towards science and technology, a considerable *time lag* is required before an innovation reaches wide

acceptance” (1962, p. 2). This remains a reality when an organization chooses whether to adopt an innovation. In the development and implementation of school MakerSpaces, there are stakeholders who will readily accept the innovation and those who will question whether adopting it is the correct decision. As the leaders of the school who are responsible for ensuring that an innovation is adopted, principals must work with all stakeholders in realizing this change.

Rogers (1962) proposed that the adoption process consists of different phases—awareness, interest, evaluation, trial, and adoption—which can be applied to MakerSpace implementation on school campuses. The initial information or *awareness* phase comes from different conduits such as site leaders and district leaders. A leader whose message inspires during the awareness phase of MakerSpaces sets a positive tone for the innovation and can create *interest*. In the *evaluation* phase, educators contemplating adopting MakerSpaces into their practice weigh the benefits and risks of the innovation by talking with opinion leaders they trust. This can result in a *trial* phase, which could include trying maker activities within their individual classrooms or, if on a campus with a MakerSpace, attempting the activities in that space. The success of the trial is a predictor as to whether the innovation will be *adopted*. Leaders must make sure that during this trial phase teachers are supported in their initial attempts. Support may be in the form of ensuring that structural conditions are optimal and cultural conditions are conducive to success.

The rate of adoption varies within each group, and Rogers (1962) theorized that individuals contemplating adopting an innovation fall into one of five categories: innovators, early adopters, early majority, late majority, and laggards. In the examination of the proposed categories of adopters that Rogers posits, teachers considering MakerSpace implementation fall into the same categories. Within the first phase of schools using MakerSpaces, some teachers

will move directly into the innovation as early adopters, while others may be resistant towards the change, possibly becoming the laggards in this particular situation. Principals must work with all members in their efforts to promote the innovation.

Rogers (1962) posited that potential adopters weigh several factors in considering the innovation, including relative advantage, complexity, trialability, and observability. First, with respect to *relative advantage*, the culture of the organization considering the innovation is an important factor, and one over which leaders have a considerable amount of influence. Rogers punctuated that compatibility of the innovation with the norms and practice of a given community is critical. As teachers and school leaders consider the role of MakerSpaces within their campuses and as a part of their professional practices, the norms of the organization are important to consider.

Further, Rogers (1962) discussed the importance of considering the *complexity* of an innovation. MakerSpaces, as a relatively new addition to the educational sphere, present as more complex environments due to the technology that is embedded within them. In order to provide teachers with an attainable access point, a trial period, which Rogers termed as *trialability*, is crucial. The results of the trial, whether formal or informal, can be communicated to potential adopters and stakeholders. Leaders can build momentum through the messaging based on the *observability* of these results

The role of change agent, as proposed in Rogers's theory, is the person who "attempts to influence adoption decisions in a direction that he feels is desirable" (1962, p. 254). Principals are charged with implementing MakerSpaces on school sites successfully, thereby becoming the change agents. Rogers (1962) found a correlation between the promotional efforts of an innovation by the change agent and its adoption. Likewise, using diffusion of innovation theory

as a lens, Polizzi (2011) studied the role of principals in promoting the use of information communication technologies (ICT). Polizzi found that the principal played an important role and had strong influence on the diffusion of this innovation, particularly based on attitudes and beliefs about ICT. A 2015 study by Stieler-Hunt and Jones examined the adoption of digital games play in classrooms through diffusion of innovation theory. They found that because teachers needed to experience individual success to find the innovation valuable, this led to a slower diffusion of the innovation

Principals can develop a vision for the use of MakerSpaces on their campuses that provides teachers with well-defined support in purveying NGSS-aligned instruction. According to diffusion of innovation theory, when principals provide the tools for teachers to increase individual capacity in STEM instruction using MakerSpaces, the diffusion of the innovation will occur through informal communication with opinion leaders, successful trials, and ultimately adoption.

Conclusion

K–12 science education is in the midst of a transformation. Previous pedagogy is being replaced, driven by a combination of calls from industry for K–12 educators to strengthen STEM preparedness, coupled with political pressure to increase STEM achievement. The traditional programs that were the foundation of science instruction in K–12 no longer produce outcomes that support industry’s personnel needs, causing talent to be imported from nations with a more robust pool of STEM applicants.

The Next Generation Science Standards were developed to address the future landscape of STEM education in the United States. They provide the opportunity for K–12 educators to reimagine science instruction and align it with the needs of a changing world. With an emphasis

on hands-on exploration and processes beginning in early elementary school, and with the first-time integration of engineering principles, educators are charged with finding ways to increase their capacity to provide this instruction. They are being asked to provide instruction that may not mirror their previous exposure to STEM as students or teachers.

The constructionist learning opportunities that are the foundation of MakerSpaces are predicated on building self-efficacy in teachers using MakerSpaces. Diffusion of this innovation begins with early adopters and continues to spread through the development of teacher self-efficacy in purveying successful experiences in MakerSpaces. Transformational leaders must both inspire early adopters to take those first steps and create the culture and conditions for the innovation to diffuse all the way to the late adopters—the laggards. As teachers grow in their individual capacity to provide STEM experiences, MakerSpaces have the potential to provide a conduit for them to explore different ways of conveying STEM content.

Educators are in the midst of a transition from a book study model of science instruction to a more dynamic applied science model. Due to their hands-on nature, MakerSpaces are perfectly positioned to support this instructional metamorphosis. The successful implementation and support of school MakerSpaces by instructional leaders can help create the conditions for more connected and applied STEM instruction leading to a globally competitive, STEM-ready workforce.

CHAPTER THREE:

METHODS

The rate at which science and technological advances are occurring requires schools to revisit pedagogy and content to ensure students are prepared for a quickly evolving world. One of the ways that schools are working towards increased STEM exposure for students is through the development of the Next Generation Science Standards, which stress the importance of hands-on investigation and have a focus on engineering principles.

In working to address these new demands, some districts are interpolating MakerSpaces, which can provide a conduit for meaningful NGSS-aligned, hands-on experiences, provided school conditions support it. But due to the newness of this idea, there may be little guidance for school administrators in developing MakerSpaces to meet NGSS guidelines. In designing a system to support the purposeful implementation and use of MakerSpaces administrators need to examine the conditions and supports on their campuses.

Research Questions and Design

Research Questions

The identification of school site conditions and practices worthy of attention in early success models of MakerSpace implementation and use can help to inform principals' next steps with newly implemented or underutilized MakerSpaces. With this in mind, the following research questions guided this study:

1. According to teachers and principals, what are MakerSpaces and how are they being used in schools?

2. According to teachers and principals, what are the conditions (structural and cultural) and affordances that are conducive to teacher use of MakerSpaces to provide NGSS-based instruction?
3. According to teachers and principals, what are the barriers that impede the use of MakerSpaces?
4. What are the observational indicators of hands-on, NGSS-based teaching and learning in early success models of MakerSpace implementation that principals can use to guide next steps?

The answers to these questions were best obtained through a qualitative research study. Qualitative methods allowed me to delve into the nuances and descriptors necessary to describe the early success of MakerSpaces on some campuses within the Happy Hills School District (HHSD). Since MakerSpaces in K–12 are a newer innovation, rich description was necessary to provide context. Such nuanced description could not be attained through quantitative methodology, particularly in the absence of already defined criteria. Thus, using a qualitative success case methodology (Brinkerhoff, 2003), I sought to explore and examine the conditions surrounding MakerSpace use on campuses identified as early success models.

Success Case Method

Brinkerhoff (2003) argued that the success case method (SCM) can reveal useful information for organizations regarding what is or is not working in an initiative and can help to identify best practices. Further, he postulated that success cases provide “models and examples to motivate and guide others” (p. 15). The information gleaned from success cases can help organizations continue to meet demands or allow for course correction. Given the substantial investment of time and resources towards implementing MakerSpaces throughout the district,

this information is critical to obtain. Brinkerhoff proposed that information about what is working and what is not working is critical information that managers can use to improve success on initiatives.

The SCM approach begins with the identification of success cases (Brinkerhoff, 2003). After the first year of MakerSpace implementation in HHSD, sites were identified as experiencing the most and least success. Since MakerSpaces are at the infancy of use in the district, early success to determine the identification of research sites was primarily informed by level of use. The second prong to the SCM approach comprised in-depth interviews and observations of success and counter cases in order to gather data that could provide description about what is occurring in these models.

Themes related to MakerSpace implementation emerged from interviews with principals, survey data, and classroom observations. The nature of these themes was descriptive, yielding data that were conducive to qualitative analysis. A district-administered survey (Appendix A) included open- and closed-ended questions to query teachers on challenges and successes in using MakerSpaces at their schools. Additionally, it asked about teachers' current use of the MakerSpace and their opinions of how MakerSpaces should be used. I examined these data to provide additional context on selected observation sites, further validating the selection of these sites.

Research Site Selection and Access

District Site Selection

At the time of the study, some districts were in the process of planning and developing MakerSpaces for some school sites, particularly those with a STEM focus. The Happy Hills School District, a district with 6,500 students located in a suburb of Los Angeles, was the only

district in the area that had completed construction of MakerSpaces at every one of its 11 schools. HHSD is the only elementary school district in the city, and the configuration of schools throughout the district is varied. There are six K–5 schools, three K–8 schools, and two comprehensive (Grade 6–8) middle schools. Currently, the K–5 schools feed into the two comprehensive middle schools in the district. Students matriculate to a unified high school district.

The schools in HHSD vary widely in terms of demographic configuration. Some schools have as low as 6% percent of students designated as socioeconomically disadvantaged, while the highest poverty school has a rate of 65%. Overall, 29% of students in the district are socioeconomically disadvantaged. The ethnic configuration of the district is 44% white, 36% Hispanic/Latino, 6% Asian, 5% Filipino, 3% Black/African American, and 5% two or more races. Students designated as English language learners make up 10% of the district's enrollment; Spanish is the largest primary language of these learners.

At the time of the study, the schools in HHSD were all at different points in the MakerSpace implementation process. Some had MakerSpaces for more than one calendar year at the inception of this study; some had them for less than a year; others had just inaugurated the spaces on their school campuses. The varying implementation points were an advantage: those that were further along could share best practices and pitfalls with the new implementers. Each site could offer information to inform the work of other sites, essentially creating a feedback loop. Early success cases and the counter case in this study were selected from campuses at similar implementation points.

Another factor that made HHSD a strong candidate for this study is that the district had provided some staff development on MakerSpace tools to district teachers. This professional

development included workshops on the use of different technologies available in the MakerSpaces such as 3D printing, various robots, circuits, stop-motion animation, and the use of green screens.

Some teachers had received staff development on the NGSS through voluntary professional development opportunities. This staff development was planned to continue as the tools and processes within MakerSpaces become more clearly articulated and aligned to support the NGSS and CCSS. Teachers had not received a consistent degree of professional development on the NGSS, as the standards will not be implemented until the 2018–2019 school year.

In the year that data were collected, each MakerSpace had additional support from an instructional assistant (IA). HHSD had made a commitment to MakerSpace implementation and success and tied direct funding to this objective. District Local Control Accountability Plan goals reflect this commitment and site plans also demonstrate this alignment.

Case Study Site Selection

Since MakerSpace use in K–5 schools is in its infancy, the selection of sites was primarily based on level of use, with early success models defined by teacher usage. The site with the lowest level of individual teacher use served as the counter case. Brinkerhoff (2003) discussed the importance of providing a counter case to provide information on an initiative's lack of success. Comprehensive middle schools were excluded from this study due to the variation in class configuration and teacher credentialing. Three different sites with different models of early MakerSpace implementation were observed in this early success case study: Cielo Vista School, Hidden Valley School, and a counter case site, Golden Springs School. All three campuses had their MakerSpaces for over one year at the time of data collection.

All three case study sites provided knowledge for future implementers of K–5 MakerSpaces spanning a range of school typology. Based on teacher use rates, two of the selected sites, Cielo Vista and Hidden Valley, had multiple visits from outside districts seeking information on the implementation of school MakerSpaces. Both were identified by district administrators as models to learn from in the implementation of MakerSpaces throughout the district. They were the early success case sites in this study.

Cielo Vista is a larger K–5 school with an active parent community. It is located in an upper-middle-class area of the city. The parent community has been a strong financial advocate of the MakerSpace and the school sponsored a Maker Faire, a hands-on event sponsored by the larger Maker Movement. Hidden Valley is a smaller K–5 campus located in a mixed working- and middle-class area of the city. Prior to the incorporation of the MakerSpace, Hidden Valley had transitioned to a STEM-focused academy emphasizing hands-on learning and incorporating the first K–5 science lab in the district. Both campuses had the support of teachers who were early adopters of MakerSpaces (Rogers, 1962).

At Golden Springs School, the counter case, implementation was based on a different model. Golden Springs is located in a highly affluent area of the city; the school's parent organization holds an annual dinner dance that raises an average of \$100,000 each year. This site developed its MakerSpace through the use of a content specialist teacher who taught a section and procured equipment through the school's parent organization.

Site Access

Given that my study utilized an SCM approach, access was a critical piece, as the direct observation of practice and in-depth interviewing of principals provided significant data. As a school principal in HHSD, I was granted access to pursue this study. In the proposal stage, I met

with the district superintendent, assistant superintendent of educational services, and director of curriculum and instruction on several occasions to provide information about my study. This included including familiarizing them with my proposed research questions and theoretical framework. They fully supported the study, as the district has committed fiscal resources to the success of MakerSpaces.

It is important to note that HHSD had a new superintendent in the year that data collection took place, as the previous, long-time superintendent had retired. Prior to her departure, the retiring superintendent drafted and signed a memorandum of understanding (MOU) granting me access to conduct the study in the district. The new superintendent was trained in project-based learning, which is highly compatible with the constructionist premise on which MakerSpaces are predicated. She was strongly supportive of the study and also approved the MOU. The MOU outlined the safeguards in place to protect employees and data; it also stipulated that I had permission from the district to complete the study. In addition to this agreement, I obtained individual permission for principals and teachers to observe the MakerSpaces on their sites.

I reached out to my principal colleagues at our principal meetings. Since most of us were in the process of constructing personal meaning of MakerSpaces, several indicated they would like to work together in defining MakerSpace systems of support on their campuses. This proved helpful, since I needed to interview principals of the two success cases as well as the principal of the campus demonstrating the counter case.

Data Collection

Survey

The identification of early success sites in MakerSpace implementation was the launching point for this study. While I identified these sites preliminarily based on use, the survey provided additional information (Appendix A). To assure teachers that the data would not identify them personally, no demographic identifiers were used in the survey. Teachers used a Google link to connect to the survey, which did not require a login. These measures were taken to reduce any perceived threats by teachers of being identified through the survey.

The survey asked teachers about the current use of MakerSpaces in their schools. In particular, the items sought information about the frequency of MakerSpace use by teachers; whether the MakerSpace was used to instruct or reinforce NGSS concepts; MakerSpace lesson development; support of MakerSpaces; and use of technology in the MakerSpace. The responses to these items indicated current use patterns and familiarity/comfort with NGSS lesson connections. The survey included open-ended items that queried teachers about their vision of MakerSpaces as well as how they were or were not currently using their school's MakerSpace. This set of questions provided insight on Research Question 1.

