LEBANESE AMERICAN UNIVERSITY

Bringing a Maker-Centered Classroom into the Elementary School

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Dedication page

To my loving daughter

And my support system Chirine Karout and Lina Mahmassani
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Bringing a Maker-Centered Classroom into the Lower Elementary School

Nathalie Hanna Shaikh

ABSTRACT

At its basic level, a Makerspace is viewed as a learning space equipped with tools and materials with which people of all ages can produce useful and meaningful products through social interactions and problem solving. In this study, we aimed at identifying the components of a KG1 maker-centered classroom, investigating the effects of a maker-centered unit on second-graders, and exploring the reasons of the lack of maker-centered classrooms at the lower elementary level. The form and function of a KG1 maker-centered classroom was observed, using three distinct checklists over four weeks of observations. One checklist focused on the children’s conduct in the Makerspace, another targeted the role of the teachers and students, while the third checklist was dedicated to studying the physical environment of the Makerspace. A Maker-centered unit was designed and implemented in a grade-2 classroom to study its effect on students’ learning. Data were collected and later analyzed using researcher’s anecdotal records, an evaluation rubric and students’ making journals. Finally, teachers and administrators were interviewed to get a glimpse their perceptions of Makerspaces in the lower elementary classroom. Content analysis was used to study the transcripts of the interviews.

From the observations, we learned that the KG1 classroom couldn’t be labeled as a maker-centered classroom due to the lack of teacher involvement and purpose. The findings showed that the maker-centered instructional unit implemented in grade 2 promoted students’ problem solving abilities. The interviews with teachers and
administrators showed that they all had a positive attitude towards Makerspaces, however several challenges need to be addressed before a Makerspace can be implemented at the lower elementary level.

**Keywords:** Makerspaces, Maker-centered classroom, STEM approach, Problem solving, Engineering, Early childhood education.
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Chapter One

Introduction

1.1 Background of the Study

It is well known, by many, that students learn best by designing, constructing and deconstructing objects. By putting things together or breaking them apart for a purpose, critical thinking and problem solving skills develop. Makerspaces are becoming a more common sight in schools and after-school clubs around the world in an attempt to provide and encourage design, creativity and hands-on opportunities. They are built upon the fact that people learn when they are actively operating upon their environment (Dougherty, 2012). Many educators have envisioned using this student-centered, interest-driven and creative approach to optimize learning and critical thinking in their classrooms.

Students are social beings; they communicate by asking questions and expressing their learning in various forms, therefore, they learn from others as well. New ideas come from people collaborating and sharing ideas. The combinations of exciting ideas lead to the creation of novel tools that gradually become basic needs for modern life, such as refineries, computers and mobile phones. Many innovations start this way.

Studies have shown that students learn best by doing (Ackermann, 2001). From birth onward, children create knowledge and make connections because they are curious beings. The child learns many important skills through trial and error or through imitation. At a certain age, children become autonomous and start “making” with minimal guidance from an adult, reflecting the most natural process of learning.

Nowadays, the learning process in schools has become too structured and allows for little creativity on the part of the learner. Instead of the student being the producer of
knowledge, the student is bound to be the consumer of knowledge. Hands-on learning, if integrated into the learning process, is one of the best ways to equip students to take ownership of their own learning (Martin, 2015). Therefore be more likely to retain what they have learned.

Piaget believed that children learn by doing and that they create their own learning experiences. Children are active and motivated learners who construct their knowledge over time. Papert, “the father of the maker movement”, (Martinez & Stager, 2013, p. 17) worked with Piaget and added to his theory. Papert and Harel (1991) asserted that knowledge develops better when students build, make and share their products. Papert believed that when technology is integrated with constructivist ideas, children create for themselves new experiences and ways of thinking, as cited in Stager (2014). This is the basis for constructionism.

Papert is considered by many to be one of the leading figures in educational technology. He developed the learning theory of constructionism, which states that when learners use tools, new ideas, and their mind to create things learning will naturally occur (Ackermann, 2001). It is a student-centered approach where learners are active and engaged while learning. In brief, constructionism is learning by making, inventing, doing or creating.

1.2 The Statement of the Study

A significant body of literature revolves around the concept of how a makerspace is run in an out-of-school setting. How to incorporate makerspaces into schools and their curricula or run a maker-centered classroom is still however understudied. A review of
the literature reveals the lack of studies conducted about the implication of makerspaces on students’ learning in lower elementary school setting.

1.3 Purpose of the Study and Research Questions

The purpose of this paper is to study the form and function of a makerspace in a KG1 classroom, to investigate the reasons for which a makerspace is not adopted in the lower elementary and to implement an instructional unit in grade-2.

The research questions that this study attempted to answer are:

1. What are the main features and components of the makerspace in the studied KG1 classroom?
2. How does the makerspace contribute to the learning in the KG1 classroom?
3. How do administrators and teachers perceive extending the model of makerspaces to the lower elementary level? What challenges do they foresee?
4. What impact does a maker-based instructional unit have on the learning of grade-2 students and what are the challenges actually faced?

1.4 Definition of Terms

- Making: personal fabrication to produce a functional product. In the process of making, students: plan, design, test, fail, iterate, and make decisions. So making “Refers to a set of activities that can be designed with a variety of learning goals in mind” (Halverson & Sheridan, 2014, p. 501)

- Makerspaces: Dale Dougherty (2013), in the book Design, Make, Play, describes a Makerspace as:
“… [A] space where kids have the opportunity to make – a place where some tools, materials, and enough expertise can get them started. These places, called makerspaces, share some aspects of the shop class, home economics class, and the art studio and science labs. In effect, a makerspace is a physical mash-up of different places that allow makers and projects to integrate these different kinds of skills.” (p.9)

For the purpose of this study, a makerspace is defined as a student-centered learning environment where making, designing and collaboration are encouraged to develop critical thinkers and problem solvers.

• Maker-centered classroom: In the context of Lebanese preschools, a maker-centered classroom is referred to as “play centers”. At other levels in school, it is a classroom where the teacher challenges the students by providing opportunities to spark the learners’ curiosity through projects connected to real life that may or may not have solutions. Sometimes, the challenge can sprout from the learner; the problem can be posed to the whole class or it can be investigated in small groups or on an individual basis.

• Maker-based unit: For the purpose of this study, it is an instructional unit in which students must identify the problem presented to them in the fairy tale of Little Red Riding Hood. During the unit, the students will design a catapult with certain criteria, which will lead to a solution. The unit will follow the engineering cycle phases and be administered over five class sessions. Next, the students will build and test the catapult, which is the solution to the problem suggested in the fairy tale. Throughout the design process, the students will make the necessary
modifications to their product, as needed, since they are exploring. At the end of each phase of the unit, the students will orally reflect on the process to show how they have grown as makers.

- STEM education: STEM is an acronym that stands for Science, Technology, Engineering and Math. It is a unique approach to teaching and learning that centers on individual students and their learning interest. Unlike traditional education, STEM education stresses on the integration of the STEM subjects. It is important to note that STEM is not a subject, nor a curriculum but rather an approach and a way of thinking. It is an interdisciplinary approach that may combine the four disciplines and integrates them into the real world. The characteristics of STEM education are authenticity by connecting the learning to the real world, hands-on learning by building a product, student-centered learning that empowers the learner, and is focused on developing higher order thinking skills. Collaboration, communication, research, problem solving, critical thinking and creativity are the soft skills that students will need in order to be successful in today’s world.

1.5 Rationale and Significance of the Study

Constructionism is the learning theory that is most associated with Makerspaces. Papert coined this term in the mid 1980s and only recently is it starting to resonate in the educational setting. Papert (1980) highlights the fact that making happens in the head of the learner and that it is only through construction or building that we are able to see the accumulated knowledge.
The presence of makerspaces in the educational setting has sparked several inquiries. In their study, Fourie and Meyer (2015) presented anecdotes about the development of makerspaces in the school library. They concluded that in the context of the library, the work produced by the learner must be aligned with the school curriculum. Halverson and Sheridan (2014) also wanted to understand the role and purpose of a makerspace in an educational setting at all grade levels. They found that by bringing the maker movement to an educational setting, it would transform the educators’ vision of the learning, the learner and the learning environment (Halverson & Sheridan, 2014). More studies are being conducted to further understand the benefits of an educational makerspace.

A lot of the literature is based on high school and university students. Children are natural born tinkerers and makers, so why don’t administrators and teachers take advantage of that point and create a curriculum, which supports those natural tendencies? In their study, Jordan and Lande (2014), concluded that young makers must be exposed to an engaging K-12 curriculum to provide an opportunity for them to develop and apply learned knowledge to “make” and be creative.

Educational Makerspaces are a new trend in schools around the world and just now have begun to sprout in Lebanese schools. Therefore, there is little research conducted to examine the benefit of makerspaces on elementary students’ thinking and creativity. When makerspaces are introduced in schools, the members of a school community have to adopt a maker mindset and ensure curricular connections with the addition to continuous teacher training (Noss, & Clayson, 2009). In addition, the environment plays a big role in the success of a makerspace.
Despite the evidence provided in the aforementioned publications, conclusions about the issue of implementing educational makerspaces in lower elementary remains inconclusive. The debate revolves around three areas: 1) Space allocation, 2) Budget distribution 3) Curricular connections.

The proposed study examined how a maker-centered KG1 classroom functions, and explored the lack of such places at the lower elementary grade levels (Grade 1, 2, 3) of the same school. So far, in Lebanon Makerspaces exist in few schools at the middle and high school levels. Only a couple of schools in Beirut have started to build a makerspace for elementary students. Makerspaces outside of school are a more common sight in Lebanon. There are at least five makerspaces in Beirut open to the public and that cater to different age groups. Furthermore, the study exposed the perception of administrators, preschool and lower elementary teachers towards the idea of educational makerspaces at the lower elementary level. It is noteworthy to mention that this study further highlighted the importance of incorporating a makerspace or a maker-centered classroom environment into elementary schools.