The survey was also used to gather self-reported information from teachers on the supports they perceived they needed to provide MakerSpace instruction as well as staff development they had received in the use of MakerSpaces. Some of the questions focused on the affordances the district provided teachers in the using MakerSpaces, informing Research Question 2. The survey questions also directly informed the barriers that inhibited use of school MakerSpaces, which provided information on Research Question 3.

I piloted this survey with a TOSA, a math coordinator, and the former and current directors of curriculum and instruction. Once the survey was finalized, all 168 Grade K–5 teachers in schools other than the school where I am currently principal were invited to participate. The director of curriculum, instruction, and assessment sent school site-specific survey links by email to encourage participation. On Day 7 of the survey, she sent out a final request for participation by resending the links to the teachers, yielding a final response rate of 41%. Three of the eight schools that participated were case study sites: Hidden Valley School, with a response rate of 65%; Golden Springs School, with a response rate of 35%; and Cielo Vista School, with a response rate of 33% (Table 1).

Table 1

Teacher Survey Response Rates

Site	Eligible Respondents	Number of Respondents	% per site based on eligible respondents
Hidden Valley School	17	11	65%
Twin Rivers School	14	5	36%
El Capullo School	29	6	21%
The Wells School	19	11	58%
Cactus Heights School	17	10	59%
Butterfield School	30	12	40%
Golden Springs School	17	6	35%
Cielo Vista School	27	9	33%
TOTAL	170	70	41%

Observations

In order to obtain a more comprehensive view of MakerSpace use at the identified case study sites—and to address Research Question 4—I conducted observations of teachers using

them. Merriam (2009) noted that observations allow an outsider to notice things contextually that might not be revealed in interviews. Observations of the models in action provided a first-hand account of the context being studied. I used the observations to gather data on MakerSpace early success models. My role was as an observer participant (Creswell, 2013). I observed three lessons in the MakerSpace of each of the three K–5 schools—two early success models and one counter case campus. The classes were selected by the school principal at each site.

Merriam (2009) highlighted the importance of accurately capturing what is observed. To this end, I developed an observation protocol form (see Appendix B) to record setting, participant actions, tools, and explicit and implicit content connections. The form also included a reflection/clarification space to capture my thoughts. Additionally, a checklist with the eight engineering practices highlighted in the NGSS helped me capture connections to the standards. The observations lasted from 45 minutes to one hour. I composed my observation notes into a narrative as soon as the observation ended to avoid inaccuracies due to time lag.

Interviews

Brinkerhoff (2003) proposed that managers must gather information about the successes or challenges of initiatives in order to guide next steps and “help identify and understand the factors that they need to manage if they wish their employees to make successful use of an innovation or program” (p. 51). Applying this logic to MakerSpace use, it was important to gain information on the school conditions over which school principals felt they had influence in MakerSpace use and implementation, particularly because the intent of this study was to help inform next steps in guiding the use of these spaces. By learning from early models of success, principals can influence the meaningful implementation of MakerSpaces at their schools. Their reflections regarding the successes and challenges in the infancy of this initiative is valuable

information. In addition to myself, eight of the 11 principals in Happy Hills School District had K–5 students on their respective campuses. I conducted in-depth interviews with all eight of these principals using a 15-question protocol (Appendix C). The questions addressed the individual visions the principals had for their school MakerSpaces, thereby informing Research Question 1. The interviews focused on the barriers and affordances that principals perceived in the use of MakerSpaces, thereby informing Research Questions 2 and 3. In order to evoke fuller descriptions the questions were open-ended.

Principal interviews ranged from 30 minutes to one hour. Two took place at the respective principals' school sites. One principal traveled to my site to be interviewed. Four principals were interviewed at a middle school site during a staff development day as a result of technology failures that interfered with the sessions the various principals would otherwise be attending. I had initially planned to interview the principals in the MakerSpaces at their sites in order to provide a more contextualized interview.

The interviews were audio recorded with two iPad devices using the SuperNote application. Subsequently, the interviews were transcribed by a secure, online transcription service.

Data Analysis

Using a structural coding approach (Saldaña, 2009) the survey results were first disaggregated into the different elements that teachers reported such as time, resources, materials, space (i.e., structural conditions), or cultural conditions like principal support or collaboration. This was helpful in determining if particular supports were more in place on high use campuses than on low use campuses, thereby informing possible next steps for support. This coding was also consistent with Brinkerhoff's SCM (2003) in defining barriers and supports in

the case study sites. Further, survey data were coded by site using attribute codes (Saldaña, 2009). Additionally, magnitude coding was utilized in examining frequency of forced response survey items (see Appendix A).

The principal interviews were coded in several ways. For the first cycle of coding (Saldaña, 2009), I coded the data holistically into macro categories: barriers, affordances, vision, and NGSS connections. I defined a barrier as any hindrance a principal mentioned that inhibited the use of the campus MakerSpace. Affordances were defined as anything that the principal perceived as supporting teachers in their use of MakerSpaces. Vision was defined as actions, activities, or outcomes principals stated they wanted to see in the space. These codes were directly derived from my research questions. During my second cycle of coding, I coded the interviews into micro categories within the macro category to more specifically inform the research questions. The interviews were also coded into specific leadership actions that relate to MakerSpace support.

Additionally, I employed affective coding methods (Saldaña, 2009) specifically analyzing values pertaining to the vision of MakerSpaces as described by teachers and principals in order to “reflect a participant’s values, attitudes, and belief representing his or her perspectives” regarding MakerSpaces (p. 89). For example, codes included STEM connections, student engagement, use of technology, and hands-on learning. I coded data from the observations into categories consistent with the observation protocol, including content connections observed, use of NGSS practices, and use of materials/technology by teachers and students.

Ethical Considerations

Role Management

Since I interviewed my own colleagues, my role was not one in which there was a power differential. However, there were some underlying factors that could have surfaced. Namely, we had a new superintendent. Our previous superintendent had been employed with the district for over 35 years and was the main proponent of MakerSpaces—in fact, it was her vision that brought them to our school district. Since we were all trying to make a good impression on our new superior, it was important to frame this study as beneficial to all schools and not divulge which were being observed specifically. The research could not be seen as if it was self-serving to make me stand out for our new superintendent. I clarified with her that my role was to document successes in the district that could inform our next steps.

In addition, I did not use my current school site as a model of success or failure. Since much of this research was predicated on observation of MakerSpace instruction, I could not observe my own teaching staff, as any observation would fall into the realm of formal certificated observation. When I went to observe MakerSpace lessons at other school sites, I obtained permission from each teacher as well as the site principal. I provided written assurance to each teacher and principal (see Appendix D) that none of what I observed would be reported to a supervisor, used in a certificated evaluation process, or disclosed in a way that would reveal participant identities.

Credibility

There were two threats to the credibility of my study. First, as a success case study, it is not replicable. Very few districts have MakerSpaces on all of their campuses, and the findings from this research may not apply to other schools. In addition, my study only involved a small

number of cases. What can be extrapolated from the study are examples of successful practices and examples of how to deal with challenges as districts or individual schools consider adopting MakerSpaces. Since engineering practices are inherent in the NGSS, other districts might consider MakerSpaces as a way to address these new demands. In addition, it was important to acknowledge my personal bias. I began the study with my own preconceived ideas of what MakerSpaces should be, and I checked this bias through my observation field notes.

Validity

The use of interviews, observations, and a survey to triangulate information was a critical component of this study. To ensure that the observations captured the essence of the lessons, I discussed the protocol with each teacher to ensure accuracy in reporting what was observed. I verified the transcription by listening to the recordings to ensure they had been accurately transcribed.

Positionality

The ethical issues related to positionality that could have emerged from this study were twofold. First, my principal colleagues may have felt pressured to participate because others had already agreed to do so and/or because they thought it would make a good impression on the new superintendent. I mitigated this issue by providing assurance to all principals that their willingness to participate (or lack thereof) would not be disclosed to anyone, including the superintendent—something that could have been particularly worrisome for principals who expressed frustration and reluctance towards the implementation of MakerSpaces at their school sites. Therefore, I provided assurance that the individual interviews of principals would be confidential through a confidentiality agreement as part of the IRB consent form.

Second, our principal group in many ways is highly competitive while at the same time collaborative. Part of this competition is based upon the fact that we are a district of choice—parents are able to choose which school their students attend, provided there is space on the campus. We are constantly competing for enrollment and we develop unique signature programs within each school to attract students. In this climate of competition, it could have been challenging to have honest conversations with principals about their successes and failures with this new initiative. I frontloaded the study as something that other districts could look towards in creating MakerSpaces through the sharing of best practices. This defined the research as a district effort rather than a site-specific effort, and hopefully allayed any concerns.

CHAPTER FOUR: FINDINGS



Figure 1. Students at Hidden Valley School participating in a robot race.

Students in this third-grade class at Hidden Valley School are all getting ready for a big robot race, excitedly measuring, programming, testing, and re-coding. As they prepare for the race, they work collaboratively on trying to code robots to turn and move to navigate the course. A member of a dyad states, “We are trying to make it go over there [pointing] but it keeps going past. How do we get it to turn around?” The dyad tries programming several different ways, each time telling the robot, “You can do it.” Their engagement is evidenced by the energy in the room.

The description above is one example of the experiences of early success cases of MakerSpace implementation. The stories of the MakerSpaces and their respective models of implementation are unique to each of the sites. While each MakerSpace was afforded similar furniture and basic infrastructure by the district, there were differences based on campus use and available resources. This chapter discusses these similarities and differences as evidenced by in-depth interviews of eight K–5 principals, nine classroom observations (three at each case study site), and a survey of 70 teachers. These data were collected to answer the research questions described in earlier chapters.

I begin the chapter with a description of each case study site through thick description obtained through my observation notes. Utilizing Brinkerhoff's (2003) SCM approach, I discuss findings from this multi-site, early success case study of MakerSpaces in Happy Hills School District providing site-specific information in each finding with a cross-case analysis within the finding. Brinkerhoff (2003) proposed six main conclusion types that SCM studies typically investigate: program description and practices; identification of program elements that are and are not working; barriers and helpful factors; scope of impact; estimating return on investment; and estimating unrealized value. According to SCM, two or more of these conclusion types frame the purpose of a study. This study focused on three of the SCM conclusion types: MakerSpace program and practice description; the identification of MakerSpace elements that are working and not working; and the barriers and affordances that facilitate MakerSpace use. The findings were distilled and are presented in accordance with these conclusion types.

Success Case Study 1: Internal Capacity Builder

Nestled in a solidly upper-middle-class neighborhood of single-family homes, Cielo Vista is a newer school in HHSD. As I entered the MakerSpace, a red, human-sized cardboard cutout of a robot, a memory of the Cielo Vista Maker Faire, prominently stood guard. The school hosted a full Maker Faire at the end of the 2015–2016 school year and was prepping for a new Maker Faire in just a few days, with the help of the district's TOSA in charge of MakerSpace implementation. The TOSA was a former Cielo Vista teacher, still actively building capacity in the school through her new role. Her Twitter feed continued to show collaboration between herself and the Cielo Vista teachers. She demonstrated and co-taught lessons, and often brought ideas to the site to support teacher use of MakerSpaces.

All three teachers I observed in the MakerSpace lessons at Cielo Vista had built capacity by working closely with the MakerSpace TOSA. They co-presented with her at multiple conferences and staff development events. The TOSA was the innovator, as defined by Rogers (2003) in his diffusion of innovation theory. Her work created a cadre of early adopters on the campus. In our interview, the principal described her as a person whose caring way with the teachers helped coach many along in their use of MakerSpace, steadily building their capacity.

The MakerSpace at Cielo Vista was outfitted with the basic affordances present at other district MakerSpaces. There were collaborative tables, work stations, a green screen, and a large flat screen monitor. This MakerSpace branded itself uniquely and was generously outfitted due to parent donations and fundraising through the school's parent organization. A logo of the Cielo Vista MakerSpace was displayed on a wall along with various Cielo Vista MakerSpace decals throughout the room.

The principal explained to me that a converted "pick a prize" arcade machine that a parent donated now houses their 3D printer. A large Lego building wall was available for students in one alcove of the classroom. Bins with a plethora of supplies were housed under each of the work stations, replete with recycled cardboard, old spools, plastic containers, and other recycled materials that students could use for building. I had the opportunity to observe three distinct lessons: a fifth-grade free exploration lesson where students used the Dash and Dot robots (programmable movement robots); a second-grade lesson where students designed and built a monster; and a fifth-grade lesson in which students designed and tested a catapult.

Success Case Study 2: The Collaboration Model

Hidden Valley School, is situated in an eclectic middle-class neighborhood. The first view when approaching the campus is of an overgrown yard that serves as a parking lot for an

old car in front of an apparently-abandoned house; next door is a neatly-manicured home. From one house to the next, there is little esthetic consistency.

Hidden Valley was the first school in the district to employ an elementary-level science lab, as part of the school's transition to a STEM magnet. The teachers collaborated on lessons for science lab instruction. When the MakerSpace was created, teachers continued to work together through monthly STEM-dedicated planning time. Without the expertise of an SCT or a lead capacity builder, the teachers gained experience through collaboration.

In many ways, the MakerSpace at Hidden Valley repeated the scene of the previous two I visited: It had work stations, collaborative furniture, a green screen, a 3D printer, and large monitors to project from. There were blue painter's tape lines throughout the vinyl tile floor that appeared to be measurement lines. There was little that was remarkable about the space, as it did not have the additional equipment the other two MakerSpaces had; regardless, there was a flurry of excitement that surrounded the students as they entered the room.

I observed three different lessons at Hidden Valley over several days. The first was a second-grade lesson with students redesigning catapults. The second was a third-grade lesson with students testing and refining parachute prototypes. The final lesson was a third-grade exploration lesson in which students experimented with robots and snap circuits and built with Legos or Play-Do.

Counter Case Study 3: Dedicated MakerSpace Teacher

Golden Springs School is cradled among custom-built homes on rolling lots in an unincorporated area outside of the city limits. The campus was the first in the district to have an outfitted MakerSpace. The site principal learned of the concept at a conference and brought the idea back to his school. Soon, the library was replaced by the new MakerSpace. The school has

the support of a high-socioeconomic parent base, which supplements the MakerSpace through multiple fundraisers including a high-yielding dinner dance. The principal's vision was to equip the space with a credentialed STEM teacher to provide STEM-rich activities to the campus. He hired a single-subject credentialed science teacher who developed the space.

The STEM teacher had calendared time for each class and, according to the principal, the class teacher is required to accompany the class to the MakerSpace. The principal's vision was for elementary teachers without a STEM background to build capacity during the time they accompany their students to the MakerSpace for lessons instructed by the STEM content teacher (SCT). Exposed to a strong model of STEM content knowledge and application, the general education teacher has the opportunity to learn alongside students. Golden Springs is the counter case site of this study due to the SCT being the primary user of the space with general education teachers not using the space independently.

The space was outfitted quite similarly to other MakerSpaces in the district. There were workstations where students could build as well as tables that could be configured for collaboration. At the center of each collaborative table group was a power hub where students could plug in tools and devices. The room was well-utilized, and I observed several projects in different phases of development. There were small-scale outdoor games that students had created, such as a model beach volleyball diorama. A partially complete model of an underground building structure was visible. Student drawings of the rock cycle were posted on the walls.

The tools in this MakerSpace demonstrated the access these particular students had to technology and resources. Two 3D printers were available, computer stations were set up, and a wide array of hand tools and supplies filled the space. Given the parent financial resources

available, the principal had future plans for outfitting the MakerSpace: “We are getting a laser cutter,” he proclaimed in our interview.

During my observation, the teacher had prepped the materials for the lesson. She informed me that the lesson came from STEMscopes, a vetted curriculum that presents the concepts of the NGSS in a hands-on lesson format. In the three identical lessons I was given access to observe, students created a compost bin prototype. Each time, the lesson was taught by the SCT with the classroom teacher there to support group management.

The SCT explained to students that as they built their compost bins they would have access to 50 Popsicle sticks, a roll of masking tape, and a pair of scissors. She cautioned the students to think about volume and shape as they were building their bins. She reminded them to read the list of factors to consider. The students eagerly embarked on the task, soon designing and building.

Finding 1: How Are MakerSpaces Being Used?

The implementation models at the three campuses varied considerably in structure. These differences can be traced to who instructed the MakerSpace lessons, the teacher role in the MakerSpace, who decided what lessons would be instructed, and who developed the MakerSpace capacity of the classroom teachers.

MakerSpace Use on the Success Case Campuses

At Cielo Vista, there was not a dedicated STEM teacher instructing the students during MakerSpace time. The classroom teacher delivered the content and was responsible for classroom management. The classroom teacher also decided what content would be instructed in the MakerSpace. Building teacher capacity was partially supported through the site’s relationship with the district’s TOSA, as revealed through the principal interview and responses

on the teacher survey. One Cielo Vista teacher pointed out, “Teachers on special assignment currently TOSA (sic)—they support us and drive the lessons and we assist.”

When teachers were asked in the survey how they were currently using the MakerSpace, one Cielo Vista teacher responded, “I am using it when our team comes up with an idea that goes with our curriculum or if we have a TOSA who has an idea for our grade level.” Due to the Cielo Vista teachers’ relationship with the TOSA as a former peer, she served as an attainable model of success, which may have increased teachers’ self-efficacy in their use of MakerSpaces. The teachers at Cielo Vista were also supported through a part-time MakerSpace IA. Five of the six Cielo Vista teachers who stated they were using the MakerSpace at least once a month also said they were working with other teachers in planning MakerSpace lessons and activities. Of the lessons observed at Cielo Vista, two were site-wide grade-level lessons, indicating collaboration among teachers using the MakerSpace.

The emerging model at Hidden Valley School is similar in some ways to the model at Cielo Vista. At Hidden Valley, the classroom teacher provided MakerSpace instruction to students and was the sole selector of the content. The teacher was responsible for classroom management as well, with the support of a part-time IA to help with supplies and materials preparation.

With regard to the MakerSpace capacity building model at Hidden Valley, teachers worked together to plan and share MakerSpace lessons. Bandura (1977) asserted that vicarious experiences can build self-efficacy. As Hidden Valley teachers worked together to build experiences in MakerSpaces, the self-efficacy of the group improved. Of the 11 Hidden Valley teachers who responded to the survey, 10 stated they were working with other teachers on MakerSpace lessons and planning. Ten of the 11 reported using the MakerSpace at least once a

month, and six of these reported using the MakerSpace at least once per week. Similar to Cielo Vista, two of the three observed lessons were site-wide grade-level lessons, evidencing this collaboration. The Hidden Valley principal described the importance of teachers working together to build on the experiences of one another:

I think this is the case for anything when we have change. You have different people at different stages of growth, and you're experts, but I utilize those experts to support the ones that don't feel that comfort level yet.

MakerSpace Use on the Counter Case Campus

As noted previously, the fundraising efforts of the parent organization at Golden Springs had largely supplemented the resources available in their MakerSpace. The 35% survey response rate at Golden Springs was considerably lower than at other sites, and comprised only six teachers; nevertheless the findings are useful here.

Three of the six responding teachers stated that the STEM teacher was in charge of the MakerSpace lessons. These teachers did not appear to view themselves as the facilitators of MakerSpace instruction. They made comments like “MakerSpace teachers can design activities and have materials on-hand (sic) to reinforce math and science content” and “We only go there for Stem (sic) lab and it's taught by our science teacher.” Four of the six Golden Springs teachers who responded to the survey indicated that they used the space less than once a month.

In his theory of self-efficacy, Bandura (1977) espoused the importance of people observing the success of a task conducted by a similar peer. Notably, the Golden Springs teachers did not appear to consider the STEM teacher as a peer—they specifically referred to her as the STEM or science teacher in four of the six survey responses. However, the principal's

expectation was that the general education classroom teacher would extend the learning from what the STEM teacher instructed. He explained:

Then getting the right teacher in the MakerSpace room. I've got my middle school science teacher teaching STEM to the K–5 kiddos, and she's also teaching an elective.

The teachers also know that that's not a free time for them. They have to come there and assist the teacher. They're learning how to take what she's teaching in the MakerSpace back into their classrooms to do the follow-up.

Observations at Golden Springs School revealed that the classroom teacher's role in the MakerSpace was to support classroom management. The SCT would find and develop lessons based on connections to science that the general education teacher was instructing outside of MakerSpace time. The teachers did have the opportunity to access the content that the SCT provided, as they were present in the lessons. The principal explained that his expectation was for the teachers to be partners in this instruction. Providing an example of when the SCT demonstrated how to use a green screen in a lesson, his expectation was for the general education teacher to close the lesson. He noted: "It was key that my STEM teacher taught them how to do it, made them finish in their classrooms."

Finding 2: How Do MakerSpaces Enhance Learning?

One of the survey questions—proposed by the district's administration to assess the impact of MakerSpaces on student learning—was about whether or not teachers believed MakerSpaces enhance student learning. Of the 70 survey respondents overall, 93% agreed that MakerSpaces had enhanced student learning. Papert's (1980) theory of constructionism proposes that learning occurs through the physical act of building. His theory is well-aligned to the espoused and observed vision of hands-on learning in HHSD MakerSpaces.

Centrality of Hands-On Activities

One Hidden Valley teacher explained that the MakerSpace “helps the children by using hands on (sic) materials and working as a cooperative group.” A teacher from Wells School responded that they enhance learning “instead of worksheets or videos. It’s another way for students to show their learning that is more engaging.” A Cactus Heights teacher explained, “We are allowing students to be exposed to things that are new to them and they get to explore and do hands on activities that are always engaging and fun.” And a Cielo Vista teacher questioned whether hands-on learning enhanced learning: “I think yes and no. It does not necessarily enhance learning of foundational skills because I feel it is often heavily focused on the use of ‘cool gadgets.’ However, children who are excited about school and activities are engaged, and therefore do learn new things.”

The theme of hands-on learning was repeated in all eight principal interviews. The Cactus Heights principal, for example, illuminated both engagement and hands-on learning in her response about what practices she would like to see in the MakerSpace:

I think kids have to be hands-on engaged with what they’re doing. There can be a little bit of a direct instruction piece in terms of how we use the tool we’re going to use or helping them make that connection between this thing we did in the classroom a couple days ago and now how this is the extension of that, but if they’re not in there with their hands on something, doing something, moving around the room, then I feel like we’ve missed the boat. They have to be engaged with the materials.

The Hidden Valley principal likewise emphasized the importance of hands-on work:

Definitely, I feel like hands-on learning has to be in there. Because we know if you have your own kids, or if you’ve been in a class, you know what happens to your brain if

you're just sitting there listening or you're just doing paper-pencil and you're not engaged in a meaningful activity or project.

And when discussing practices he had observed in the MakerSpace, the Twin Rivers School principal noted: "The hands-on activities that, again, relate to what they're learning is, to me, one of the best practices that I see, especially through the span of grade levels."

The teacher surveys also emphasized this theme, with 60% of teachers asserting that MakerSpaces are places for hands-on learning. "Creating," "making," and "building" (all verbs that are hands-on) were repeated throughout open-ended responses. Teachers provided specific examples of the hands-on activities that students were engaged with such as snap circuits, building projects, and using the video green screen. A Hidden Valley teacher responded that, "My perception of the MakerSpace is to enhance a grade level lesson or skill being taught within the classroom, participating in activities using hands-on materials and or technology." Another teacher at the same school noted, "When students are involved in hands on learning they generally retain more." Two of the six teachers who responded to the survey from Golden Springs School also named hands-on learning as a facet of MakerSpaces.

Observed Hands-On Learning

At all three observed school sites, the espoused vision of hands-on learning occurred in each of the lessons. At Golden Springs School, for example, students in all three lessons were creating compost bin prototypes. The SCT instructed them to form sticks in the shape of a triangle and a square. Students worked in groups of two to three to build their designs, and all of the tables approached this hands-on task in a different way, whether it was taping the sticks together, breaking sticks to make them smaller, or holding sticks together so that a partner could tape the pieces (see Figure 2).



Figure 2. Golden Springs School students work in groups to create compost bin prototypes.

Likewise, in all three lessons that I observed at Cielo Vista School, hands-on learning was present and documented. My first observation in this space was of a fifth-grade class engaged in a free exploration session in which students had access to the following stations: Rover snap circuits (an electric circuit learning tool), guitar building with a kit, and coding of Dash and Dot robots. The exploration lesson was hands-on for all students, as they programmed robots, made guitars, and worked with the circuits. Students used trial-and-error and problem solving in the different stations.

Two students struggled with attaching the arm to the guitar using a screwdriver (Figure 3). The teacher reminded them to follow the diagram and directions. Another dyad was working on a guitar to tighten the strings. One member of the dyad said, “I don’t know if I am opening it or tightening it.” He experimented with turning the screwdriver the opposite way. In the next rotation, I observed a set of students connecting and disconnecting different parts of the Rover snap circuit.



Figure 3. Cielo Vista School students work together to assemble a guitar.

On my second visit to the Cielo Vista MakerSpace, second-grade students were engaged in hands-on learning as they applied their knowledge of building with solids. They were designing and constructing a “monster” using simple materials. And in my final visit to Cielo Vista, I observed a hands-on learning experience for another fifth-grade class as they created and tested catapults by launching Peeps candies. The students built the catapults from basic materials and then tested them to assess how far they could launch the Peep. They measured the distance the Peep traveled and documented their results.

The hands-on experience was also evident in my observations at Hidden Valley School, the counter case. In one lesson, third-grade students were involved in an exploration experience in which they were using snap circuits, building with Legos, and programming Dash and Dot robots. They designed a “racing scenario” for their robots as they programmed the robots with codes.

During another lesson at Hidden Valley, students used simple materials to improve parachutes they had previously constructed. The purpose of the parachute was to help “Jack” get down from the beanstalk—a connection to their language arts study of the story, “Jack and the Beanstalk.” I observed students redesigning and improving their parachutes. Subsequently, they tested their parachutes and they timed the rate of the parachute’s descent (see Figure 4).



Figure 4. A student at Hidden Valley School tests a parachute.

During yet another lesson at Hidden Valley, students tested the launching capabilities of catapults they had previously constructed. They worked through different stations to test their variables (Figure 5). One dyad measured the object’s range by using the floor tiles to measure each foot and then used a measuring tape to measure portions of the tiles. Students modified their catapults as they tested them and recoded the data.

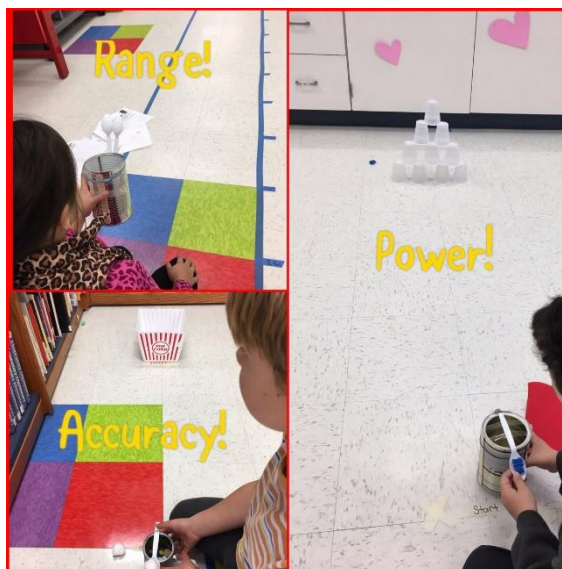


Figure 5. Hidden Valley School students test range, accuracy, and power of their catapults.

Finding 3: How Does the MakerSpace Connect to the Broader Curriculum?

Observed Connections

The Golden Springs School MakerSpace SCT provided instruction using the STEMScopes curriculum, which the district had piloted in a few classrooms. This curriculum provided clear alignment with the NGSS. The lessons observed in the space also supported a plant unit that students were studying in their classrooms with their general education teachers. The SCT was able to link this content as prior knowledge into her lesson.

At Cielo Vista, the curriculum the teachers used was not consistent. The monster creation lesson was from STEMScopes on the properties of matter, and it did align with the NGSS standards for second grade. Additionally, the teacher's use of the See-Saw iPad application to make the diagram of the monster's labeled parts supported the English language arts text feature standards in second grade. Conversely, the catapult lesson observed in fifth grade did not come from a vetted curricular source; as the teacher shared with me, it came from a

resource she procured through Teachers Pay Teachers, an online educational marketplace. This lesson had minimal alignment to fifth-grade NGSS standards.

At Hidden Valley School, the second-grade catapult lesson I observed was not from a district-adopted or piloted curricular source. However, the graphing of the catapult results did align with the second-grade level math standards, which included graphing. The teacher said she found the lesson through a curricular source that was sponsored by NASA. Similarly, the third-grade “Jack and the Parachute” lesson came from an online resource (More Than a Worksheet, 2014).

Risk of Repetition

Some of the activities observed in the different MakerSpaces were similar in terms of tools and complexity, but these same tools and levels of complexity were observed at more than one grade level (both second and fifth grades). The fifth-grade Cielo Vista catapult lesson was teacher-purchased and had some ties to the NGSS. This was similar to the teacher-procured second-grade catapult lesson at Hidden Valley School. Without a clearly defined scope and sequence, activities were repeated across various grade levels without an increase in task expectation or complexity. A Cielo Vista teacher underscored this issue in the survey:

“If they want us to do MakerSpace, we need have a curriculum given to us that follows our math and science program by grade level. Teachers need a continuum, so kids aren’t repeating lessons each year. (This happened this year.)”

I also observed the limited differences in tasks from grade level to grade level in the fifth-grade exploration lesson at Cielo Vista and the third-grade exploration lesson at Hidden Valley, which had similar elements. Both sets of students had access to Dash and Dot robots and snap

circuits. The principal at another school, Cactus Heights, highlighted the problem with this approach:

We're kind of revamping their curriculum right now to make sure there isn't overlap and also to make sure that as K-5 students become more comfortable in this space— Truthfully, what our middle school curriculum is right now, by the time a fourth grader gets there in two years, they'll be bored and they'll be past that.

Lack of Established Curriculum

All principals interviewed and the majority (57%) of teachers who responded to the survey pointed to MakerSpaces as a way to connect curriculum or classroom learning. However, seven of the principals expressed concern about the lack of curricular connections in MakerSpaces due to lack of curriculum or familiarity with connecting the MakerSpace to the standards.

The lack of MakerSpace curricular alignment was also a teacher concern. One Cielo Vista teacher expressed, "MakerSpace could be used to reinforce math or science skills IF there were lessons available that aligned with common core per grade level. I do not think that teachers should be required to create these lessons." Another Cielo Vista teacher lamented: "There is not enough time and many of the lessons are more fluff than authentic aligned with curriculum around our subjects." And a Hidden Valley teacher remarked in the survey, "Other subjects required to teach doesn't leave a lot of extra time for the MakerSpace lessons with the students or planning for them."