1.6 Thesis Division

The thesis is divided into five main chapters. The first chapter introduces the focus of this study, its rationale, context, definition of key terms and the research questions. Following the introduction, Chapter Two exposes the literature that supports this study. The literature review identifies the main contributors, the studies and theories, which support the purpose of this study. After that, Chapter Three reveals the chronological method in which the study was conducted. In addition, it also includes the sampling, participants and setting, the instruments used and the data collection.
techniques. The fourth chapter’s emphasis is on the results found by using the prepared instruments. Chapter Five contains the discussion part of the paper, which is based on the data analysis and comprises the conclusion, recommendations for further research and the limitations of the study.
Chapter Two

Literature Review

2.1 History of the Maker Movement and Makerspaces

The Maker Movement began around a decade ago (Smith & Smith, 2016). It has allowed students to use their hands to create original products to solve problems or fulfill needs, based on their interest and to learn in the process. The Maker Movement has emerged as a response of hobbyists and tinkerers who have come together to share their inventions. From there, the first Maker Faire was organized in 2006 to make these creations open and available to the public (Martin, 2015). Nowadays, this movement is making its way into education.

Several articles investigating the Maker Movement suggest that a culture of hands-on making, creating, designing, and innovating has been booming worldwide for years (Peppler & Bender, 2013). The Maker Movement originated from the do-it-yourself (DIY) mindset, which encourages experimentation and creativity. The origin of the Maker movement exists inherently within the person, what Dougherty (2013) calls “experimental play”. Makers have a need to engage with objects around them in a way that turns them into producers rather than consumers (Dougherty, 2013).

Makerspaces are currently available in Lebanon, but mainly in an out-of-school setting. Many schools have adopted aspects of a Makerspace at the elementary level, but it has not been fully integrated into the learning environment or the school curriculum. Only a few of Lebanese private schools are in the process of building a makerspace for their elementary students. As studies start to reveal the benefits of educational
makerspaces, more schools will accept the concept and create room for these spaces.

2.2 The Environment and Tools of a Makerspace

2.2.1 The Makerspace as a Learning Environment

A Makerspace is a combination of a science laboratory, art atelier and shop class. It is a space where makers are given the chance to create projects and integrate all kinds of skills and prior learning from different disciplines (Petrich, Wilkinson, & Bevan, 2013). The Makerspace is open to all ages, however it is key that the maker has the right mindset (Dougherty, 2013). We can put the best tools under one roof, yet if the makers and their facilitators do not foster the maker mindset, little or no making will take place.

Kurti, Kurti, and Fleming (2014a) assert, “No two school Makerspaces should be exactly alike”. According to them, a school Makerspace must be unique to the needs and interests of the school community to assure its sustainability in the future. They add that a Makerspace is a learning environment that allows for open-ended exploration for all.

Using Makerspaces moves away from traditional education and falls better under career technical education or vocational education. Makerspaces shed light on the importance of enriching the learning process by allowing students to acquire new knowledge physically, cognitively, socially, and with enthusiasm (Hlubinka, Dougherty, Thomas, Chang, Hoefer, Alexander & McGuire, 2013). In their research, Harron and Hughes (2018) highlighted that making is not only about the tools, “but rather about creating authentic challenges and empowering both students and teachers to actively redesign and create the world around them.” (p.255)
Waters and Kessler (2015) and Davee, Regalla and Chang (2015) agree that there are three main models of Makerspaces in the school setting. However, both groups of researchers dub the spaces using different names.

1. The Maker-Centered Classroom Model (Walters & Kessler, 2015) or Dedicated Makerspaces (Davee et al., 2015): is when there is a space dedicated to making inside the classroom. The making area is integrated in the student’s daily learning and resources are always made available by the teacher or the student.

2. The Resource Model (Walters & Kessler, 2015) or Distributed Makerspaces (Davee et al., 2015): is when the making tools are located outside the regular classroom, not necessarily in one place, but they are accessible to everybody. The aim of this model is for the teacher and the students to use the tools in different locations as an additional enrichment to the class inquiry. This model allows the students to showcase their work to likeminded students and maybe make others interested.

3. The third type is a Makerspace aimed for Maker Education courses (Walters & Kessler, 2015) or Mobile Makerspaces (Davee et al., 2015). Here the students are taken to a special space where they are exposed to tools, materials and different projects, which can spark their design thinking. The students are given a chance to be makers without any curricular or teacher guided instructions.

This research study was based on the first model where the making happens inside the classroom. The observations and the instructional unit occurred in the class because students perform best when they are in a safe and familiar learning environment. Additional materials were needed for the implementation of the instructional unit, as
were not originally found in the class.

A Makerspace is not only a place to make and experiment, but also a social space. It brings people together. Dougherty (2012) asserts that people in makerspaces are “happy” and show a “sense of optimism”. Those emotions are shared among people who are making things, or seeing people make things. These people listen to one another and build on each other’s ideas, thus forming a community of explorers. This highlights the flexibility and free atmosphere that a makerspace embeds and how it naturally calls for group work and problem solving.

An elementary Makerspace can help students develop character-building traits (Kurti, Kurti, and Fleming, 2014a). Creativity, curiosity and responsibility are just a few of those traits that are fostered in the young maker. Instigating the student through activities, videos or a simple quote will inspire the learner. It will also spark curiosity in the student and at the same time allow him or her to take ownership of their work, and eventually foster these aforementioned traits. Several supporters of school Makerspaces stress that Makerspace projects should focus on the process and not the final product.

Falbel (1993) states that learning happens best when a learner is producing a product they care a lot about or that is meaningful to them and it can only happen in a learning environment with certain characteristics. A good learning environment must have these three conditions: choice, diversity, and congeniality. When a child is given a choice, the level of engagement and commitment will be high. To maximize engagement there should also be a diversity of skill and style. The learning environment must include people of all ages (similar to the Samba Schools described in the next section) with different levels of expertise. Falbel (1993) affirms that when students of the same level
are grouped, at one point the learning might stagnate. The third condition, congeniality, is of utmost importance. The Makerspace should be a friendly, welcoming, and safe space where the person is not judged. The learners should not feel pressured by time or in a rush to complete their product. They must be given the chance to be curious, walk around and visit other workstations, be inspired and most essentially communicate with others in the room. In conclusion, the best circumstances of a good learning environment in any kind of Makerspace, is when a maker is given a choice, is when makers of different levels of expertise collaborate with one another and when a maker feels safe to make errors.

Recently, Harron and Hughes (2018) identified new benefits to makerspaces. It was evident in their study that a makerspace provides opportunities to both genders due to the interest-driven specification. Another benefit they discovered was that students, in a makerspace, develop a “failure-positive” attitude where mistakes are valued as learning moments and opportunities to grow. In a makerspace, students become the creators of knowledge rather than its consumers.

### 2.2.2 Samba Schools

Almost four decades ago, in the early 1980s, Papert (1980) had a vision for the future of education and the way learning should look like. In his book, *Mindstorms Children, Computers, and Powerful Ideas*, he describes the learning environment of a samba school he visited in Brazil. Papert (1980) was amazed by the way these schools were run and the way learning happened.

In the samba school that Papert (1980) visited, there were members of all ages, “from children to grandparents”. They all danced together, and as they danced, learning
and teaching were taking place. The dancers were not segregated according to age or level of expertise at the samba school. There was a sense of belonging and a common goal among all the dancers.

The learning environment of the samba school that Papert (1980) described in his book can be transferred to an educational makerspace and the constructionist learning theory supports it. According to Papert (1980), both environments are similar in three ways; real activity, human relationship and the learning is not a one-way street. In constructionist makerspaces, the learning and making are based on real authentic activity. This allows the learner to be more engaged and have ownership of the learning and be able to apply the knowledge to life outside of school. The second similarity targets the social aspect of makerspaces. All the members of a makerspace or the samba school are learners; they all learn from one another and depend on each other to overcome any difficulties. The third similarity is concerned with the manner of teaching. In a samba school, just like in a makerspace, one person does not convey the knowledge; no one takes the role of the “expert.” On the contrary, all makers learn from one another and sometimes they might need help from people in the community or resort to different resources.

2.2.3 Makerspace tools

The tools present in the space must inspire the makers to want to create products with a purpose. According to Kurti, Kurti and Fleming (2014b), once the space has been allocated, it is time to fill it with making tools. To start off, it is best to display sample projects made by the members of the community.
There must be a wide range of tools in a makerspace, from a pencil all the way to heavy-duty machinery. The tools can be sorted into three groups: simple tools, intermediate tools and advanced tools (Kurti, Kurti and Fleming, 2014b). The simple tools can be Legos, magnets, things to take apart or electric wires. This class of tools should only spark the learner’s curiosity. The next level of tools is the intermediate tools, where the learners can find 3D printers, design software, 3D scanners and electronics. The tools in the advanced level will be the same as the intermediate ones, but as the name implies, they must be more advanced. Therefore, it is possible to find more powerful 3D tools, design software (CAD), and coding software. Raspberry pi, a computer the size of a credit card, and other operating system can be introduced at this level too.

2.3 The Characteristics of Spacemakers and Makers

2.3.1 Characteristics of a Spacemaker

Kurti, Kurti and Fleming (2014c) nicknamed the person in charge of a Makerspace as “The Spacemaker”. The spacemakers can be teachers, technology instructors or anyone with a maker mindset that can lead and manage the space. The spacemaker must be “resourceful, failure tolerant, collaborative, and always willing to learn” (Kurti, Kurti and Fleming, 2014c, p.10). They must exemplify the way students should behave in the Makerspace. The spacemaker’s role is to stay up to date with the latest tools and create a fantastic environment for the learners to seek out answers.