The Wells School principal mused, "I think the one thing I would like to see, too, as a staff, is to develop a curriculum, year to year, [so that] they have lessons they can pull from."

The El Capullo School principal's assessment of the weakness in the district's MakerSpace implementation supported this opinion:

I think if I would say there was one glaring weakness of MakerSpaces as a whole, as I've done all the research and read the books, is there really isn't a scope and sequence to say these are really first-grade skills or second-grade skills.

A Butterfield School teacher also shared this concern: "When we have no help. No ideas on projects. We spend hours and hours looking up stem (sic) projects on Pinterest, but it can be overwhelming and many projects just don't match up to the curriculum being taught."

Two of the MakerSpace lessons I observed, one at Cielo Vista and one at Hidden Valley, were exploration lessons that had no curricular alignment or direct teacher instruction. In these observations, students explored programming robots or different building activities. While the students did have to have some familiarity with measurement to successfully program the robots, this was not the focus of instruction in either of the exploration-type observations. According to the surveys completed by Golden Springs teachers, the MakerSpace was also used for free exploration time during unstructured periods. There were multiple projects in progress in the space that demonstrated this. The principal also discussed in the interview that there was a Maker Club available at lunch where students could tinker freely:

It's allowed kids just another niche at the site and allowed them to utilize their nutrition [break] and their lunches every day as a spot to go in and, without any teacher direction, just to tinker, to build, to learn from their mistakes, to break things down and to continue.

Due to a lack of scope and sequence and lessons, the issue of not having the time to plan MakerSpace lessons was a thread throughout the teacher surveys. The relative advantage

(Rogers, 1962) that teachers could perceive in using MakerSpaces was undermined by a lack of curricular guidance.

Finding 4: How Do Engineering Practices in MakerSpaces Align with the NGSS?

Perceived Relevance of Engineering

Perhaps one of the biggest shifts in the NGSS is the introduction to engineering practices beginning as early as kindergarten. It is significant, then, that the majority of teachers who answered the survey (76%) stated that they had received little to no training in the NGSS. When asked how a MakerSpace should be used, however, 10 teachers said engineering should be part of what occurs.

A Twin Rivers teacher noted, for example, “The students should be using it to make things either related to a subject in school or to learn general building/engineering skills.” A Cactus Heights teacher offered, “MakerSpace should be a space to learn, explore, and experiment with inquiry-based science, math and engineering concepts that are grade level and standards based.” Providing her opinion on MakerSpace supporting STEM instruction the teacher continued:

Kids need hands-on experiences to build their understand[ing] of concepts in math, science, and engineering with the use of technology as well as with simple tools and materials. MakerSpace provides that space and opens the opportunities for instruction in these areas.

Principals also discussed the connection between engineering and the MakerSpace. The Golden Springs principal described: “When I walk into my MakerSpace, it is a beehive of just intensity, where we have kids working on circuit boards and kids working on reverse

engineering.” Likewise, the Cactus Heights principal discussed how engineering was part of her vision for MakerSpace use on her campus:

My vision is that, on a rotating basis in K–5, they get in there on an every other weekly basis and that it’s a combination of hands-on science application and then a MakerSpace activity—something that’s deeply rooted in science content, one trip, and then something that’s a little more engineering and “makey” on an alternating week so that they’re getting all of those skills.

When describing the engineering practices she had observed in the space, she provided the following example:

I’ve seen them do bridge building projects where they have to know the different mathematical and scientific equations ahead of time, and why the base that they’re building is going to make this a strong structure, or why the fact that it’s this long or this tall works. They have the science and the math to back that up, but it’s that engineering practice that I think is the biggest connection to NGSS, because they’re actually doing it. They’re having to create something or create a proposal, they’re having to build it, they’re having to redesign, which is what engineers do. If it worked out perfectly the first time, we’d all be engineers.

Observed Engineering Practices

Observations of MakerSpaces at all three sites revealed consistent exposure to two of the engineering and science practices contained in the NGSS: defining problems (engineering) and designing solutions (engineering). The lessons I observed at Golden Springs School provided students with the challenge of building a compost bin that met certain constraints (Figure 6).

Students then built their solutions and evaluated their adherence to the constraints when their bins were completed.

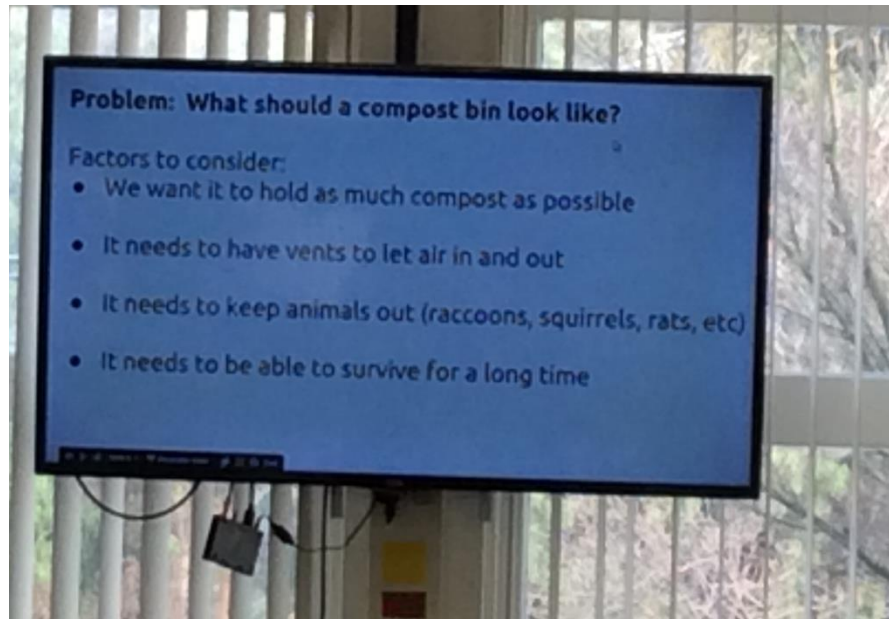


Figure 6. Compost bin activity guidelines at Golden Springs School.

Students were also engaged in engineering-type activities in Cielo Vista. Similar to the activity at Golden Springs School, they had to construct a product—in this case, a monster for a toy company—given certain constraints. Students self-assessed their adherence to constraints through a self-evaluation rubric (Figure 7). The teacher reminded them to check off the constraints from the list as they completed their monsters. One student was struggling with having his monster stand. “He won’t stand,” he told the teacher. She reminded him that, as an engineer, it was his job to make him stand. Students approached the tasks in different ways, self-assessing through the checklist rubric.

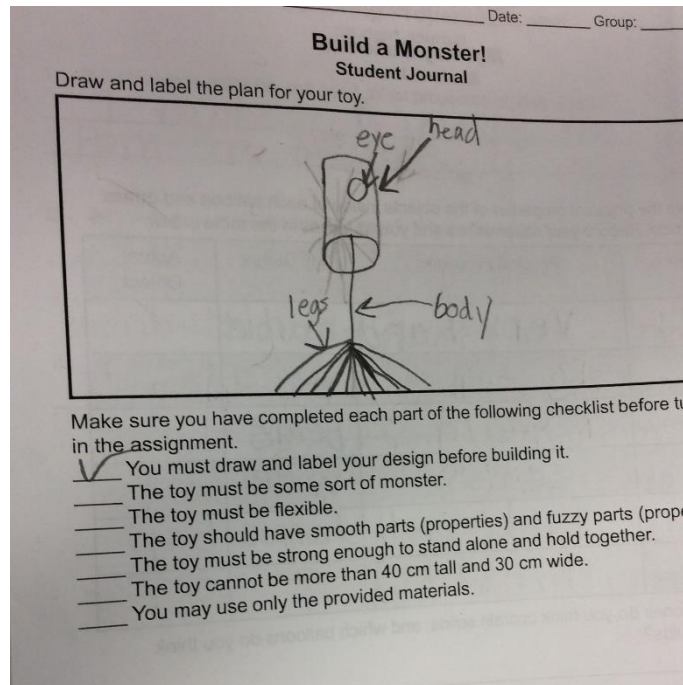


Figure 7. Self-evaluation rubric for monster activity at Cielo Vista School.

The fifth-grade Peep catapult lesson also required students to build a product, though this was not in response to a problem. The teacher began the lesson by projecting pictures of different catapult models. Students were given three minutes to talk about the different designs and to discuss a common design. The teacher provided a list of constraints and told students, “Your goal is to launch your Peep the farthest distance in five tries.” She asked them what they would do if the catapult did not work. A student answered, “change something and try it again.” Students tested their models and used measurement to assess the effectiveness of their launching designs. (See Figure 8).

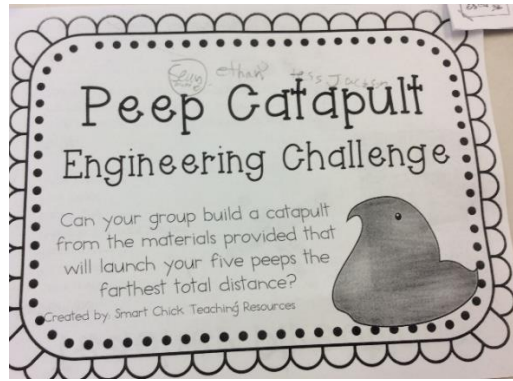


Figure 8. Description of Peep catapult challenge.

Two of the lessons observed at Hidden Valley also provided students with exposure to engineering practices. The second-grade catapult lesson required students to produce a model and test it (see Figure 9). Students assessed their models based on how they could perform at different stations that measured accuracy, range, and power. At one of the stations, the catapult rubber band had slipped. The MakerSpace IA asked the students, “What happens if your catapult breaks? What would an engineer do?” The student responded, “You fix it.”

Name: Nick

Evaluate Accuracy

Your challenge is to accurately launch ~~cotton balls~~ ^{cotton balls} from 3 feet back into a container. Launch and count how many cotton balls out of 5 fall into the container. You will do 3 trials.

	Catapult
Trial 1	<u>0</u> out of 5
Trial 2	<u>1</u> out of 5
Trial 3	<u>0</u> out of 5
Best Trial	# <u>2</u>

aim

What design changes would you make to improve the accuracy of your catapult?

Draw a sketch of the changes.

Figure 9. Accuracy evaluation form for catapult lesson at Hidden Valley School.

The Jack and the Parachute lesson observed in the Hidden Valley MakerSpace also demonstrated the engineering exposure students were being provided. During the previous

week's lesson, the students had dropped the first design of their parachutes from a playground structure, and they timed the descent in seconds. The day of the observation, the teacher provided each student with his or her parachute's previous descent time. She explained that they would need to adjust the control and design to make it go slower. One student stated, "Mine broke in the middle of it, so I have to tie it back together." (See Figure 10.)

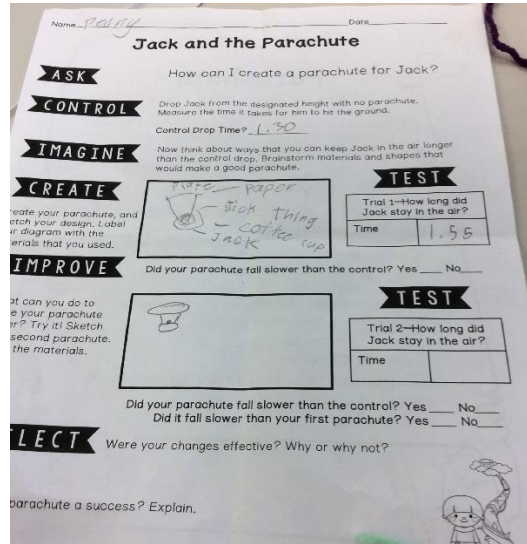


Figure 10. Jack and the Parachute activity sheet at Hidden Valley School.

Throughout the two engineering lessons at Hidden Valley, both the teacher and the MakerSpace IA discussed the engineering design process with students. In two of the lessons, students were called to a gathering spot where there was a large poster of the engineering design process (Figure 11). The MakerSpace IA asked students to think about what part of the engineering design process they were engaged in. Students responded that they were on the evaluating part of the process.

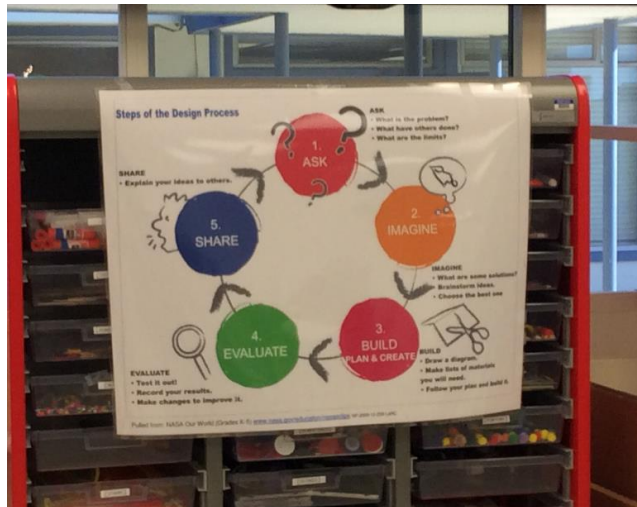


Figure 11. Poster describing the engineering design process at Hidden Valley School.

Finding 5: What Facilitates MakerSpace Use?

Prior to the 2016–2017 school year, MakerSpaces in HHSD did not have IAs assigned to them. This year, each MakerSpace was provided with an IA, with the allocation of hours based on student enrollment for the site. IAs for the MakerSpaces were required to be high school graduates with a minimum of 48 college units and one year of experience working with children.

Prior to the IAs being assigned, teachers were responsible for procuring and prepping supplies in advance of their MakerSpace lessons. In observations of lessons at Hidden Valley and Cielo Vista, the support and involvement of the IAs were prominent. At Hidden Valley, the IA prepped for the three observed lessons; from preparing the catapult launch stations to organizing the material stations for the parachute, the materials and set-up were ready to go before each of the lessons. One teacher explained that she had done the catapult activity in the prior year, but that it had made a big difference to have the IA this year to help with prepping the stations and the materials.

The MakerSpace IA at Hidden Valley also reinforced the concept of engineering in two of the lessons that I observed. She reviewed the engineering design process with the students to help them determine what part of the process they were working through and reminded them about the role of engineers as problem solvers. She ensured that the materials were organized and accessible for students. Hidden Valley teachers punctuated the importance of the IAs' support in their survey responses; nine of the 11 who responded to the survey indicated that hiring the MakerSpace IA had helped them to use the space. One reflected, "Having our helper has made it a much better experience."

The MakerSpace IA at Cielo Vista also prepped the supplies needed for all of the observed lessons prior to the class coming to use the MakerSpace. For the monster lesson, all of the building materials were organized for students to access right away, and the design constraints were posted at each table group. Prior to the free exploration lesson, the IA set up the Dash and Dot, Rover, and guitar building stations. The teacher shared that the MakerSpace would be tough to use without the support of the IA. She cited the instructional demands in preparing students for high-stakes testing as another reason she would have to reconsider her time in MakerSpace if not for the support of the IA. When I asked the teacher instructing the Peep catapult lesson what the role of the MakerSpace IA was in supporting her use of the space, she explained that the IA set up materials and managed the schedules for the teachers. The Hidden Valley IA was also responsible for maintaining the classroom schedules for MakerSpace use.

Every principal interviewed pointed to the additional human capital as facilitating MakerSpace use on their campuses. The Cactus Heights principal eloquently discussed this support:

In the second full year of implementation, a district employee was provided for 18 hours of aide support, meaning that they couldn't teach lessons, but they could support lessons. I have my IA doing research on lessons for teachers when they give her some topics. A lot of the things they don't have time to do, she can do. She helps with setup and clean up, and then when they go in and do a lesson that they might be a little nervous about doing for the first time.

Reiterating the value of the MakerSpace IA, the Butterfield School principal, where MakerSpace was in its first year of implementation, stated, "Oh man, she's amazing. She's amazing. She's amazing. She's awesome. What would we do without her?"

While the Golden Springs School model did not include a MakerSpace IA, the SCT fulfilled many of the same organization functions with regard to supply organization and scheduling. That school's principal described the importance of having a keeper of the space: "It looks like a bomb went off in there at the end of every day. If that teacher who's working out of there had to clean it, then they're shirking the responsibilities of their own classroom." The importance of having the support to organize the space and ensure that it was well supplied resonated throughout teacher surveys: Overall, 45 of the 70 teachers (64%) pointed to the benefit of having a dedicated employee in charge of the space.

Finding 6: What Are the Barriers to MakerSpace Use?

Rogers' (1962) diffusion of innovation theory attaches task complexity to success of a trial in a new innovation. If a task is considered too complex, he postulated, the adoption of the innovation will be impeded. Notably, then, as a new innovation, the MakerSpace is not a resource that all teachers feel comfortable using, particularly due to the devices and technology present, such as 3D printers, robots, and video green screens. Within HHSD, teachers pointed to

a lack of training and not knowing what to do as a barrier for using the space. A lack of training led to the perception of increased task complexity.

Unfamiliar Technology

Due to the various technological pieces available in the MakerSpaces, principals pointed to teacher fear of not knowing how to use the equipment or of not being versed in the STEM content as barriers for MakerSpace use. Additionally, the principal stated that:

“A lot of it was fear of using some of the big purchases, like, ‘I’m going to break that 3D printer. I’m going to break that video camera. Or, how do I allow my second grader, who is eight years old, to use that expensive device?’ A lot of it was just removing that fear that hey, it’s just a device.”

Similarly, the Wells School principal noted, “Knowledge is definitely a barrier on content knowledge. ‘How do I do a stop motion? I’m not sure I actually know how to do that.’” This principal further noted that connecting the technology to content was also a barrier for MakerSpace use.

Lack of Professional Development

The Twin Rivers principal explained that teachers’ lack of familiarity with the equipment as well as staff development were obstacles to MakerSpace use:

MakerSpace, I think creates a lot of anxiety in many of our teachers. It puts them in a place that is foreign to them with lessons they’ve never learned how to teach. They really haven’t received much professional development on the different strategies, the different STEM lessons that can be done in a MakerSpace.

This was echoed by the Wells School principal, who expressed that the engineering practices that align with MakerSpace use were a specific area of staff development need for teachers.

The principals discussed that some professional development had occurred for teachers, though not all sites provided the same types of training opportunities. The Twin Rivers School principal explained:

We've had TOSAs come here and provide professional development during staff meeting time primarily, and have had TOSAs invited to come meet with our teachers and our grade-level teams, but really just to accompany them those first few times into the MakerSpace and to model lessons for them that they simply could watch and learn.

While some site principals reported that they facilitated time for teachers to work with district TOSAs on MakerSpace lessons and training, others provided training opportunities by way of conferences. Principals also discussed that some teachers had worked with other teachers to provide peer professional development. The Golden Springs principal described their experience:

Then, when CUE (an educational technology conference) rolled around, the objective of CUE was to go and everybody who goes has to take at least one course or one class in MakerSpace, so that I knew they were furthering that professional development. They brought that back. They were expected to, and at staff meetings I'd give everybody a 15-minute window for a series of about eight staff meetings where they had to teach what they learned at CUE with regards to makers to the rest of the staff.

The teacher survey asked about the amount of staff development teachers had in using MakerSpaces—a lot, some, a little, or none at all. More than half of the teachers (54%) said they had received little to no training. From site to site, the training provided was inconsistent. For instance, one out of six (17%) Golden Springs teachers reported they had received some or a lot of training; at Hidden Valley, six of the 11 teachers (55%) responded that they had received

some or a lot; five of the nine Cielo Vista teachers who responded to the survey (56%) stated they had received some training (see Appendix A).

The Twin Rivers principal reflected, “They really haven't received much professional development on the different strategies, the different STEM lessons that can be done in a MakerSpace.” This was echoed by the Wells School principal who expressed that the engineering practices that align with MakerSpace use were a specific area of staff development need for teachers.

The need for MakerSpace training resonated in teacher survey comments regarding what hindered them from using MakerSpaces. “People are afraid to try it, and some people do not know what resources are available to be used in it,” noted one Twin Rivers teacher. A Cielo Vista teacher contributed, “I do not usually use MakerSpace if I am not sure about how to approach a lesson or manage or use the materials properly.” And an El Capullo teacher said, “I am not familiar with most of the technology and cannot teach it.”

Conclusion

Happy Hills School District is a pioneer in the landscape of MakerSpace use in elementary school settings. With no models to emulate or district office-supplied framework, different models of use have emerged. The three models that were closely observed in this study included a dedicated MakerSpace teacher, an internal capacity builder, and a collaboration model. There are characteristics that span the three models, such as the vision of hands-on learning that was supported by teachers and principals and was observable in each of the three observed MakerSpaces. Across the models, students had access to early engineering experiences, particularly practices related to developing solutions to problems. The sites all had

access to a keeper of the space who organized supplies and scheduling, thereby providing an ongoing support for teachers to utilize the space.

Within these models there were distinct differences, too. Only one of the sites, the counter case, had a dedicated STEM teacher to instruct students in the space with general education teachers not independently utilizing the space. The two early success cases instead had a MakerSpace instructional assistant, with content purveyed by non-STEM general education teachers. There were pronounced differences in how the sites approached the curriculum and the technology, with some curricular alignment but wide variation in task complexity due to a lack of scope and sequence. The inconsistency in experiences was also influenced by lack of standardization in professional development throughout the district with regard to MakerSpace implementation. Each site had taken on the responsibility of designing these experiences, supports, and expectations in the absence of a district-wide centralized implementation plan. Each model of implementation possesses advantages to learn from and challenges in support from which current and future implementers can learn. These are discussed in the next chapter.

CHAPTER FIVE:

DISCUSSION

This study examined early MakerSpace implementation at three sites in the Happy Hills School District, a suburban, medium-sized K–8 district. I found that the practices in HHSD MakerSpaces were emergent and still largely undirected, without clearly defined models to emulate. Coupled with a teacher-training gap in using MakerSpaces, this resulted in missed opportunities for connected learning. Despite these limitations, MakerSpaces in HHSD allowed for hands-on experiences for students and early engineering exposure. Many of these experiences were supported by dedicated staff in charge of MakerSpaces at individual schools.

This chapter analyzes the implications of the study’s findings, including practices worthy of attention and areas to revisit. I will discuss the research findings and SCM conclusion types while addressing limitations in the research. Brinkerhoff (2003) illuminated that the information gathered in an SCM study can help leaders to plan course corrections and next steps in an initiative. Therefore, this chapter includes recommendations for continued use of MakerSpaces in HHSD as well as recommendations for districts that want to begin using MakerSpaces. The chapter concludes with noted areas of future research.

The findings from this study contribute to a growing body of literature that shows the possibility of expanding hands-on science opportunities for K–5 students, and an established body of literature on constructionist theory that supports tangible and product-based experiences to help learners make meaning. The use of school MakerSpaces has largely been unexplored in the literature due to the short time they have been in use, particularly in K–5 school settings. Thus, this study contributes to this scarce research by describing how MakerSpaces can be used

effectively in K–5 settings and providing guidance for future implementers of MakerSpaces, particularly those in site leadership and district leadership positions.

Discussion of Key Findings

Different Models of Implementation Have Emerged

This study sought to answer how MakerSpaces were being used in HHSD. As noted, the description of practice is an area that the SCM approach seeks to define. The analysis of the three sites indicates that each has developed a different model of implementation for its MakerSpace: the dedicated teacher model, the inside capacity builder model, and the collaboration model. Each model provides ways for districts and school sites to implement MakerSpace use, though each has specific limitations.

The dedicated teacher model at Golden Springs School provided STEM content to students in a way that a multiple subject credentialed teacher typically could not, due to a lack of formalized training in STEM (Bybee, 2014). This model also provided the opportunity for general education teachers to learn in tandem with students, honing their individual STEM practice. However, the dedicated teacher model did not appear to yield an increase in MakerSpace capacity of general education teachers.

In my observations of this space, I did not perceive an intentional effort to ensure that classroom teachers accompanying students into the MakerSpace were co-facilitating or documenting lessons for future development. Further, of all schools participating in this study, Golden Springs' teachers had the smallest number of responses on the survey, and their responses indicated that they either did not have the skillset to facilitate MakerSpace experiences or they perceived the STEM teacher to be the purveyor of such experiences. Put another way, their feedback demonstrated a sense that they did not perceive themselves as responsible for

being MakerSpace teachers, because that role was already filled by a content specialist. A second limitation to this model is that the funding needed for a dedicated SCT is not accessible to most school sites.

In the internal capacity builder model observed at Cielo Vista, some teachers had worked with the TOSA for district MakerSpace implementation and use. These teachers were early adopters, guided by the efforts of the opinion leader (Rogers, 2003), the TOSA. This model provided an accessible entry point for teachers to explore lessons and ideas that the TOSA shared, thereby increasing the individual capacity of the teachers who communicated with the TOSA. The MakerSpace expertise of the TOSA provided an additional scaffold for these teachers.

The grade-level lessons observed in the space are an indicator that some sharing of practices was occurring at Cielo Vista. The limitation to this approach is that the innovation may not spread beyond members of this inside group—those who collaborated closely with the TOSA. As such, the challenge remains of how to build capacity with the late majority of teachers and late adopters who do not directly collaborate with the TOSA. Diffusion to the majority could continue if teacher-to-teacher collaboration were to occur.

At Hidden Valley School, the collaboration model was predicated on the sharing of practices and grade-level planning. While none of the teachers at the site were content experts, they shared grade-level lessons and resources. Through a collaboration model they decided, as grade-level teams, what the intended MakerSpace experiences would be. This functioned as the operating norm of the community—something that Rogers (1962) underlined as an important element to the diffusion of an innovation. This study did not uncover that Hidden Valley

teachers were reliant on any outside facilitators to help decide what MakerSpace experiences were developed.

There is an opportunity for increased self-efficacy in the collaboration model due to the collaboration among peers. As posited through Bandura's (1977) theory, as teachers see others whom they perceive as similar to themselves experiencing success in the MakerSpace, their self-efficacy increases. The limitation to this model, however, is that without a content expert or a MakerSpace expert guiding the direction and selection of the curriculum, there is increased risk of selecting materials that are not aligned to content. Likewise, without a STEM content specialist, no one is readily available to answer science content-specific questions, and if teachers deviate from connecting the content to the MakerSpace, there are no mechanisms to get them back on course.

Comparative advantages and disadvantages of the three models. The three models described above all have advantages and disadvantages in key areas, including with respect to teacher capacity and self-efficacy and capacity building, impact on students, and overall model sustainability. First, the dedicated teacher model, in its current form of implementation, does not build teacher capacity, thereby making it the counter case of this study. Within this structure, teachers do not appear to see MakerSpace instruction as their role—indeed, there a content specialist filled that role. However, with some modifications, this model does have the potential to build teacher self-efficacy. If teachers are expected to co-facilitate each lesson or collaborate with the STEM teacher on lesson development, they have an opportunity to grow their skillsets and become better prepared to provide MakerSpace instruction.

The internal capacity builder model also has the potential to increase teachers' capacity to use MakerSpaces, though it would require diffusion outside the core group that has already

adopted the innovation. Intentional efforts to encourage further peer-to-peer collaboration would be necessary to create the proper conditions. In the Hidden Valley collaboration model, the capacity building potential is strong because of the collaborative use of the space, but it is hindered by the lack of a content or MakerSpace “expert” to guide the process. This model has the least amount of external input from a STEM or MakerSpace content expert. While the ability to diffuse knowledge is high, the amount and depth of the knowledge being diffused within the collaborative model is contingent upon the teachers seeking the knowledge themselves.

The district’s vision of a hands-on learning environment for students is compatible with all of the models, as evidenced by the observations of hands-on learning in HHSD MakerSpaces. The advantage to students in the dedicated teacher model is that the content specialist has the background knowledge to make more explicit and deeper curricular connections to the NGSS. The internal capacity builder model provides an advantage to students based on the TOSA’s direct work with teachers on the technology and tools available in the MakerSpace. This translates into the potential for more technologically-connected experiences for students in the MakerSpace. The Hidden Valley model was not predicated on either of these two supports, however, so students did not have access to tight content explications from a specialist or the same level of exposure to advanced technology, unless a teacher involved in the model happened to possess those skills independently.

The sustainability of the three models varies greatly, as many of the resources and the human capital are linked to funding availability. The dedicated teacher model is predicated on the school committing human capital for a dedicated MakerSpace teacher—something that may not be fiscally sustainable for schools. The STEM content teacher in this study was employed as a science teacher for the other periods of the school day, so her position was contingent on the

school's master scheduling needs. If more science sections are required, her availability to have a dedicated STEM section would be removed. Given these constraints, her availability is tenuous at best. Finally, the success of the dedicated teacher model is also contingent upon the knowledge and ability of one person.

The internal capacity builder model likewise has constraints with regard to sustainability. The district TOSA for MakerSpaces was contingent upon finances. If the position were to be dissolved, the TOSA would return to a school site, not necessarily Cielo Vista. Without the continued diffusion of the innovation to the other teachers, the sustainability of the model could be compromised. The model at Hidden Valley was the most fiscally sustainable because it required no additional staff. However, without the opportunity for continued teacher development in the use of MakerSpaces and the NGSS, the level and depth of knowledge within the system can become stagnant.

Hands-on Learning in MakerSpaces

The vision of learning espoused by HHSD teachers and administrators of MakerSpaces centered on hands-on, constructionist learning. This pedagogical focus pivots away from traditional instructional practices and is a strong conduit for engagement (Papert & Harel, 1991). When considering Rogers' (1962) diffusion of innovation theory, for an innovation to spread, one of the preliminary factors is the relative advantage of the innovation. The overwhelming majority (93%) of teachers in HHSD viewed the spaces as enhancing student learning; such support may help to diffuse MakerSpace innovation throughout the district.

Although a district vision for the use of MakerSpaces has not been formally defined, the lived vision is that of hands-on learning. In all three case study MakerSpaces, I observed hands-on learning not only occurring, but also as the basis for the experiences in the MakerSpaces.

Notably, HHSD departed from the traditional constructionist principles of MakerSpaces—which encourage the exploration or creation of undefined products through unstructured tinkering—in that the lessons were predominantly planned experiences. There was only occasional inclusion of more unstructured exploration where teachers selected different materials and tools with which students could experiment.