In addition to these qualities, spacemakers are always ready to listen to the students’ concerns and questions. Spacemakers must react to the students by asking another question, in order to empower them and to increase their confidence. This
process will instill in the makers the notion of life-long learning and eventually become experts in their field of interest.

Spacemakers are always alert to recognize talent, offer challenges and encourage productive discussion among the makers. They are not considered teachers or experts, but the spacemakers must exhibit the qualities of a leader to create a thriving educational makerspace (Kurti, Kurti and Fleming, 2014c, p.10).

2.3.2 Characteristics of a Maker

Makers are technology buffs who play with a variety of tools and materials to nurture their technological skills. Any new technology presents an invitation for play, and makers regard this kind of play as highly satisfying (Dougherty, 2012). Makers explore what they can do and learn as they explore. From that process, emerge new ideas that may lead to real-world applications (Dougherty, 2013). Making is a source of innovation to reimagine education (Peppler & Bender, 2013).

Makers give it a try; they chase wonder, embrace curiosity and seek the sparks that ignite their imagination. Makers are also thoughtful planners and strategic risk takers who take things apart. A maker may attempt to do things that even manufacturers did not think of doing. A maker is a dreamer with a purpose in mind and is always willing to make a positive change.

Makers have a sense of what they are doing and what they want to learn. They are inspired by other makers’ work and are self-initiated to take on projects (Dougherty, 2013). They sense the necessity to do something; they do not miss an opportunity. It is important to note that makers are not only engineers or inventors; cooks, gardeners and
knitters are also considered makers.

In his article, Kalil (2013, p.12) describes makers as “people who design and make things on their own time because they find it intrinsically rewarding to make, tinker, problem solve, discover, and share what they have learned.” Dougherty (2013, p.7) adds, “Makers were enthusiasts who played with technology to learn about it.” Both experts agree that makers are unique people.

Peppler and Bender (2013) state that, “The maker movement is driven by makers.” (p. 26) The spread of Makerspaces depends on the online communities, which share their expertise, step-by-step instructions and their work on the Internet. Since these makers live around the world, this support is available 24 hours a day. Additionally, Maker Faires taking place in different countries, on a yearly basis, positively influence the spread of Makerspaces. The White House encouraged the idea of Makerspaces; the former president of the United States, Barak Obama, himself, hosted a Maker Faire when he was in office (Martin, 2015).

The maker mindset needs to be nurtured. Chu, Quek, Bhangaonkar, Ging and Sridharamurthy (2015) explain making as “a continuous exploratory process that integrates both ‘process’ and ‘product’”. When they observed elementary students in a making session, they noticed three distinct attitudes: fun and excitement, tension and boredom, and frustration. According to their study, the last two states are due to low levels of self-efficacy, motivation and interest on the part of the student. For the students to remain engaged in making, it is essential to instill in them the Maker mindset by developing self-identity, which is a developmental milestone at the ages of 8 to 11 (Chu et. al, 2015). To support the development of the Maker mindset in elementary students,
Chu et. al. (2015) posit that STEM or making activities must not result in the teaching of skill, but rather focus on the interest of the child.

### 2.4 Creating Learning Conditions in a Makerspace

“Any expedition begins with an invitation, making is about new pathways and stories,” states David Jakes. Jakes (2011) is a long time educator who at the end of his teaching career got caught in the web of design. He now owns a design firm, David Jakes Designs LLC, and is a reference when it comes to sustaining educational Makerspaces. He believes that the purpose of maker projects is to give students the chance to tap into their imagination by offering them the right opportunity.

In his presentation, Creating New Conditions for Learning Through Makerspaces, he talks about three key considerations when planning for a school Makerspace:

1. **Exploration and expression:** The expression of creativity and exploration are paramount to a successful makerspace. Students must be given opportunities to use different media and tools to express what they know, what they believe in and who they are in a unique way.

2. **Focus on skill and disposition:** Making gives students the chance to learn and develop skills in an innovative way. Through the projects created in a Makerspace, the students will learn making skills that will give them a life long disposition for making. The projects must instill in the students the love of making for the rest of their lives. Just like reading and writing, once those skills are learned the children will use them constantly. By exposing them to making skills they start to develop a mindset with which they will continue to make and create.
3. Focus on the creative process: It is not enough to instill making skills in students. They must learn to make things of value. The tools, materials and media found in a Makerspace have to invite students to want to create something of essence and at the same time make something new. The children need to be aware that everything they create must have a purpose and give meaning to their product.

At the end of his presentation, Jakes (2011) shares the characteristics for a successful Makerspace that students would want to visit on a regular basis. The Makerspace must promote wonder and curiosity in order for the students to be productive. There should be a balance between curriculum-based projects and passion or interest based projects. Sometimes students should be given the opportunity to choose what they want to learn and make their own decisions, instead of giving them a prepared recipe for success. They must be put in a situation where failure is valued in order for them to iterate their design and learn from their mistakes.

Hatch (2013) and Jakes (2011) are supporters of the maker manifesto. The maker manifesto encourages makers to structure their planning and thinking. It allows them to see thoughts, designs, and projects from a new perspective. The purpose of the manifesto is to guide the maker to locate the opportunity for making and to exhibit certain making behaviors throughout the making process. Yet, it is important to point out that without the proper mindset, the outcome may not be significant.

The manifesto, which Hatch describes thoroughly in his book *The maker movement manifesto: rules for innovation in the new world of crafters, hackers, and*
*tinkerers* (2013), is based on the nine traits a maker must adopt to be successful. Below, is the manifesto as stated in Hatch’s book (2013):

1. **Make:** Making is fundamental to what it means to be human. We must make, create, and express ourselves to feel whole. There is something unique about making physical things. These things are like little pieces of us and seem to embody portions of our souls.

2. **Share:** Sharing what you have made and what you know about making with others is the method by which a maker’s feeling of wholeness is achieved. You cannot make and not share.

3. **Give:** There are few things more selfless and satisfying than giving away something you have made. The act of making puts a small piece of you in the object. Giving that to someone else is like giving someone a small piece of yourself. Such things are often the most cherished items we possess.

4. **Learn:** You must learn to make. You must always seek to learn more about your making. You may become a journeyman or master craftsman, but you will still learn, want to learn, and push yourself to learn new techniques, materials, and processes. Building a lifelong learning path ensures a rich and rewarding making life and, importantly, enables one to share.

5. **Tool up:** You must have access to the right tools for the project at hand. Invest in and develop local access to the tools you need to do the making you want to do. The tools of making have never been cheaper, easier to use, or more powerful.

6. **Play:** Be playful with what you are making, and you will be surprised, excited, and proud of what you discover.
7. Participate: Join the Maker Movement and reach out to those around you who are discovering the joy of making. Hold seminars, parties, events, maker days, fairs, expos, classes, and dinners with and for the other makers in your community.

8. Support: This is a movement, and it requires emotional, intellectual, financial, political, and institutional support. The best hope for improving the world is us, and we are responsible for making a better future.

9. Change: Embrace the change that will naturally occur as you go through your maker journey. Since making is fundamental to what it means to be human, you will become a more complete version of you as you make.

After describing the nine factors of the Maker Manifesto, Hatch (2013) strongly suggests that the manifesto be modified to suit the culture of the school.

2.4.1 Universal Design for Learning

The principles of Universal Design for Learning (UDL) tie in with the STEM approach used in a Makerspace. They both share common aspects, two of them being learner-centered and interest-driven (Bernacchio & Mullen, 2007). The concept of UDL sprouted from architectural design in the late 90s. UDL is an educational framework, which minimizes curriculum barriers and maximizes learning (Rose & Meyer, 2002).

UDL has three major guidelines (Rose & Meyer, 2002). UDL is not about changing or fixing students but it is about the teacher being flexible to cater for the needs of each learner to be able to push them forward. There are actually three parts of the brain that need to be activated in order for true learning to occur. First, the students have to be engaged, the teacher needs to
make a connection with all the students in the classroom and show them that what he/she is teaching is important. After the students have made a connection with the information, they will have to choose a way in which to represent that information. In the end, the students must be able to produce a product in the form of their choice.

2.5 Constructionist learning theory

The maker movement in education is based on the constructionist learning theory, which supports hands-on learning through building things (Kurti, Kurti, and Fleming, 2014c). The learning theory is also based on creativity, tinkering, exploring, building, and presentation (Donaldson, 2014). Thus, the learner is always encouraged to initiate the learning process. Teachers are simply the facilitators of knowledge, which might sound simple, but entails a lot of planning and research. The teacher must be aware of all the details of the projects being created and at the same time be able to ask the right questions to push the students’ thinking further. Their role is to ensure that the acquisition of new knowledge and thinking is happening simultaneously as the students are making.

Constructionism is based on two characteristics (Donaldson, 2014). First, learning is an active construction of knowledge. Second, people make ideas they don’t get them. The first aspect is based on Piaget’s constructivism, while the second is Papert’s extension of Piaget’s learning theory. Papert agreed that people must be engaged when constructing new knowledge and added that the learning would be more effective if the learner created a meaningful product (Donaldson, 2014). Hence, the meaningful creation must connect to real-world issues and be shared with others.
2.5.1 Constructionist Learning Laboratory (CLL)

In 1999, Seymour Papert devised a constructionist project dubbed Constructionist Learning laboratory (CLL). He administered this project, which was rich in technology, in The Maine Youth Center (a center for troubled teens). His goal was to study the effects of a constructionist-learning environment on students with high-risk behavior issues (Stager, 2013).

The CLL was aimed for students from the age of twelve to almost twenty-one years. The leadership team of the prison picked the students who could take part in the project. Papert and his team wanted to offer those students an alternative way of learning. For three years, these teens were exposed to learning which required the use of computers. The CLL was based on Papert’s view of what learning might look like in the future (Stager, 2005).

The CLL project succeeded because it was not based on a curriculum and the students did not have to worry about their products being evaluated. The intent of the CLL was to create a constructionist environment in which the students are involved in long-term projects based on interest, expertise and prior knowledge (Stager, 2005). This empowered the students to learn through the act of constructing personal meaningful projects.

After three years of the start of CLL, Papert developed the “Eight Big Ideas of Constructionism”. These eight big ideas explain how making can lead to deeper learning. The big eight ideas that Papert devised are: (Martinez & Stager, 2013, p. 73-74)

1. Learn by doing! – For learning to occur there must be direct interaction with the knowledge and content. We all learn best by doing something we find interesting.
2. Technology as a building material – By using materials to build things, you can make interesting and meaningful products.

3. Hard fun – Learning should not be too easy or too difficult. The task should be just right for the student to feel that he/she is having fun but learning something new at the same time.

4. Learning to learn – A learner must discover how to learn.

5. Taking time, the proper time for the job – To make anything important you must learn how to manage your time.

6. You can’t get it right without getting it wrong – You need to be given the opportunity to make mistakes in order to grow as a learner.

7. To do unto ourselves what we do unto our students – we learn all the time; each difficulty we run into is an opportunity to learn. The teachers must model how they overcome difficulties.

8. Enter the digital world – Digital technology is the new literacy.

In a constructionist-learning environment, the learner is put up-front and in the center. By giving the student the opportunity to make mistakes and to discover new concepts with scaffolding, the student will develop deeper learning through hands-on projects. The students need to remain motivated to learn, explore and have fun.
2.6 Makerspaces and the STEM approach

Makerspaces are sometimes referred to as STEM studios, stemming from the STEM approach. It is a unique approach to teaching and learning that centers on individual students and their learning interest. Collaboration, communication, research, problem solving, critical thinking and creativity are examples STEM skills. The STEM approach is the foundation for setting up a Makerspace. A formal definition of STEM does not exist, yet a common understanding is that there should be an integration of subjects along with collaboration (Whitmer, 2016). The STEM approach indeed has several models and schools have adopted the one that fits their curriculum and goals, whether at the high school level or across the levels (Waters and Kessler, 2015).

The four STEM subjects do not have to be present in each STEM unit created, but permit the maker to produce creative products with a purpose. In any STEM or maker-centered project, there must be a balance between exploration and engineering. It is important to note that a makerspace allows for differentiation and caters to the different learning preferences (Waters and Kessler, 2015).

In a Makerspace, students are viewed as problem solvers and innovators. They are encouraged to find solutions to the authentic problems that they are exposed to. For makers to discover and design solutions they will indirectly develop maker skills, such as communication, collaboration, research, modeling and tinkering (Whitmer, 2016). The solution is student-centered, however there are expectations on the teacher to set up a learning invitation that allows the maker to acquire those skills, and stay motivated to complete the task. For the makers to succeed in completing the task, they must rely on
their STEM background and develop new knowledge as the making progresses (Waters and Kessler, 2015).

2.7 Benefits and Challenges of an Educational Makerspace

Makerspaces in the educational setting originated at the higher education level as Digital fabrication labs (fablabs) (Halverson & Sheridan, 2014). Paulo Bilkstein and Dennis Krannich created Fablabs with the purpose to encourage students to develop their design and engineering skills. After that, out-of-school makerspaces sprung around towns for families to spend time together. Then, afterschool and summer programs emerged in schools. However, those programs were not linked to the school curriculum. This could be viewed as a challenge when a school decides to build a Makerspace in their institution.

Now is the time for schools to incorporate Makerspaces into their curricula. By taking this step, students can develop ownership and passion for their work. The student initiates the learning that takes place in a Makerspace; hence, it is student-centered and interest-driven (Thompson, 2014). In the collaborative environment students cooperate and give peer feedback to help with the completion of the projects. The makers join forces to overcome obstacles through iterating the problems they may face.

John Dewey and Maria Montessori realized the significance of “making” decades ago (Waters and Kessler, 2015). They believed that “making” is pedagogically appropriate for a child. Hence, they gave students choice and exposed them to interesting and concrete materials. Most importantly, they exposed the students to engaging learning experiences.
The goal of making is to motivate students to learn and give them ownership of their learning. By integrating the disciplines and adding technological innovations, students will be engaged and develop 21st century skills which they will need in the workforce. Thus, making is not only valuable for students in the school setting, but also for the community when those students advance in their education (Waters and Kessler, 2015). Those students will end up running the businesses and industries of tomorrow.

Employing Makerspaces into schools does not come without any challenges. First, the teachers must themselves be makers and have the appropriate training. The school must have a space that is suitable to hold a Makerspace with all of the required equipment. Thus, the school ought to be continuously replacing and updating the tools in the space to ensure sustainability. Curricular alignment is also a limitation; consequently, if the projects done in the space are not linked to the disciplines, it will be difficult for the learning to be authentic and for the learners to make connections to the outside world (Harron & Hughes, 2018).

In their paper, Hira, Joslyn, and Hynes (2014) stated four challenges that educators face in implementing the maker principles in a classroom setting. The first challenge is standardized testing and official exams. The future of the student is evaluated by one standardized test that only measures content. A student is trained to be able to sit for such exams while other skills such as: social, research, thinking and 21st century skills are disregarded. The study conducted by Harron and Hughes (2018), further supports the challenge of standardized testing. They concluded that courses that are based on design and allow integration of maker-centered activities to be a success.
The curriculum is a barrier in schools with a standardized testing culture. Second, employing a makerspace requires a certain level of teacher training. A teacher must undergo professional development that targets “pedagogical practices, knowledge of and experience with appropriate materials and equipment, and sufficient self-efficacy to implement unfamiliar curriculum and navigate unanticipated problems” (Hira et. al., 2014). According to Hira et. al. (2014), the third and biggest challenge is technology and resource management. Although this challenge is not directly related to Makerspaces, it is a struggle that many schools have faced since the integration of technology has began. The purchase of new tools and devices and their management is a must to support the teachers and the students’ learning in a makerspace. Lastly, the representation of minorities such as gender, race, and disability is a challenge. The engineering domains have always been geared towards the white male population. Nowadays, with the implementation of makerspaces in schools and the exposure of students to more engineering problems, the minority gap is closing up.

In a nutshell, it is fortunate that some school administrators are now coming to realize the importance of the constructionist learning theory and the positive impact that Makerspaces have on the students’ learning. Ten years ago, it was a dream and now teachers are shifting their teaching methods and resorting to the constructionist theory and the UDL approach to center more on the students’ needs and interests.
Chapter Three

Method

3.1 Method

The research design of this study took the form of a case study. This design was chosen in order to conduct an in depth exploration of the postulated research questions. The design included a descriptive part to be conducted in a KG1 classroom and a quasi-experimental part based on an intervention in Grade-2. For the descriptive part, observations of a makerspace in a KG1 classroom were conducted to identify its unique characteristics. For the quasi-experimental part, an instructional unit was developed and implemented in a grade-2 classroom to study the effects of the unit on the students’ problem solving skills. The grade-2 classroom instructor underwent training, by the researcher, to ensure the smooth implementation of the unit. Lastly, interviews were conducted to collect data about the administrators’ and teachers’ perceptions about extending makerspaces into the lower elementary.

This exploratory study identified the characteristics of the studied maker-centered learning environment in KG1 and, consequently, a maker-based instructional unit was prepared and implemented in a Grade-2 lower elementary classroom. This permitted to further investigate the challenges involved in the installation of a Makerspace in lower elementary classes.
3.2 Sampling

3.2.1 Participants and Setting

The study took place in a Lebanese international school that adopts an American-type education and the International Baccalaureate program. The participants were addressed and asked to participate in the study after securing both school and parental consent. The participants were 2 administrators, 6 homeroom teachers (Nursery to Grade-3), 18 KG1 students and their teacher, and 24 second-graders and their teacher.

The KG1 children and grade-two students are a convenience sample. The KG1 teacher is one of the few teachers in the preschool that has adopted a maker-centered approach to teaching. Furthermore, the second grade homeroom teacher had the most experience, out of the three lower elementary classes, with makerspaces. The KG1 students were observed in their classroom makerspace and the instructional unit took place in the second graders’ corresponding classroom.

The six-homeroom teachers, from nursery to grade-three, were interviewed to learn about their beliefs and perceptions about makerspaces in a school setting. The second grade homeroom teacher implemented the unit, after she had been debriefed about the unit and trained, therefore was not be interviewed.

The administrators who were interviewed are the assistant to director and the curriculum coordinator. The director of the preschool/lower elementary was initially on the list to be interviewed. However, due to her heavy schedule, the interview did not take place. The director’s assistant aids the director with major decisions and deals with the concerns of the teachers, parents and students. The IB-PYP (International Baccalaureate – Primary Years Program) coordinator was also interviewed; she is in charge of the
implementation of the PYP curriculum from nursery to grade 5. The purpose of interviewing the administrators is to identify their perceptions on Makerspaces and the challenges they report to extending a Makerspace into the lower elementary.

A group of twenty-four second graders took part in a maker-based instructional unit. It began with a two-task individual diagnostic assessment, which pinpointed the students’ prior problem solving skills. Then, in groups of four they experienced a maker-centered activity. During the implementation of the unit, the researcher collected anecdotal records while the students were making. As well, at the end of each day an oral group reflection session took place where the students provided feedback about the work they have completed during that specific day. The purpose of the reflection sessions was for the researcher to keep track of the students’ reasoning processes and to identify the changes in their problem solving skills. This reflected the effectiveness of including a makerspace as part of the regular learning experiences at the lower elementary level.