There is tension between a focus on increasing student outcomes to demonstrate growth on public metrics and an expectation that teachers will provide engaging hands-on experiences for students. In an era of testing accountability and the related instructional demands teachers face, it is understandable that schools cannot take an entirely unstructured approach to MakerSpace use. It is critical for school leaders to lay the foundation for tying these worlds together by framing MakerSpaces as a way to frontload curricular content prior to instruction of key concepts, to synthesize and apply already-instructed concepts, or to purvey instruction on an entire topic.

Connections to the Curriculum

During the MakerSpace lessons I observed, some of the teachers made connections to NGSS-aligned content, while others employed a less connected approach. The NGSS are partially organized into four disciplinary core ideas (DCIs): physical sciences; life sciences; earth and space sciences; and engineering, technology, and applications of science. Four of the MakerSpace lessons observed in this study were linked directly to DCIs beyond just engineering. A lesson observed at Cielo Vista, for example, addressed physical science as students explored structures and properties of matter by building monsters; the compost bin building activity at Golden Springs explored earth and space science as related to human impact on the earth; the Jack and the Beanstalk parachute lesson, as well as both catapult lessons, applied the physical

science DCI, specifically exploring motion and stability, forces and interactions. While four of the six observed lessons were related to a DCI, only two of these four were directly related to a grade-level performance expectation, underscoring the need for clear articulation of scope and sequence.

Without a defined nexus between MakerSpace use and classroom curricula, teachers were left to develop or find different types of lessons to teach in these spaces. In Happy Hills there was evidence of these lessons coming from outside sources such as STEMScopes and online resources for STEM curricula. Research indicates that elementary teachers generally rely on textbook curricula to frame their lessons; in the 2012 Survey of Math and Science Education, 77% of elementary teachers followed the textbook for overall structure and content emphasis. An adopted science curriculum that aligns with the hands-on practices expected in the NGSS was not available, however, which led to teachers exploring different options to fill this void. The lack of articulated curricular connections was a barrier for effective MakerSpace instruction in HHSD and this was compounded by a training gap in STEM and MakerSpace practices.

Engineering Practices in MakerSpaces

One of the most surprising findings of this study is that engineering practices were consistently occurring in MakerSpaces in HHSD. Bybee (2014) discussed that for teachers to have the background to instruct the concepts in the NGSS, they need professional development to close content gaps. Osborne and Sikma's 2014 study and the 2012 NSSME emphasized that teachers with K–5 experience and training are less confident than their secondary subject teacher counterparts in their science instruction, particularly with respect to the engineering aspects of science. The current study contradicts Osborne and Sikma's findings; one of the most promising aspects of MakerSpace use in HHSD is that early engineering practices consistently occurred.

Students were observed designing, creating, and testing different objects, as well as utilizing basic engineering principles.

The risk is that this engineering may often be disconnected from learning objectives in classrooms, providing a more siloed approach to STEM instruction. While four of the six lessons observed in the MakerSpace were predicated on designing a solution to a problem, an important element of the engineering DCI, the two exploration lessons were not intentionally designed to solve a problem. Similarly, MakerSpaces are typically equipped with tools that teachers may not feel comfortable using such as 3D printers, robots, and drones. This is significant, since Cuban (1986) described a lack of technical knowledge as a barrier to teachers implementing technology in classrooms.

Dedicated Support in MakerSpaces

Rogers (2003) explained that the complexity of an innovation could serve as a barrier to its adoption. One of the most resonating findings in this study was how much teachers and principals valued the support of the MakerSpace instructional assistants. A critical function of the IAs was the coordination of schedules for the MakerSpace to ensure availability. Moreover, with the challenge of managing students while prepping and cleaning up materials in a limited amount of time, the IAs made using MakerSpaces less logistically complex by ensuring that materials were organized and available. While teachers held students responsible for helping to clean up the space, having a dedicated keeper of the space maximized the time students could spend working. Teachers indicated that without this support they would have been less likely to use the MakerSpace. In the absence of district-directed curriculum, in order to use the MakerSpace, teachers have to seek, plan, and execute MakerSpace lessons. The logistical support of a MakerSpace IA affords the teacher some of the needed time for that essential work.

Consistency with Diffusion of Innovation Theory

Teacher use and adoption of MakerSpaces in response to the district's top-down implementation is largely consistent with what would be expected when we look through the lens of diffusion of innovation theory. Indeed, there is evidence that the innovation of MakerSpaces has diffused inconsistently throughout HHSD, and diffusion of innovation theory provides reasons why. In particular, Rogers (1962) proposed that when individual awareness of an innovation is achieved, the decision to adopt or reject it is made based on several factors: relative advantage, compatibility, task complexity, trialability, and observability.

Relative advantage weighs the benefits of adopting an innovation to replace an existing practice. The precursor to hands-on MakerSpace lessons was the traditional textbook-based model of instruction. Because MakerSpaces were housed in separate physical spaces outside the classroom, and because the idea that the hands-on instruction was meant to replace textbook instruction may not have been communicated clearly, it is possible that teachers perceived MakerSpaces as “one more thing to do” rather than a replacement of an existing practice. If the goals of MakerSpaces can be communicated to teachers—together with a strong theoretical foundation for constructionism as a pedagogical approach—then their relative advantage can be understood. This chain of knowledge is important messaging for principals to convey in order to fully create awareness among teachers that there is a relative advantage to the use of the MakerSpace.

In terms of *compatibility*, student engagement is a stated and evaluated expectation for teachers. Standard 1 in the California Standards for the Teaching Profession calls on teachers to engage and support all students in learning (Commission on Teacher Credentialing, 2009). Since 93% of teachers who responded to the survey stated that MakerSpaces did enhance learning, the

innovation appears to be compatible with the larger organizational structure that values and expects student engagement. Furthermore, the development of school-based calendars that afford time in MakerSpaces creates compatibility of use with the organizational structure.

Another of the factors that potential adopters weigh when considering an innovation is the *complexity* of its use. MakerSpaces contain tools such as 3D printers, robotics, and green screens, which generally require training prior to use. There was a training gap in HHSD, as highlighted by the 54% of teachers who responded on the survey that they had little to no training in the use of MakerSpaces. Moreover, the perception of task complexity could vary from teacher to teacher depending on prior knowledge and the training they have or have not been afforded by their site principals and the district. This can create a barrier to widespread diffusion. Notably, training can help to overcome this barrier. A 1995 study by McCormick, Steckler, and McLeroy of several districts' adoption of a health curriculum, for example, found that teachers who were trained in the curriculum were more likely to adopt it. Further, the study found that in smaller districts, the curriculum diffused more quickly than in larger districts.

The ability to try out an innovation and achieve success within that trial is another element that potential adopters take into account when considering an innovation—what Rogers (1962) called *trialability*. Because MakerSpaces were added to HHSD campuses, there was an underlying expectation of use expressed by principals. However, within this expectation there was not a consistently communicated expectation of how the MakerSpace should be used. This created an environment in which teachers felt comfortable using and experimenting within the spaces, thereby making the innovation conducive to trialability.

Finally, concerning *observability*, there were observable examples within HHSD of teachers using MakerSpaces to spread hands-on learning. However, the second piece to

observability, the translation of hands-on activities to improved student outcomes, would require more time to assess.

Some of the adopter categories that Rogers (1962) proposed (innovators, early adopters, early majority, late majority, and laggards) were found in HHSD, but they varied from site to site depending on the model of implementation that emerged. Therefore, the proportions of these adopter categories did not follow the same distribution that Rogers outlined. Golden Springs had very few adopters despite having a clear innovator—the dedicated teacher who was, in effect, the sole purveyor of MakerSpace instruction. At Cielo Vista, the innovator, the TOSA, worked with early adopters to build capacity in MakerSpace use, but the diffusion had not spread to an early majority. At Hidden Valley, survey results indicated that the innovation had diffused to an early majority.

Recommendations for Practice

Inform Teachers of the “Why”

Establishing the relative advantage to using MakerSpaces is an important element of the diffusion of this innovation. While the majority of teachers across the district believed that MakerSpaces enhanced student learning, some questioned the research that supports their use. A clear communication plan about the district’s vision of a MakerSpace, as well as the purpose of the space and the link to increased student engagement, should be developed and communicated to all stakeholder groups prior to implementation. Additionally, communicating that MakerSpaces can replace traditional textbook instruction would help with the perception that they are simply an added demand on teachers. The principal is key in communicating this vision to staff.

To reduce the potential ambiguity and interpretation of MakerSpace use, district leaders should develop a plan for communicating that experiences in the space should be connected to learning in the classroom. The development of sample lessons that demonstrate how MakerSpaces can be applied to classroom instruction should be shared with teachers as part of this communication plan. Further, since exploration is a facet of MakerSpace use, the plan should include support for schools in providing unstructured exploration during non-instructional time.

Develop a District MakerSpace Task Force

The development of a district MakerSpace task force is an important step towards defining the use of these spaces. Such a task force should comprise content specialists, a MakerSpace expert, classroom teacher representatives for different grade-level spans, and school principals. The task force should develop the vision for MakerSpace use and align resources to the attainment of the vision. As part of this work, the task force should develop a model for MakerSpace implementation, including defining the role of teachers, selecting curricula, developing alignment tools, and developing training opportunities for teachers and principals.

Through a gap analysis, the task force would determine resources needed for each school, including staff development, and develop a baseline standard of the tools available for students in each MakerSpace. This work would address any variation in available funding at individual school sites in order to ensure equity for students. Finally, the task force should create an evaluation tool to assess the effectiveness of MakerSpaces. The tool would become part of an iterative process to plan next steps in the district's MakerSpaces.

Develop Teacher Capacity

As K–5 teachers delve into the NGSS, there may be a content gap based on the more developed science concepts inherent in the standards. Building mentorship opportunities where the district’s single-subject science teachers provide any necessary content support to general education teachers would help bridge this gap. Additionally, members of the MakerSpace task force could work with teacher leaders at each site to provide consistent MakerSpace staff development with the expectation that the teacher leaders work with other site teachers on implementation, thereby furthering the diffusion.

The principal could coordinate this interface through a MakerSpace leadership team structure on each campus. This would cultivate MakerSpace teacher leaders at each site, providing self-efficacy models that would ultimately increase the collective capacity of the teachers. The MakerSpace leadership team would also serve to increase the sustainability of the MakerSpace by providing onboarding to new teachers unfamiliar with their use.

Provide Professional Development Prior to and Concurrent With Use

The technology to which students have access in MakerSpaces is constantly changing and becoming more complex. The district should consider a professional development plan that addresses these changes and that is updated as new technologies become available for MakerSpace use. Because MakerSpace and NGSS staff development needs will vary by teacher, multiple professional development opportunities should be available based on teachers’ current needs, spanning the range from introductory to advanced. This will be particularly important for new teachers as they are on-boarded to the district. It will be incumbent on principals to gauge the level of staff development teachers need to grow in their use of MakerSpace. Doing so will reduce the barrier of increased task complexity and increase the diffusion of innovation. In order

to support teachers by analyzing needs, principals will also need specific training in MakerSpace use. Polizzi's (2011) found that when principals were trained on information communications technologies (ICT) integration, the innovation diffused more rapidly and they were better able to support teacher use of the technologies.

Provide STEM-Rich and MakerSpace-Compatible Curricula

The lack of a centrally-directed curriculum or scope and sequence regarding MakerSpaces was a barrier for teachers and principals highlighted in this study. Without a specific curriculum, experiences in MakerSpaces across the district provided inconsistent learning expectations and outcomes for students. It will be important for district leaders to consider the adoption of a science curriculum that is compatible with MakerSpace experiences during the curriculum adoption cycle. This will require the development of an evaluation rubric that tests the curricula under consideration for compatibility with MakerSpace use, as well as the provision of content support for teachers. Without the background to develop and instruct on STEM concepts, the selection of the curriculum and materials is tenuous and inconsistent, with some students having greater access to content-aligned lessons than others.

Further, to help teachers make day-to-day instructional decisions on lessons that can be applied and contextualized in MakerSpaces, the district should consider the development of a curricular alignment tool. This tool would guide teachers on how to ensure adequate content alignment and rigor. Additionally, the development of a district-wide scope and sequence for tools and technology exposure would provide students with an increasing depth of knowledge and complexity. Once students have exposure to the different tools, the scope and sequence would differentiate the application of the tool in relation to the grade-level expectation for use of

the tool. This would ensure that students do not repeat experiences and would prevent students from approaching the same tasks with the same tools in different grade levels.

Maximize Teacher Use of Time

One of the most underscored affordances that teachers and principals perceived as conducive to MakerSpace use was the addition of a MakerSpace IA at each school site. It will be important for district and site leaders to continue this support. HHSD has provided IAs with training on the different technology and tools available in the MakerSpaces in order to directly support teachers. To further grow teacher capacity in the use of these tools, the IAs should provide teacher mini-trainings on them. Principals can provide dedicated time for them to consult with teachers during staff meeting or collaboration time. In addition, principals and district leaders should allow for regular planning time for teachers to collaborate on STEM and MakerSpace lessons.

It will be important for planning meetings to also encompass all school sites to ensure a cohesive and consistent experience in a district's MakerSpaces. This collective planning time will provide more models of self-efficacy for teachers. The district should consider implementing a structure in which teachers can observe MakerSpace instruction in job-alike classrooms, building their collective capacity. As leaders consider the implementation of any large-scale initiative, barriers to use—such as the impact on teacher time—must be considered and addressed.

Limitations to the Research

Due to the case study nature of this work, an obvious limitation is that it may not be generalizable to other sites. Districts that have implemented MakerSpaces as a district-wide initiative are uncommon. Similarly, the sample size was small, with only eight schools surveyed

and three analyzed in more depth. This was a pilot study about a very new field with very limited prior research.

A further limitation to this study is my bias as the researcher. I am a principal in HHSD and the former principal of an HHSD school that is featured as an early success case in this study. The knowledge that I have about the early implementation of the site's MakerSpace efforts was not included in this study. This hidden knowledge prohibits me from sharing some of the reasoning behind the model that was developed at one of these sites. I wrote the case study of the site solely from the data retrieved through my prescribed research methods in order to mitigate my reactivity as a researcher (Merriam, 2009).

The difference in observation opportunities at the different school sites must also be acknowledged as a limitation. I was able to observe three distinct lessons at both Cielo Vista and Hidden Valley. However, I observed the same lesson (with three different classes) at Golden Springs School because that was the only opportunity I was offered. The relatively low number of observations may also be a limitation.

Recommendations for Future Research

As MakerSpaces become more prevalent in K-5 education, it will be critical to evaluate their use in relation to student achievement. The question of impact did surface in this study, and should be an area of future inquiry once there is enough longitudinal data to provide information on student achievement with regard to NGSS on campuses that have MakerSpaces. This is predicated on clearly established expectations for use and connections to the curriculum. Future studies could also focus on the impact of MakerSpaces on student engagement over time.

Future research might also delve into teachers' sense of self-efficacy in STEM instruction on campuses with MakerSpaces. Again, this would require time to gather longitudinal

information on teachers' experiences using MakerSpaces over a longer duration. This could be explored in relation to the types of professional development models teachers have access to in the implementation of MakerSpaces. A final area of research could include analysis of the attitudes of students towards STEM on campuses with school MakerSpaces compared to campuses without.