3.3 Data Collection

This study examined the constituents of a makerspace in a KG1 classroom and the way it is run. After the observation of the KG1 classroom, a maker-centered instructional unit was developed and implemented in a grade-2 classroom, to identify its challenges and benefits. The unit was implemented over five days. A daily session of sixty minutes was allotted for the completion of the unit. Finally, teachers and administrators were interviewed to pinpoint their perception of makerspaces in the lower elementary.
3.3.1 Class Observation

The study began with the researcher observing a makerspace in a KG1 classroom. The 5-year old makers were observed in their maker-centered learning environment. The researcher created three observation checklists. The first checklist (Appendix A), based on Papert’s Eight Big Ideas of Constructionism (Martinez & Stager, p. 73), was used to study the students’ making behavior. The second checklist (Appendix B), developed on the basis of literature, was used to examine the role of the teacher and the learners in the maker-centered class. The third checklist (Appendix C) helped detect the equipment available and to study the setup of the physical learning environment. The students were observed twice a week, in the morning, for thirty-minute intervals over a 4-week period.

3.3.2 Development of the instructional unit

Based on the collected data from the observations in the KG1 classroom, an instructional unit was developed that is pedagogically appropriate for second graders. The unit was based on the STEM approach and the engineering cycle, mainly the integration of subjects and the collaboration factors. The instructional unit began with a diagnostic assessment of two tasks. Then a STEM activity followed over five days.

The STEM activity was completed in groups, whereas the diagnostic assessment was an individual task. Before the students were assigned the main maker-centered activity, an individual diagnostic was administered to pinpoint the making skills that each student possessed. The diagnostic assessment was considered as a pre-assessment, which is always conducted in class before a new concept is introduced to detect the students’ prior knowledge of that concept.
After completing the diagnostic assessment, it was time to group the students and to launch the maker-centered activity. Throughout the implementation of the activity, the groups relied on their making skills and communication skills in order to collaborate and produce the best solution. This was done to identify the skills the students had acquired from the diagnostic assessment and to detect the slightest change in their thinking and problem solving skills by the end of the unit.

### 3.3.3 Diagnostic Assessment

In the grade-2 classroom, a maker-centered unit was implemented starting with a diagnostic assessment (Appendix D) followed by an oral group reflection session. This diagnostic was administered to detect the problem solving skills that the second graders have. Second graders were subjected to a couple of making tasks with certain criteria. Once the students completed the tasks, they orally shared their making processes with the whole class. The oral reflection session revealed the thinking of each student. Furthermore, the sharing allowed the students to learn from one another the different manners of solving the same problem. The researcher jotted down anecdotal records during the reflection session and probed the learners for problem solving skills. Furthermore, an evaluation rubric (Appendix G) was used for both tasks of the diagnostic assessment to make sure they measured the same outcomes and skills.

### 3.3.4 Maker-centered activity

The diagnostic assessment was trailed by the implementation of a maker-centered activity (Appendix E), with the same group of second graders, with a reflection session at the end of each of the five days. The activity was based on a purchased resource created by Westby (2016). The collaborative activity was spread out over five days with the
The purpose of targeting a different phase of the engineering cycle each day. More information can be found in Appendix E.

The purpose of the activity was to test the improvement, or detect any change in the students’ problem solving skills. The activity was based on a building challenge. The students used their newly accumulated skills, from the diagnostic assessment, to solve the activity. The activity did not only target their problem solving skills, but also their ability to “think outside the box” and to realize that they can learn from their mistakes. A group reflection session wrapped the unit.

3.3.6 Interviews

Finally, Three semi-structured interviews were developed, one for the administrators, another for the preschool homeroom teachers and the third for the Grade-1 to 3 teachers. The questions are available in Appendices G, H, and I. The goal of the interviews was to probe information about the teachers’ and administrators’ perceptions and knowledge of Makerspaces. In addition, the interviews included questions targeting the challenges and reasons for the lack of a Makerspace in the lower elementary level.

3.4 Instruments

Several instruments were developed to collect data for this study, three checklists for observation, three semi-structured interviews, two for teachers and one for administrators, and a maker-based unit made up of a diagnostic assessment and an activity. The researcher took anecdotal records during oral reflection sessions, which took place throughout the implementation of the maker-centered instructional unit.
3.4.1 Observation checklists

The purpose of the checklists was to study the interactions of the KG1 students in the classroom Makerspace, with the materials, with the environment, with the teacher and with each other. All the checklists were used in a similar manner, the researcher checked off the criteria on the list that corresponded to the observations. Checking of the criteria will take place over short periods all along the thirty-minute session (every 10 minutes). Additional notes were written about significant happenings that were not addressed by the criteria on the checklist, as example and proof to support the criteria.

The first checklist, *observation checklist of children’s behavior in a Makerspace* (Appendix A), focused on the conduct of the learners in the Makerspace. This checklist was created with Papert’s “eight big ideas” of constructionism in mind. Papert came up with these eight ideas after spending three years in a teen prison where he set up a lab rich in technology for the teenagers to use (Martinez, S. L., & Stager, G., 2013). These “great ideas” came as a result of this implementation. The technology lab that Papert established in the prison is comparable to an educational Makerspace. The criteria of making, collaboration and learning from mistakes are all present in both spaces. Hence, it is appropriate to base the observation checklist on Papert’s eight big ideas.

The checklist is divided into seven criteria, with each criterion corresponding to one of Papert’s big ideas of constructionism. One criterion was omitted (criterion 7); *do unto ourselves what we do unto our* students, since it concerned teachers more than the students. The first criterion is *learning by doing*. The researcher looked for the way the learners used what they already know to create things and add on to the product. The second criterion is *technology as a building material;* this criterion looked at the tools and
the equipment that are present in the space and how the students use them. Third
criterion is hard fun; the researcher looked for whether the learner is given a challenge
that is neither too easy nor too challenging. The researcher studied the motivation and
engagement of the learners. The fourth criterion is learning to learn; are the learners
active and taking responsibility for their own learning?

The next three criteria are dedicated to time, making mistakes, and the digital
world. The observer searched for how the learners manage their time. Do the learners
make a plan and follow it, or are they always in a hurry to finish? Next, making mistakes
is a sign that the learners are learning. However, the learners need to figure out that if
something goes wrong that there are many ways of fixing the problem. The final
criterion focuses on digital technology. In this criterion, Papert insists on the importance
of knowing about digital technology and being able to use it (Martinez & Stager, 2013).
So, Papert believes it is essential for the 21st century learners to learn how to use the
technology because it is as significant as learning how to read and write.

A second checklist (Appendix B), Observation Checklist for the role of the
teachers and learners, was constructed to study the role of the teacher and learner in the
KG1 maker-centered classroom. The first checklist focused on how the children
interacted with their learning environment. The second checklist examined whether the
children take control of their learning by being an active creator and natural collaborators.
The observer looked at what made them active creators, do they ask questions, do they
take ownership of their learning and do they become an expert at a certain skill?

As for the teacher’s role, we examined whether the teacher models characteristics
of a mentor and learner. Also, we identified how the teacher supported the learners when
they faced difficulties and whether she prepared authentic learning engagements to activate the learners’ curiosity. We wanted to detect if the teacher is an active participant in her maker-centered classroom or if she is a passive observer.

The third checklist, *observation checklist of the Makerspace learning environment* (Appendix C), served to study the learning environment in which the Makerspace was located. The goal of this checklist was to study the physical learning environment in which the making takes place. Therefore, the created checklist targeted the setup and layout of the space, the materials and tools available and the safety of the Makerspace. The checklist is available in Appendix C.

While observing the learning environment, the researcher followed the last checklist created on the basis of the literature. The observer attended to the details of the space, such as how learning invitations are set up, the accessibility of the tools and their exact location in the space. Furthermore, the observer noticed the tools and materials available in the space, for example digital tools and arts and crafts tools. Safety is the third criterion that the research took into consideration.

### 3.4.2 Maker-centered instructional unit

A maker-centered instructional unit, which included a diagnostic assessment and a maker-centered activity, is an instrument that was created to study the benefits of a makerspace in the lower elementary classes. The diagnostic assessment is an individual assignment where the students took part in two tasks. The purpose of the assessment was to identify the students’ prior knowledge (if any) of “making”. General guidelines were given to the students along with the chosen materials and the criteria that they need to abide by. The students first created a paper airplane and measured how far it traveled
then, for the second task, they built a straw tower with tape that could withstand three
tennis balls. For each task, the students were allowed half an hour, but not limited to that
time frame, to define the problem, brainstorm, design, build, test their product and make
the necessary modifications. The students were never informed of the time at any point
of the unit. Each task was completed on a different day. These tasks detected how
students react to a maker task, whether they accomplish the task according to the set
criteria and how they go about making the product.

During the phase where the students were making their products, the researcher
observed how the students planned their steps, designed their product and dealt with
struggles. All the while, the students were documenting their steps on a recording sheet.
The goal of the diagnostic assessment was to identify the ways students solve a problem
and what steps they follow to reach a workable solution. The investigator detected and
described ways the students discussed problems, exchanged ideas and brainstormed. The
investigator also collected the designs of the students to analyze them. In addition, the
investigator explained how the students modified their ideas upon testing their product
and how they overcame the failure or struggle. Lastly, after the group reflection session
that took place at the end of the task, the researcher pinpointed what the students believed
the purpose of these tasks was and scaffolded them into discovering that there could be
more than one solution to the same problem.

At this point, the researcher had a global understanding of the making skills of
each student. This was made possible by looking at the individual recording sheets, the
observer’s narrative notes and the evaluation rubric that was used to assess each child at
the different phases of the engineering cycle. The evaluation rubric (Appendix G) was
created to ensure that all the tasks are aligned and measured the same skills. The observer referred to the rubric during the process.

The rubric is based on the engineering cycle and it has been modified to fit the age level of the students involved in this study. The engineering cycle is a six-step process that guides students to complete a maker project. It is important to note that it is a cycle, meaning it is flexible and the student can move back and forth between the phases (NGSS, 2013).

The engineering cycle is a cycle designed to engage students in building a product with a purpose (NGSS, 2013). The purpose of the cycle is to put students in a puzzling situation that needs a solution. Therefore, before they begin any work they must define and brainstorm solutions to a problem then choose which one is the best. Next, they need to start developing the solution by designing and building. Finally, the product must be tested and modified if needed. By following the engineering cycle, the students are given the chance to be creative innovators.

3.4.3 Maker-centered activity

An activity, adapted from a purchased resource created by Westby (2016) and the collected data from the KG1 classroom observations, was implemented after the diagnostic assessment. In the activity, the students were subjected to make a product using their problem solving skills. The objective of the activity was for the students to collaboratively create a testable and usable solution for the problem at hand.

Before the activity was administered, the grade-2 teacher needed to be trained by the researcher. She had little knowledge of what a makerspace was and how to administer a maker-centered activity. The training was based on the “Facilitation Field
Guide”, found in Appendix J, developed by the Tinkering Studio and Exploratorium® (2015). The Tinkering Studio is located inside the Exploratorium, the museum of science, art and human perception in San Francisco.

The facilitator’s guide was given to the teacher in a table format (Appendix J) to refer to at anytime. A facilitator should focus on three areas when administering a maker-centered unit. The role of a facilitator is to spark the students’ interest by introducing them to an activity that will grab their attention. Next, the facilitator must keep the students interested by sustaining their level of engagement by allowing them to make mistakes and learning from others. Finally, a successful maker-centered unit should result in the learners deepening their understanding of new concepts by making connections between the project and the real world.

In addition to the table, the Grade-2 teacher was handed an article to read entitled: The Better Boat Challenge written by Aaron Schomburg (2008). The boat challenge is a challenge that Schomburg (2008) engages his third grade students in every year. The boat challenge and the maker-centered activity have similar aspects, such as time frame, exposure to the engineering cycle and problem solving skills. This article also allowed the teacher to visualize the unit she is about to give and at the same time gave her some tips on how to overcome problems that may arise.

The activity is a STEM challenge in which the students were given a collaborative problem-solving activity. The students worked together to brainstorm solutions, make plans, test ideas and improve designs after testing. The fairy tale “Little Red Riding Hood” will be the driving force of the activity. The activity will stem from the problem in the story. Little Red must deliver a basket of cookies to her grandma’s house, however
the wolf is an obstacle she cannot avoid. In the story, Little Red attempts different solutions but fails, and at the end of the story, another solution is proposed. The solution is to build a catapult to make the basket of cookies fly over the forest and land close to grandma’s house.

The activity began by the students role-playing the fairy tale “Little Red Riding Hood” and ended by them constructing a catapult. The students worked in groups of four to define the problem, brainstorm solutions, make plans, design and build, test their ideas, and improve their design after testing. Those are the fundamental traits of any maker-centered STEM activity. All the mentioned steps will be documented in the student’s Making Journal (Appendix F).

The making journal is where the students brainstormed, collaborated, planned and described the process of making the catapult. It is where the students documented their personal learning journey. From the journal, the researcher learned about the students’ feelings at different stages in the activity and about how they overcame struggles while they were building. At the end, the student chose their favorite part of the project.

A daily morning session of sixty minutes was reserved for the maker-based activity. The time frame for the completion of the activity was five consecutive days. Below is a detailed plan with information about the daily engagements. A detailed account of the activity can be found in appendix E.

On day one, the teacher provided a positive atmosphere in the class and introduced the task. She explained the purpose of the five-day activity. In addition, the teacher announced the required materials that the students can use to produce the product. In groups, the students proceeded to read and act out the fairy tale “Little Red Riding
Hood”. Then in their making journal, the students individually defined the problem and brainstormed idea(s) for the catapult. Day one ended with a group reflection session.

The session on day two started with a quick recapitulation of the previous day. The students got back into their groups and shared their brainstormed idea(s). This was the basis of their collaborative design for the catapult. They had the choice of creating a new design together, to combine their ideas or to come up with several new designs. These designs were drawn in the making journal. The session ended with a group reflection session.

During the third day of the activity, the students began to create the product using the provided materials. As they created their design, they also tested it and made appropriate modifications to improve their catapult. In the process, they had to make a note of the amendments they made to their product in the making journal. The session ended with a group reflection session.

On the fourth day of the activity, each group was given five minutes to present their catapult and share information they believed is important for the rest of the students to learn. After the presentations, the students completed the last pages of their making journal, and then the session ended with a group reflection session.

Finally, on the fifth day, the students filled out a self-assessment checklist, found on the last page of their making journal, to make sure they had gone through all the phases of the activity. The students also individually assessed their actions during the previous four days and wrote about their favorite part of this challenge. Along with that, the students orally reflected on:

1. How they felt about collaborating with others
2. How they dealt with the frustration during some of the activity
3. What do they think they learned from the activity
4. What would they change about this activity and why?

3.4.4 Semi-structured interviews

Six teachers and three administrators were subjected to a thirty-minute interview to depict their perception of Makerspaces and what challenges they perceived if makerspaces were to be implemented in the lower elementary level.

The teachers interviewed were the nursery, KG1, KG2, Grades 1, 2 and 3 classroom instructors. There are two languages of instruction at the school, thus there are French and English classroom instructors for each grade levels. The teachers who were interviewed teach in English, except for the grade 2 instructor who teaches in French. Another Grade-2 teacher, whose language of instruction is English, implemented the instructional unit in her classroom. The teacher interviews pinpointed their perception and viewpoints about Makerspaces in a school setting and their beliefs about whether a Makerspace could hinder or support the students’ learning. In addition, there were a couple of questions soliciting them to give an answer as to how they would react to setting up a Makerspace in their respective classrooms and how they would begin.

Initially, three administrators were going to be interviewed. They were the preschool/lower elementary school director, her assistant and the International Baccalaureate Primary Years Program (IB-PYP) coordinator. Their questions were similar to the teachers’ questions, in addition to questions that targeted administrative decisions. For example, budgeting matters, teacher assignments, and curriculum planning.
Unfortunately, out of three administrators only two were interviewed. During the data collection phase, it was impossible to find a suitable time to meet with the director. The questions were emailed to her but alas; the interview never took place. Therefore, only the IB-PYP coordinator and the director’s assistant were interviewed.

### 3.5 Data Analysis

The data were gathered in three stages. First, data were collected using three observation checklists. Second, data were composed of scores the students received at different stages of the maker-centered instructional unit. Finally, more data were gathered using three semi-structured interviews, conducted on a one-to-one basis.

#### 3.5.1 Observation checklists

During the weekly observations, students’ actions were analyzed against the 8 big ideas of Papert’s constructionist theory. The learning environment and the role of the teacher also played a factor in the analysis of the students’ activity and was observed using other checklists created on the basis of literature.

Once the observations were completed, the data were analyzed to identify if the KG1 classroom fit the requirements of a constructionist and maker-centered environment. All the notes related to each criterion and indicators on the checklist were color-coded to identify patterns and compare data of different observations. Finally, the observation notes were used to create a maker-centered instructional unit that was implemented in a Grade-2 classroom.
3.5.2 Instructional unit

A STEM unit created by Westby (2016) was the basis of the Maker-centered instructional unit, which was implemented in the Grade-2 classroom. Westby’s (2016) unit was modified, by the researcher, based on the previous observations and to fit the pedagogical level of the learners. The students collaborated to solve problems by making different products. As the students were making they were responsible to document their thinking in their making journal, which included the steps of a Maker task and follow the engineering cycle. Any change detected in their problem solving skills was noted.

To detect the change in the students’ problem solving skills, the researcher used the anecdotal records collected from the reflection sessions at the end of the diagnostic assessment and the activity. In addition, the making journals were reviewed and analyzed to identify students’ thinking processes to solve the problems that were presented.

The anecdotal records were analyzed to study a change in the students’ problem solving skills. The anecdotal records were a gathering of the students’ oral reflections. The students’ reflections were compared, across the duration of the unit, to identify the change in the students’ thinking and words that reflected that change. As the records were analyzed, the researcher detected if the phases of the engineering cycle were consistent throughout the unit.

The data from the making journals were also analyzed and compared to the anecdotal records collected during the unit. The researcher searched for instances of the students’ thinking skills present in the journal. In addition, the researcher also studied how the students fixed or reiterated the ideas that did not work.
3.5.3 Semi-structured interviews

The answers of the interviewees were analyzed based on a content analysis color-coding qualitative technique. The eight interviews were digitally transcribed then color-coded according to the purpose and research questions of the study. The coding detected recurring themes connected to third research question.

The researcher identified two categories, the administrators’ and teachers’ perceptions of Makerspaces in the lower elementary and the challenges they report or foresee. This step allowed the researcher to interpret the data qualitatively and to reflect on the answers that were provided by the participants to form a new list of subcategories for each theme.
Chapter Four

Findings

4.1 Introduction

In this study, observational checklists (Appendices A, B & C) were designed to examine the conduct of KG1 children and their teacher and to study the physical environment of a KG1 maker-centered classroom. A maker-centered instructional unit was administered to Grade-2 students made up of a diagnostic assessment and an activity to investigate the development in their problem solving skills. The result of the assessments and the anecdotal records taken during the implementation of the unit were compared and analyzed to identify changes in the students’ problem solving skills. Finally, six teachers (from Nursery to Grade-3) and two administrators were interviewed, and content analysis was used to study the transcripts of the interviews and to explore certain themes.