Conclusion

Since attitude and perception are highly predictive of achievement in any field, elementary school is a critical stage for the formation of positive early perceptions of STEM fields. It is imperative that children at the elementary level gain positive exposure to the content and processes required to succeed in future STEM-related education. MakerSpaces are an opportunity for students to experience engagement with hands-on STEM content. These positive early experiences can provide the foundation for students to pursue STEM courses and careers. Traditionally, there has been an underrepresentation of people of color and women in advanced STEM courses (Nekuda Malik, 2016); positive early exposure can be a conduit to ameliorating this opportunity gap. Furthermore, the Common Core State Standards and Next Generation Science Standards require a more hands-on, applied approach to teaching and learning. MakerSpaces offer the ideal environment to provide this type of instruction. Through intentional planning and necessary supports for teachers, the innovation of MakerSpaces, with their many advantages, can be widely and successfully adopted. School leaders can thereby pave the way for the inventors and engineers of tomorrow.

APPENDIX A:

TEACHER SURVEY AND FORCED RESPONSE ANSWERS BY SITE

Research Questions

1. According to teachers and principals, what are MakerSpaces and how are they being used in schools?
2. According to teachers and principals, what are the conditions (structural and cultural) and affordances that are conducive to teacher use of MakerSpaces to provide NGSS-based instruction?
3. According to teachers and principals, what are the barriers that impede the use of MakerSpaces?
4. What are the observational indicators of hands-on, NGSS-based teaching and learning in early success models of MakerSpace implementation that principals can use to guide next steps?

Alignment Key

Question that helps provide context for early success sites = C

District Interest Question = DI

Research Question 1 = R1

Research Question 2 = R2

Research Question 3 = R3

Research Question 4 = R4

Staff Needs for MakerSpace Implementation and Use

Thank you for your participation in this survey. Your participation in this survey is voluntary.

This survey will provide information regarding current MakerSpace use and the supports needed for teachers to use MakerSpaces. This survey will take approximately 30 minutes to complete.

Your answers will be submitted through an anonymous Google survey and personally identifiable data will not be collected. Thank you for your support. If you have any questions, please contact Veronica Ortega at vortega@pvsd.k12.ca.us.

- 1. What is your perception of how a school MakerSpace should be used? (R1)**
- 2. How, if at all, can MakerSpaces be used to reinforce or instruct math or science? (R1, R4)**
- 3. What conditions facilitate my use of MakerSpaces? (R2)**
- 4. What conditions hinder my use of MakerSpaces? (R3)**
- 5. I have received staff development in the use of MakerSpaces. (DI, R2, R3)**
 - A lot/a great deal
 - Some
 - Only a little
 - Not at all
- 6. I have received staff development in the NGSS. (DI, R2, R3)**
 - A lot/a great deal
 - Some
 - Only a little
 - Not at all
- 7. How often do you use your school's MakerSpace? (C, DI)**
 - Once per week or more
 - Twice per month
 - Once a month
 - Less than once a month
- 8. Are you working with other teachers on MakerSpace implementation? (R2, R3)**
 - Yes
 - No
 - If yes, in what ways (check all that apply)?**
 - Planning lessons
 - Co-teaching lessons
 - Sharing lessons
 - Other:
- 9. The supplies I need for my MakerSpace lessons can be found in my school's MakerSpace. (R2, R3)**
 - A lot/a great deal
 - Some
 - Only a little
 - Not at all
- 10. How are you currently using your campus MakerSpace? (R1, R4)**
- 11. MakerSpaces enhance student learning. (C, DI, R1)**
 - Yes
 - No
 - If yes, how?**
 - If no, why not?**

12. Using the MakerSpace is... (C, R1, DI)

My choice

Required

Required but also my choice

13. I am given freedom to try new things in my classroom. (R2, R3)

Completely agree

Generally agree

Generally disagree

Completely disagree

14. It is okay to have a new lesson that fails. (R2, R3)

Completely agree

Generally agree

Generally disagree

Completely disagree

15. Science instruction is a high priority at my school. (R2, R3)

Completely agree

Generally agree

Generally disagree

Completely disagree

16. What are some ways my principal or dean has supported my use of MakerSpaces? (R1, R2, R3)

17. How can my principal or dean further support my use of the MakerSpace? (R1, R2, R3)

Table 2

Survey Question 2: I have received staff development in the use of MakerSpaces.

Site	A lot	Some	A little	None
Hidden Valley School	9.1% (1)	45.5% (5)	18.2% (2)	27.3% (3)
Twin Rivers School	20% (1)	20% (1)	20% (1)	40% (2)
El Capullo School	0% (0)	33.3% (2)	66.7% (4)	0% (0)
The Wells School	9.1% (1)	72.7% (8)	18.2% (2)	0% (0)
Cactus Heights School	10% (1)	32% (2)	70% (7)	0% (0)
Butterfield School	8.3% (1)	25% (3)	66.7 (8)	0% (0)
Golden Springs School	16.7% (1)	0% (0)	16.7% (1)	66.7% (4)
Cielo Vista School	0%(0)	55.6% (5)	33.3% (3)	11.1% (1)

Table 3

Survey Question 6: I have received staff development in the Next Generation Science Standards (NGSS).

Site	A lot	Some	A little	None
Hidden Valley School	0% (0)	27.3% (3)	36.4% (4)	36.4% (4)
Twin Rivers School	0% (0)	40% (2)	20% (1)	40% (2)
El Capullo School	0% (0)	0% (0)	16.7% (1)	83.3% (5)
The Wells School	9.1% (1)	45.5% (5)	0% (0)	0% (0)
Cactus Heights School	0% (0)	20% (2)	50% (5)	30% (3)
Butterfield School	0% (0)	8.3% (1)	41.7% (5)	50% (6)
Golden Springs School	0% (0)	0% (0)	33.3% (2)	66.7% (4)
Cielo Vista School	0% (0)	33.3% (3)	44.4% (4)	22.2% (2)

Table 4

Survey Question 7: How often do you use your school's MakerSpace?

Site	Once a week or more	Twice a month	Once a month	Less than once per month
Hidden Valley School	54.5% (6)	27.3% (3)	9.1% (1)	9.1% (1)
Twin Rivers School	60% (3)	40% (2)	0% (0)	0% (0)
El Capullo School	0% (0)	100% (6)	0% (0)	0% (0)
The Wells School	10% (1)	90% (9)	0% (0)	0% (0)
Cactus Heights School	0% (0)	40% (4)	30% (3)	30% (3)
Butterfield School	0% (0)	66.7% (8)	16.7% (2)	16.7% (2)
Golden Springs School	0% (0)	33.3% (2)	0% (0)	66.7% (4)
Cielo Vista School	0% (0)	22.2% (2)	44.4% (4)	33.3% (3)

Table 5

Survey Question 8: Are you working with other teachers on MakerSpace implementation?

Site	Yes	No
Hidden Valley School	90.9% (10)	10.1% (1)
Twin Rivers School	80% (4)	20% (1)
El Capullo School	100% (6)	0% (0)
The Wells School	100% (11)	0% (0)
Cactus Heights School	90% (9)	10% (1)
Butterfield School	81.8% (9)	18.2% (2)
Golden Springs School	20% (1)	80% (4)
Cielo Vista School	55.6% (5)	44.4% (4)

Table 6

Survey Question 9: The supplies I need for my MakerSpace lessons can be found in my school's MakerSpace.

Site	Most	Some	Only a little	Not at all
Hidden Valley School	45.5 % (5)	45.5% (5)	9.1% (1)	0% (0)
Twin Rivers School	50% (2)	50% (2)	0% (0)	0% (0)
El Capullo School	66.7% (4)	33.3% (2)	0% (0)	0% (0)
The Wells School	90% (9)	0% (0)	0% (0)	10% (1)
Cactus Heights School	30% (3)	50% (5)	20% (2)	0% (0)
Butterfield School	16.7% (2)	75% (9)	8.3% (1)	0% (0)
Golden Springs School	40% (2)	20% (1)	20% (1)	20% (1)
Cielo Vista School	62.5% (5)	37.5% (3)	0% (0)	0% (0)

Table 7

Survey Question 11: MakerSpaces enhance student learning.

Site	Yes	No
Hidden Valley School	100% (11)	0% (0)
Twin Rivers School	100% (4)	0% (0)
El Capullo School	83.3% (5)	16.7% (1)
The Wells School	100% (10)	0% (0)
Cactus Heights School	90% (9)	10% (1)
Butterfield School	100% (11)	0% (0)
Golden Springs School	80% (4)	20% (1)
Cielo Vista School	88.9% (8)	11.1% (1)

Table 8

Survey Question 12: Using the MakerSpace is...

Site	Your choice	Required	Required but also your choice
Hidden Valley School	36.4% (4)	18.2% (2)	45.5% (5)
Twin Rivers School	100% (4)	0% (0)	0% (0)
El Capullo School	0% (0)	50% (3)	50% (3)
The Wells School	54.5% (6)	9.1% (1)	36.4% (4)
Cactus Heights School	60% (6)	10% (10)	30% (3)
Butterfield School	75% (9)	8.3% (1)	16.7% (2)
Golden Springs School	33.3% (2)	0% (0)	66.7% (4)
Cielo Vista School	22.2% (2)	11.1% (1)	66.7% (6)

Table 9

Survey Question 13: I am given freedom to try new things in my classroom.

Site	Completely Agree	Generally Agree	Generally Disagree	Completely Disagree
Hidden Valley School	72.7% (8)	23.3% (3)	0% (0)	0% (0)
Twin Rivers School	100% (5)	0% (0)	0% (0)	0% (0)
El Capullo School	66.7% (4)	33.3% (2)	0% (0)	0% (0)
The Wells School	72.7% (8)	23.3% (3)	0% (0)	0% (0)
Cactus Heights School	50% (5)	50% (5)	0% (0)	0% (0)
Butterfield School	75% (9)	25% (3)	0% (0)	0% (0)
Golden Springs School	50% (3)	50% (3)	0% (0)	0% (0)
Cielo Vista School	88.9% (8)	11.1 (1)	0% (0)	0% (0)

Table 10

Survey Question 14: It is okay to have a lesson that fails.

Site	Completely Agree	Generally Agree	Generally Disagree	Completely Disagree
Hidden Valley School	90.9% (10)	9.1% (1)	0% (0)	0% (0)
Twin Rivers School	100% (5)	0% (0)	0% (0)	0% (0)
El Capullo School	50% (3)	50% (3)	0% (0)	0% (0)
The Wells School	100% (11)	0% (0)	0% (0)	0% (0)
Cactus Heights School	70% (7)	30% (3)	0% (0)	0% (0)
Butterfield School	83.3% (10)	16.7% (2)	0% (0)	0% (0)
Golden Springs School	100% (6)	0% (0)	0% (0)	0% (0)
Cielo Vista School	100% (9)	0% (0)	0% (0)	0% (0)

Table 11

Survey Question 15: Science instruction is a high priority at my school.

Site	Completely Agree	Generally Agree	Generally Disagree	Completely Disagree
Hidden Valley School	0% (0)	100% (11)	0% (0)	0% (0)
Twin Rivers School	0% (0)	80% (4)	20% (1)	0% (0)
El Capullo School	16.7% (1)	33.3% (2)	50% (3)	0% (0)
The Wells School	18.2% (2)	63.6% (7)	9.1% (1)	9.1% (1)
Cactus Heights School	50% (5)	40% (4)	10% (1)	0% (0)
Butterfield School	0% (0)	75% (9)	25% (3)	0% (0)
Golden Springs School	16.7% (1)	50% (3)	0% (0)	33.3% (2)
Cielo Vista School	77.8% (7)	22.2% (2)	0% (0)	0% (0)

APPENDIX B:
MAKERSPACE OBSERVATION

Date _____ **MakerSpace Site** _____ **Time Observation Began** _____

Physical Description of MakerSpace	Description of Lesson
	Technology/Materials Used
	Math or Science Content Connections (Explicit and Implicit)

Time Observation Ended _____ **Number of students** _____ **Grade Level** _____

Science and Engineering Practices of the NGSS Observed in Lesson

_____ **Example:** Asking questions and defining problems

_____ **Example:** Developing and using models

_____ **Example:** Planning and carrying out investigations

_____ **Example:** Analyzing and interpreting data

_____ **Example:** Using mathematics and computational thinking

_____ **Example:** Constructing explanations (for science) and designing solutions (for engineering)

_____ **Example:** Engaging in argument from evidence

_____ **Example:** Obtaining, evaluating, and communicating information

Teacher Actions/Words

Student Actions/Words

Observer Reflections

Items to Clarify With Teacher About the Observation

APPENDIX C:
PRINCIPAL INTERVIEW PROTOCOL

Research Questions

1. According to teachers and principals, what are MakerSpaces and how are they being used in schools?
2. According to teachers and principals, what are the conditions (structural and cultural) and affordances that are conducive to teacher use of MakerSpaces to provide NGSS-based instruction?
3. According to teachers and principals, what are the barriers that impede the use of MakerSpaces?
4. What are the observational indicators of hands-on, NGSS-based teaching and learning in early success models of MakerSpace implementation that principals can use to guide next steps?

Alignment Key

Participant background questions = PB

Question that helps provide context for early success sites = C

District Interest Question = DI

Research Question 1 = R1

Research Question 2 = R2

Research Question 3 = R3

Research Question 4 = R4

Principal Interview Protocol

Thank you for your willingness to participate in today's interview. As a principal of a school with a MakerSpace, you have experience related to the planning, implementation, and support of MakerSpaces in schools. I will be asking you a series of questions based on your experience. There are no right or wrong answers.

This interview will last approximately 45 minutes. I will be recording our interaction today to ensure I am accurately capturing what is said, as I will later transcribe the interview verbatim. Is it okay with you to record the interview? Your identity and school name and location will be

kept confidential. Any information that could reveal your identity will be omitted or obscured from the published results.

If there are points during the interview where you would like the recording to pause, please raise your hand and I will stop the recording. Do you have any questions before we get started?

1. How long have you been assigned to your school? Are there other administrative positions you have held? (PB)
2. MakerSpaces are a relatively new innovation. How did the MakerSpace initiative begin here? (PB, C)
3. Tell me about the MakerSpace vision you have for your school (goals, student outcomes teachers' practices, etc.). How should it be used? (R1)
4. What has helped teachers to use the MakerSpace? (R2)
5. What has been a barrier to teachers using the MakerSpace? (R3)
6. As the leader of the school, what do you see as your role in supporting a MakerSpace? (C, R1, R2, R3)
7. What are the supports that you feel you need to provide teachers with? (R1, R2)
8. What staff development has been provided for your teachers in the use of MakerSpaces? (R2, R3)
9. What are the elements of school culture that you perceive are important to supporting teachers in MakerSpace use? Can you describe elements of school culture that are barriers to using MakerSpace? (R1, R2, R3)
10. What influence do you perceive you have as a principal that encourages MakerSpace use? (C, R1, R2)
11. What was the role of parents in the implementation of MakerSpaces? (R1, R2, R3)
12. What are key practices you believe are essential in MakerSpaces? (R1, R4)
13. What types of activities have you seen in the MakerSpace that support the instruction of NGSS? (R4)
14. How would you feel or respond if you observed a new MakerSpace lesson that was completely failing? (R2, R3)
15. Is there anything else you would like to share about your experience with your school's MakerSpace? (C)

I want to thank you again for your willingness to allow me to interview you today. Again, your answers will remain confidential.

APPENDIX D:
INFORMATION SHEETS FOR STUDY PARTICIPANTS

**STUDY INFORMATION SHEET
(OBSERVATIONS)**

**MAKERSPACES:
A HANDS-ON APPROACH TO INCREASING STEM EXPOSURE
FOR K–5 STUDENTS**

Veronica Ortega, UCLA doctoral candidate; Linda Rose, Ph.D., and Noel Enyedy, Ph.D., from the Educational Leadership Program at the University of California, Los Angeles (UCLA) are conducting a research study.

You were selected as a possible participant in this study because you are a K–5 teacher in a school with a MakerSpace. Your participation in this research study is voluntary.

Why is this study being done?

The study will provide information to school leaders about the conditions and supports needed for teachers to use school MakerSpaces. It may inform future steps in MakerSpaces across [the district].

What will happen if I take part in this research study?

If you volunteer to participate in this study, the researcher will ask you to do the following:

- Allow the researcher to observe a MakerSpace lesson you are instructing. The researcher will be seeking observational data such as technology utilized, content connections, student actions, and teacher actions. This is not an evaluative observation, and data from this observation will not be provided to your site administrator.

How long will I be in the research study?

Participation will take a total of about 45–60 minutes.

Are there any potential risks or discomforts that I can expect from this study?

- The act of observation may cause inconvenience in having an additional adult in the classroom. The researcher will mitigate this inconvenience by positioning herself in the periphery of the classroom and by not directly interacting with students or teachers other than seeking clarification from the teacher after the lesson.

Are there any potential benefits if I participate?

The results of the research may add to the body of literature related to MakerSpaces in K–5 settings. Additionally, this research may guide next steps for MakerSpace use in [the district].

Will I be paid for participating?

- You will receive a \$30 gift card to Amazon.com or to Starbucks for your participation in this study. The gift card will be provided within one week (7 calendar days) of the observation.

Will information about me and my participation be kept confidential?

Any information that is obtained in connection with this study and that can identify you will remain confidential. It will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of pseudonyms and a secured code book; recorded data will be redacted for any potentially identifying information and all recorded data files will be erased upon transcription. The principal researcher will be the only person with access to this information.

What are my rights if I take part in this study?

- You can choose whether or not you want to be in this study, and you may withdraw your consent and discontinue participation at any time.
- Whatever decision you make, there will be no penalty to you, and no loss of benefits to which you were otherwise entitled.
- You may refuse to answer any questions that you do not want to answer and still remain in the study.

Whom can I contact if I have questions about this study?

- **The research team:**

If you have any questions, comments or concerns about the research, you can talk to the one of the researchers. Please contact:

Veronica Ortega at ortegav@g.ucla.edu

Dr. Linda Rose at rose@gseis.ucla.edu

Dr. Noel Enyedy at enyedy@gseis.ucla.edu

- **UCLA Office of the Human Research Protection Program (OHRPP):**

If you have questions about your rights while taking part in this study, or you have concerns or suggestions and you want to talk to someone other than the researchers about the study, please call the OHRPP at (310) 825-7122 or write to:

UCLA Office of the Human Research Protection Program

10889 Wilshire Blvd, Suite 830

Los Angeles, CA 90095-1406

**STUDY INFORMATION SHEET
(INTERVIEWS)**

**MAKERSPACES:
A HANDS-ON APPROACH TO INCREASING STEM EXPOSURE
FOR K–5 STUDENTS**

Veronica Ortega, UCLA doctoral candidate; Linda Rose, Ph.D., and Noel Enyedy, Ph.D., from the Educational Leadership Program at the University of California, Los Angeles (UCLA) are conducting a research study.

You were selected as a possible participant in this study because you are a K–5 principal in a school with a MakerSpace. Your participation in this research study is voluntary.

Why is this study being done?

The study will provide information to school leaders about the conditions and supports needed for teachers to use school MakerSpaces. It may inform future steps in MakerSpaces across [the district].

What will happen if I take part in this research study?

If you volunteer to participate in this study, the researcher will ask you to do the following:

- Allow the researcher to interview you regarding your experience as a K–5 school principal with a MakerSpace. The questions will seek information about conditions over which principals have influence in supporting MakerSpaces as well as their individual vision of what a school MakerSpace is.

How long will I be in the research study?

Participation will take a total of about 45 minutes.

Are there any potential risks or discomforts that I can expect from this study?

- The interviewee may perceive it as a risk to be interviewed out of concern for disclosure of responses to other members of the organization. The researcher will not share recordings, transcripts, or any identifiable data about the interview.

Are there any potential benefits if I participate?

The results of the research may add to the body of literature related to MakerSpaces in K–5 settings. Additionally, this research may guide next steps for MakerSpace use in [the district].

Will I be paid for participating?

- You will receive a \$30 gift card to Amazon.com or to Starbucks for your participation in this study. The gift card will be provided within one week (7 calendar days) of the interview.

Will information about me and my participation be kept confidential?

Any information that is obtained in connection with this study and that can identify you will remain confidential. It will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of pseudonyms and a secured code book; recorded data will be redacted for any potentially identifying information and all recorded data files will be erased upon transcription. The principal researcher will be the only person with access to this information.

What are my rights if I take part in this study?

- You can choose whether or not you want to be in this study, and you may withdraw your consent and discontinue participation at any time.
- Whatever decision you make, there will be no penalty to you, and no loss of benefits to which you were otherwise entitled.
- You may refuse to answer any questions that you do not want to answer and still remain in the study.

Whom can I contact if I have questions about this study?

If you have any questions, comments or concerns about the research, please contact:

Veronica Ortega at ortegav@g.ucla.edu
Dr. Linda Rose at rose@gseis.ucla.edu (faculty sponsor)
Dr. Noel Enyedy at enyedy@gseis.ucla.edu (faculty sponsor)

- **UCLA Office of the Human Research Protection Program (OHRPP):**
If you have questions about your rights while taking part in this study, or you have concerns or suggestions and you want to talk to someone other than the researchers about the study, please call the OHRPP at (310) 825-7122 or write to:

UCLA Office of the Human Research Protection Program
10889 Wilshire Blvd, Suite 830
Los Angeles, CA 90095-1406

REFERENCES

- Ackermann, E. (2011). *Piaget's constructivism, Papert's constructionism: What's the difference?* Cambridge, MA: MIT Media Lab, Future of Learning Group. Retrieved from http://learning.media.mit.edu/content/publications/EA.Piaget%20_%20Papert.pdf
- Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191.
- Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). Report of the 2012 National Survey of Science and Mathematics Education. Horizon Research, Inc.
- Barrel, J. (2007). *Problem-based learning: An inquiry approach*. Thousand Oaks, CA: Corwin.
- Blank, R. K. (2012). *What is the impact of decline in science instructional time in elementary school*. Los Altos, CA: Noyce Foundation. Retrieved from www.csss-science.org/downloads/NAEPElemScienceData.pdf
- Blikstein, P. (2013). Digital fabrication and “making” in education: The democratization of invention. In J. Walter-Herrmann & C. Büching (Eds.), *FabLabs: Of machines, makers' and inventors*. Bielefeld, Germany: Transcript.
- Brinkerhoff, R. (2003). *The success case method: Find out quickly what's working and what's not*. Oakland, CA: Berrett-Koehler.
- Bybee, B. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, 70(1), 30–35.
- Bybee, R. W. (2014). NGSS and the next generation of science teachers. *Journal of Science Teacher Education*, 25(2), 211–221.

- California Department of Education. (2014). *INNOVATE: A blueprint for science, technology, engineering, and mathematics in California public education*. Dublin, CA: Californians Dedicated to Education Foundation.
- Commission on Teacher Credentialing. (2009). California Standards for the Teaching Profession (CSTP). Retrieved from <http://www.ctc.ca.gov/educator-prep/standards/CSTP-2009.pdf>
- Carnevale, A. P., Smith, N., & Melton, M. (2011). *STEM: Science, technology, engineering, mathematics*. Washington, DC: Georgetown University Center on Education and the Workforce.
- Carroll, M., Goldman, S., Britos, L., Koh, J., Royalty, A., & Hornstein, M. (2010). Destination, imagination and the fires within: Design thinking in a middle school classroom. *International Journal of Art & Design Education*, 29(1), 37–53.
- Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
- Cuban, L. (1986). *Teachers and machines: The classroom use of technology since 1920*. New York, NY: Teachers College Press.
- Deniz, H., & Akerson, V. (2013). Examining the impact of a professional development program on elementary teachers' views of nature of science and nature of scientific inquiry, and science teaching efficacy beliefs. *Electronic Journal of Science Education*, 17(3).
- Donaldson, J. (2014). The maker movement and the rebirth of constructionism. Hybrid Pedagogy. Retrieved from <http://www.hybridpedagogy.com/journal/constructionism-reborn/>

- Dougherty, D. (2013). The maker mindset. In M. Honey & D. E. Kanter (Eds.). *Design, make, play: Growing the next generation of STEM innovators* (pp. 7–11). New York, NY: Routledge.
- Fink, E., & Resnick, L. B. (2001). Developing principals as instructional leaders. *Phi Delta Kappan*, 82(8), 598–610.
- Fleming, L. (2015). *Worlds of making: Best practices for establishing a makerspace for your school*. Thousand Oaks, CA: Corwin.
- Fontichiaro, K. (2014). A charter for your school makerspace? [Blog post]. Retrieved from <http://www.fontichiaro.com/activelearning/2014/09/04/a-charter-for-your-school-makerspace/>
- Fulp, S. (2002). *The status of elementary science teaching: National survey of science and mathematics education*. Chapel Hill, NC: Horizon Research.
- Gerard, L. F., Bowyer, J. B., & Linn, M. C. (2008). Principal leadership for technology-enhanced learning in science. *Journal of Science Education and Technology*, 17(1), 1–18.
- Griffith, J. (2004). Relation of principal transformational leadership to school staff job satisfaction, staff turnover, and school performance. *Journal of Educational Administration*, 42(3), 333–356.
- Hanushek, E. A., Peterson, P. E., & Woessmann, L. (2010). *U.S. math performance in global perspective: How well does each state do at producing high-achieving students?* [Report No. 10–19]. Cambridge, MA: Program on Education Policy and Governance, Harvard University.
- Heller, J. I., Daehler, K. R., Wong, N., Shinohara, M., & Miratrix, L. W. (2012). Differential effects of three professional development models on teacher knowledge and student

- achievement in elementary science. *Journal of Research in Science Teaching*, 49(3), 333–362.
- Hira, A., Joslyn, C. H., & Hynes, M. M. (2014, October). *Classroom MakerSpaces: Identifying the opportunities and challenges*. Paper presented at the Frontiers in Education conference, Madrid, Spain.
- Leithwood, K., & Jantzi, D. (1999). Transformational school leadership effects: A replication. *School Effectiveness and School Improvement*, 10(4), 451–479.
- Leithwood, K., Seashore Louis, K., Anderson, S., & Wahlstrom, K. (2004). *Review of research: How leadership influences student learning*. Minneapolis, MN: University of Minnesota Center for Applied Research and Educational Improvement.
- Lou, N., & Peek, K. (2016). By the numbers: The rise of the makerspace. Popular Science. Retrieved from [http://www. popsci. com/rise-makerspaceby-numbers](http://www.popsci.com/rise-makerspaceby-numbers).
- Nekuda Malik, J. (2016). US administration makes efforts to increase inclusiveness in STEM industries: [Www.whitehouse.gov/demo-day](http://www.whitehouse.gov/demo-day). *MRS Bulletin*, 41(5), 355-356.
doi:10.1557/mrs.2016.103
- Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research*, 5(1), 4.
- Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation* (3rd ed.). San Francisco, CA: Jossey-Bass.
- More Than a Worksheet. (2014). Jack and the parachute [Blog post]. Retrieved from <http://www.morethanaworksheet.com/2014/09/19/jack-and-the-parachute-in-pictures/>
- NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*.

- Washington, DC: National Academies Press.
- Obama, B. (2009). President Obama's call to create not just to consume [Transcript]. Retrieved from https://dotearth.blogs.nytimes.com/2009/04/27/obamas-call-to-create-not-just-consume/?_r=0
- Olson, S., & Riordan, D. G. (2012). Engage to excel: Producing one million additional college graduates with degrees in Science, Technology, Engineering, and Mathematics. Report to the President. *Executive Office of the President*.
- Papert, S. (1980). Constructionism vs. instructionism. In *Proceedings from Japanese Educators Conference*. http://www.papert.org/articles/const_inst.
- Papert, S., & Harel, I. (1991). Situating constructionism. *Constructionism*, 36, 1–11.
- Peppler, K., & Bender, S. (2013). Maker Movement spreads innovation one project at a time. *Phi Delta Kappan*, 95(3), 22–27.
- Polizzi, G. (2011). Measuring school principals' support for ICT integration in Palermo, Italy. *Journal of Media Literacy Education*, 3(2), 113–122.
- Rogers, E. M. (1962). *Diffusion of innovations*. New York: Free Press of Glencoe.
- Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York, NY: Simon & Schuster.
- Ross, J. A., Cousins, J. B., & Gadalla, T. (1996). Within-teacher predictors of teacher efficacy. *Teaching and Teacher Education*, 12(4), 385-400.
- Saldaña, J. (2009). *The coding manual for qualitative researchers*. Los Angeles: Sage.
- Schön, S., Ebner, M., & Kumar, S. (2014). The Maker Movement: Implications of new digital gadgets, fabrication tools and spaces for creative learning and teaching. *ELearning Papers*, 39, 14–25

- Sheppard, V. (2013). Leadership helps turn around a troubled school. *Phi Delta Kappan*, 94(8), 32–36.
- Sikma, L., & Osborne, M. (2014). Conflicts in developing an elementary STEM magnet school. *Theory into Practice*, 53(1), 4–10.
- Spillane, J. P., Diamond, J. B., Walker, L. J., Halverson, R., & Jita, L. (2001). Urban school leadership for elementary science instruction: Identifying and activating resources in an undervalued school subject. *Journal of Research in Science Teaching*, 38(8), 918–940.
- Stager, G. S. (2013). Papert’s prison Fab Lab: Implications for the Maker Movement and education design. In *Proceedings of the 12th International Conference on Interaction Design and Children* (pp. 487–490). New York, NY: ACM.
- Steele, R. (2015). Learning commons or maker space? Don’t forget the library. *Teacher Librarian*, 42(5), 19.
- Stephens, M., Landeros, K., Perkins, R., & Tang, J. H. (2016). Highlights from TIMSS and TIMSS Advanced 2015: Mathematics and Science Achievement of US Students in Grades 4 and 8 and in Advanced Courses at the End of High School in an International Context. NCEES 2017-002. National Center for Education Statistics.
- Stieler-Hunt, C., & Jones, C. M. (2015). Educators who believe: Understanding the enthusiasm of teachers who use digital games in the classroom. *Research in Learning Technology*, 23.
- Trinter, C. P., Moon, T. R., & Brighton, C. M. (2015). Characteristics of students’ mathematical promise when engaging with problem-based learning units in primary classrooms. *Journal of Advanced Academics*, 26(1), 24–58.

Waters, T., Marzano, R. J., & McNulty, B. (2003). *Balanced leadership: What 30 years of research tells us about the effect of leadership on student achievement*. Aurora, CO: Mid-continent Research for Education and Learning.