This chapter is divided into three parts. Part one, is reserved for the observations that were conducted in the KG1 maker-centered classroom. It entails a description of the three checklists, followed by an analysis of the data that the checklists provided. The next part explains how the maker-centered instructional unit was implemented in a Grade-2 classroom along with the analysis of the outcomes. Lastly, teachers and administrators were interviewed using different sets of questions. Their responses were presented and the content was analyzed according to themes that recurred in those interviews.
4.2 Observations conducted in a KG1 classroom

4.2.1 Learning environment checklist

The physical learning environment of the KG1 classroom was observed once during thirty minutes. A Checklist (Appendix C) was developed to study the learning environment. The data were collected in the form of narrative notes. The checklist had three criteria: space, tools and materials, and safety. The space criterion focused on describing the physical environment. The indicators are about the way the space is organized and whether the children want to use it. For the second criterion, a list of tools and materials were suggested, in Makerspace manuals found in the literature, to cross-reference with the tools and materials available in the class. If additional tools were found then they were added to the list. The safety criterion focuses on the display of the safety guidelines, availability of an instructional handbook for the teacher to refer to and whether the tools are child friendly. The children must be safe at all times in a Makerspace.

4.2.2 Description of the physical learning environment

The physical environment is a square-shaped room that measures 64 squared meters. Three of the sides are cement walls. The top half of the walls are covered with corkboards occupied by children’s work, the bottom is reserved for shelves filled with tools, materials or children’s belongings. The fourth side of the room is a sliding glass door that leads to a playground that is sometimes used as an extension to the class. Pictures of the learning environment can be found in Appendix L.
The space arrangement in the classroom is inviting for the children to use and for learning to take place. The children continuously ask to use or “play” in different areas of the classroom. The makerspace materials occupy the bottom half of all the walls of the classroom. All the tools and materials are found on colorful shelves that are accessible and within the children’s reach. The shelves are open and low enough for the children to grab any item they want and can sit on the rug or at a table to “make” or create their idea. The items on the shelves are labeled with pictures to aid children with their organizational skills.

There are a wide variety of tools and materials available for the children to use along with general safety guidelines. The children manipulate arts and craft materials, reusable materials, building materials (wooden or foam blocks) and plastic cooking utensils. The teacher keeps the electronic devices away from the children. The children use them only in the presence of a specialist or a co-teacher. Those devices are: iPads, laptops, printers, power tools, recording equipment and digital software such as CDs and DVDs. From time to time, the children are reminded of the safety guidelines and the essential agreement of “play time”, especially in the case of a conflict where the children are encouraged to solve the problem on their own. The guidelines are visibly posted, in picture format since the children cannot read yet, next to each center for the children to refer to at anytime. When new material is brought into the classroom, the children are introduced to the safest way of using the tool.

On different occasions, there may be one or two facilitators in the classroom in addition to the homeroom teacher. One of them is a technology specialist whose role is to teach the children the basics of computational design or coding to discover the digital
world. The coding activity takes place once a week (Thursdays) during the “center time”. This is the only occasion where the learners use a digital tool. It is important to note that it was the learners’ first exposure ever to this coding application.

An iPad application called Osmo coding was used for the activity. It is an application that introduces the children to coding in an easy way. Due to the limited number of iPads, the children were paired up to complete a collaborative coding challenge. Together the children wrote a logical sequence or algorithm using coding blocks, with support from the facilitator, to reach a goal. It was noticeable that the children were facing some difficulties since they had never been exposed to such higher level thinking engagements.

The children were haphazardly paired up and together wrote the coding sequence using the physical blocks that are separately provided with the application. When they completed the sequence and their blocks were ready, the children pressed a button and got an immediate response and feedback to the code they created. It was observed that in some pairs one learner did all the thinking, while the other agreed and went along with the other’s decisions. In other pairs, they each took turns and communicated to reach a consensus. In many circumstances, the learners verbalized their thinking out-loud and modified the algorithm in case they made a mistake after testing the sequence. To fix the mistake, the children tried different strategies. Some learners traced the path with their finger on the iPad screen to check for accuracy, while others relied on trial and error and said: “Let’s try!” The children seemed confident, however there was heavy prompting done on behalf of the facilitator to ensure the completion of the task. The facilitator asked questions such as: “What do you have to do next? What would happen if you keep
the same code? Is the arrow pointing in the right direction?” hence pushing their thinking further. The facilitator never gave the children an answer; on the contrary, she encouraged them to come up with an appropriate solution.

4.2.3 Description of the “free” play time and space

This is just a glance of what happens every day during “center time” or “free play” time. Children spend thirty minutes moving from one center to another to practice different skills; some learners remain in the same center for the whole duration. There are several centers dispersed around the room. There is a play dough center, a building blocks center, a drawing center, a dramatic play corner, a puzzle corner and a plastic tube center. The centers are in far proximity of each other, permitting the children enough space to “make” and “create” freely. The majority of the centers are skill based, while a couple target concepts related to the unit of inquiry. At this point, halfway through the school year, the children are familiar with their learning environment and are at ease when circulating in the classroom.

The children are dispersed around the room and in the hallway. Picture of the students in action are found in Appendix L. They individually decide on the center of their choice. As they settle into the center of their choice, some learners play on their own, while a few collaborate and discuss how they are going to play together. The children are buzzing with excitement as they “make” or tell stories to their friends. The children are aware of the essential rules and agreements for each center and act accordingly. A poster, at each center, displays the number of children allowed and its essential agreements. From time to time, they ask the teacher for permission to switch to
another center. The approval is granted only after the children puts the toys he or she was using at their right place.

4.2.4 Observation checklists

The KG1 classroom observations aimed at 1) identifying the main features and components of a maker-centered classroom, and 2) study how the makerspace or “centers” (as referred to in the KG1 classroom) contribute to the learning. The observations are intended to answer the first and second research questions. The observations were conducted over a four-week time frame; over three ten-minute intervals twice a week during the early morning “center time” or “free play time” (this is the label of a makerspace in this preschool). The data were collected during each session. Thus, seven half-hour sessions of observation were conducted and data were recorded by chunks of 10 minutes. The focus of these sessions was on the children’s behavior and interaction in the Makerspace as well as the teacher’s role.

A checklist (Appendix A) based on Papert’s eight big ideas of Constructionism (Martinez & Stager, 2013, p. 73-74) was created to study the conduct of the children in their maker-centered class. Each of Papert’s eight big ideas will be referred to as a criterion. However, since only seven of the criteria focus on the children’s conduct, it was decided to exclude criterion number seven which is “Do unto ourselves what we do unto our students” that directly targets the behavior of the teacher. A second checklist (Appendix B) was used in parallel to observe the role of the learner and the role of the teacher in the Makerspace. In both checklists, indicators were developed for each criterion to guide the observer and obtain observations that are more accurate. The indicators were of two types: open-ended or closed-ended questions. The closed-ended indicators in the
checklists were answered with a yes or a no and thus reflected with a tick, such as “Are
the learners active?” The open-ended indicators required a written answer, for example:
“How do the learners use the tools as building material?” The researcher recorded the
answer in the form of narrative notes, which were later analyzed qualitatively.

The observations were conducted twice a week, on Tuesdays and Thursdays, from
8 am to 8:30 am over a four-week period. The non-participant observer sat at a table with
both checklists to observe the learners and their teacher. As soon as an indicator was
noticed, a tick would be placed accordingly. The indicators were monitored over seven
sessions.

The period of observation in each session was for thirty minutes, divided into
three ten-minute intervals. As mentioned before, each criterion had a different amount of
indicators to aid the observer to be more precise in the observation process. When a
criterion was detected, the observer would then look at the indicators of that criterion and
place a tick next to the indicator that best describes the situation. The data collection was
organized in this manner to pinpoint the frequency of a criterion by detecting it in the
beginning, middle and end of the thirty-minute session.

At the end of the seven sessions, each completed observation checklist was
recreated on Excel, a total of seven sheets, one for each session. For practical purposes,
on the Excel sheet the ticks were replaced with the number ‘1’ score to evaluate the
frequency of the most common criterion. If an indicator was not noticed, then a ‘0’ score
would be inserted into the cell. After entering the ‘1’ and ‘0’ scores next to the
indicators, a total score was calculated for each criterion. This step consisted of adding
up the ‘1’ scores each criterion received.
Each criterion has a different number of indicators that identifies it, meaning that some criterion would have higher scores than other. Therefore, to be consistent and to better analyze the results, an average, during each session, over the three 10-minute intervals, was computed for each criterion.

Next, the global averages, for each criterion, across the seven sessions were figured to analyze the scores. Finally, when the session averages for each criterion, in each session, were computed, they were compiled into a table and represented in Table 1. The seven criteria, coded as C1, C2, C3, C4, C5, C6 and C8, are the headings of the columns and the seven sessions, coded as S1 to S7, are headings of rows. The next four rows in Table 1 display the global average for each criterion over the seven sessions, the minimum, the maximum and the range of the scores over the sessions. They are calculated to identify fluctuations of scores among the sessions and provide a picture of a session that would eventually be different from the others.
Table 1

Average scores per criterion and session and global average per criterion overall sessions.

<table>
<thead>
<tr>
<th>Averages per criterion per session</th>
<th>Learn by doing (C1)</th>
<th>Technology as building material (C2)</th>
<th>Hard fun (C3)</th>
<th>Learning to learn (C4)</th>
<th>Taking time (C5)</th>
<th>You can’t get it right without getting it wrong (C6)</th>
<th>Digital world (C8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session 1 (S1)</td>
<td>1.88</td>
<td>0.75</td>
<td>1.57</td>
<td>0.625</td>
<td>0.4</td>
<td>0.67</td>
<td>0</td>
</tr>
<tr>
<td>Session 2 (S2)</td>
<td>1.56</td>
<td>0.75</td>
<td>1.57</td>
<td>0.5</td>
<td>0.8</td>
<td>0.33</td>
<td>3</td>
</tr>
<tr>
<td>Session 3 (S3)</td>
<td>1.67</td>
<td>0.75</td>
<td>1.43</td>
<td>0.5</td>
<td>0.8</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Session 4 (S4)</td>
<td>1.67</td>
<td>0.75</td>
<td>1.57</td>
<td>0.625</td>
<td>1</td>
<td>0.67</td>
<td>3</td>
</tr>
<tr>
<td>Session 5 (S5)</td>
<td>1.67</td>
<td>0.5</td>
<td>1.29</td>
<td>0.75</td>
<td>1</td>
<td>0.33</td>
<td>0</td>
</tr>
<tr>
<td>Session 6 (S6)</td>
<td>1.56</td>
<td>0.5</td>
<td>1.43</td>
<td>0.5</td>
<td>0.8</td>
<td>0.67</td>
<td>3</td>
</tr>
<tr>
<td>Session 7 (S7)</td>
<td>1.44</td>
<td>0.75</td>
<td>1.43</td>
<td>0.625</td>
<td>1.2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Global average per criterion</td>
<td>1.64</td>
<td>0.68</td>
<td>1.47</td>
<td>0.59</td>
<td>0.86</td>
<td>0.67</td>
<td>1.29</td>
</tr>
<tr>
<td>Minimum</td>
<td>1.44</td>
<td>0.5</td>
<td>1.29</td>
<td>0.5</td>
<td>0.4</td>
<td>0.33</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.88</td>
<td>0.75</td>
<td>1.57</td>
<td>0.75</td>
<td>1.2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Range</td>
<td>0.44</td>
<td>0.25</td>
<td>0.28</td>
<td>0.25</td>
<td>0.8</td>
<td>0.67</td>
<td>3</td>
</tr>
</tbody>
</table>

The scores in the cells range between 0 and 3, since the thirty-minute observation period was divided into three ten-minute intervals. Each indicator can be perceived zero, one, two or three times in the same session, and the average scores of indicators of a criterion would range from 0 to 3. To better analyze the scores a conditional formatting rule was set to color-code different ranges of the scores from 0 to 3. The low scores (0 to 1) are highlighted in red, the middle scores (1.01 to 2) in yellow and the high scores (2.01 to 3) in green.
An analysis of the seven observation periods will follow to highlight the extent to which the observed KG1 maker-centered classroom complies with the constructionist approach as delineated by Papert’s Eight Big Ideas of Constructionism. The checklist of the children’s behavior (Appendix A) will be analyzed first by going through each criterion at a time in the order they appear in Papert’s list. Next, the data collected about the role of the learners and the teachers will be analyzed.

Learning by doing (C1) was the most recurrent criterion during the KG1 classroom observations. C1 resulted with the highest global average of 1.64 on a scale of 3. The range of the C1 scores, across sessions, was 0.44, on a scale of 0 to 3, which indicates that the indicators were consistently present during all the sessions of observation. It was noticed that learning happens naturally and the children find what they are doing interesting since they choose the “center” to which they are attracted to the most. Once in the “center”, the children use the tools and materials provided, but the manner in which they manipulated the tools depended on the project or construction they intended to make.

The C1 criterion had nine indicators. Two of the nine indicators were not noticeable during the observation period. They are: “Do the learners use the tools to come up with new ideas or creations?” and “Are the learners creating or constructing their own knowledge?” Over the seven sessions, children never came up with new ideas or creations. At the end of each observation session, similar products were perceived, such as drawings of houses and hearts, or cookies made out of play dough. The outcome of each center was expected and pre-determined, thus there was little room for creativity. Not once did a child create an original product, that is outside the box, during the four-
week observation period. None of the children tried to combine items from different centers to produce a new artifact.

Technology as a building material (C2) is another one of Papert’s big ideas of constructionism. One goal in a Makerspace is to use materials to build things, and to build with a purpose in order to create a meaningful product. This criterion’s global average was 0.68 on a scale from 0 to 3. In the KG1 maker-centered classroom, the children used the tools as building materials, but they created objects with no purpose. For example, they built a tower just to knock the blocks over. The children were aware of the way to use the tools, but they were not encouraged to use them in an innovative or functional manner, or to create new tools. Any model or product that the children create but do not complete during “free play” should be saved for the next day in order for the learner to add on or make modifications to the product. This action will help develop the child’s thinking and reflection skills since he or she will be thinking about ways to improve the model.

The C2 criterion is ranked fifth in the frequency of observation because only one out of its four indicators was spotted during the seven sessions. The one indicator that was noticed for C2 was “Are the learners aware of the function of the tools?” This indicator was seen consistently over each session and in all the ten-minute intervals. This is why the range for C2, 0.25, was small. The range indicates further that the children knew how to handle the tools and how to use them with ease.

It was observed that the learners enjoyed what they are doing, this is why hard fun (C3), is the second most frequent criterion with a global average of 1.47 on a scale from 0 to 3. The C3 criterion was composed of seven indicators (see appendix A), two of which
were not observed. Throughout the observations, the children showed a positive attitude because nothing was required at the end of the session and they were free to do whatever they wanted. During “center time”, the children are never assessed and the teacher does not set goals for the children to accomplish. For the first twenty minutes of the “free play” time, the children interacted with the materials found in the center they chose. If a child picked the drawing center, that child would use all the materials provided in that center: scissors, glue, paper, markers and so on. However, a lot of passive play was observed, the children did not play with each other or build upon each other’s products or ideas. The children played just to play, there was no set challenge for them, and they never explored or experimented with the items found in their centers. The teacher never set up learning situations for the children to take risks or build something new with the materials.

In four of the seven sessions of observation, the motivation level of the children depleted towards the end of all the thirty-minute period. The children lost interest, focus and determination to play or create something with the tools in the center. Many, especially towards the end of the thirty-minute block, lost track of what they initially set out to make. Table 2 shows the pattern of decreased motivation in the children for sessions one to four. The last column of table 2 displays the total 1 ‘score’ of the three ten-minute intervals.
Table 2

Score of each session for criterion 3

<table>
<thead>
<tr>
<th>Hard Fun (C3)</th>
<th>0-10 mns</th>
<th>10-20 mns</th>
<th>20-30 mns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session 1 (S1) total</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Session 2 (S2) total</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Session 3 (S3) total</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Session 4 (S4) total</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Session 5 (S5) total</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Session 6 (S6) total</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Session 7 (S7) total</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Although two indicators were not perceived during the observation session, the minimum score for criterion C3 (1.29) and maximum score (1.57) were close and in about the middle of the zero to three range. These scores resulted in a 0.28 range showing the consistency of the other five indicators. Had the children been prompted, encouraged to investigate and challenged, this would have reflected an even smaller range score.

*Learning to learn (C4)* is the next to last least popular criterion, with a global average of 0.59 on a scale from 0 to 3. The low global average is due to the fact that only two out of the eight indicators of the criterion C4 were detected in the KG1 classroom. As mentioned before, the children were never challenged or asked to create anything by the teacher at any point throughout the observation period. The range of the C4 criterion is equal to the range of C2, which is 0.25. This indicates the consistency across the sessions. Therefore, the absence of the indicators of C4 is consistent across the session.

The children took ownership and were in charge of their play by choosing their center of interest and the materials they wanted to play with, yet many important factors
for achieving learning were missing. To be able to achieve the criterion *learning to learn*, children must be challenged and discover how to learn by meeting all the C4 indicators. This is only possible when the learners are actively involved and take charge of their learning. Their curiosity must be stimulated so they would want to initiate a project without being told to do so. As they create or find solutions, the learners must be committed to the product they are making and develop autonomy as they are building. If all those terms are met, then the learners should be able to transfer or apply the knowledge to a new situation. This is how learners learn to learn.

*Taking time (C5)* comes in fourth place with a global average of 0.86 on a scale from 0 to 3. To “make” a significant product, children must learn how to manage their time. In C5, three indicators were not witnessed (I1, I3 and I4). Those indicators focused on how the children managed their time, whether they made a plan or reflected on their learning. It was observed that the children didn’t need to manage their time because by the end of “play time” all of the products they created were destroyed or put away. Nothing was saved for the next day for the children to continue. Hence, there was no need for the children to make a plan for their product or to even reflect on their project in order to make modifications.

Indicator 6 (I6) “Do the learners give up easily after an error or mistake?” of C5 was perceived only once in the first session of observation. It was evident that children were seen giving up at the slightest sense of difficulty. For example, when a child was building a tower with wooden blocks, and the tower was not standing, after a couple of tries, the child would move on to a new toy or center. This sight was recurrent it might be because a mentor or facilitator was not present to support the child or to push the
child’s thinking further by asking the right questions. For the child’s creations to be successful, the learner must be trained to plan and reflect on their learning. This skill was not visible during the observation.

In C5 only two indicators were observed every session. They were indicator 2 (I2) and indicator 5 (I5). I2 ‘Do the learners manage their own time?’, the children controlled the time they wanted to spend in a “center”. They could decide when they wanted to move to another “center” within “play time”. I5, ‘Are the learners given the time to interact and learn from others?’ was the other recurrent indicator. The children are in an open space with several toys and tools to use, so the children do not have an alternative but to interact with each other, especially that the toys must be shared. The interaction was the highest in the “dramatic play” center. In this center, the children dressed up or took on different roles; therefore, they needed to rely on each other to reenact a story that was read to them in class. The range for C5 was 0.8 on a scale from 0 to 3.

You can’t get it right without getting it wrong (C6) is the sixth criterion. It was least noticed across the seven sessions of observation. This criterion’s global average was 0.67 on a scale from 0 to 3. This criterion focused on the concept that the learners need to be given the freedom to make mistakes in order to learn from those mistakes. In this case, there was very little room for error since the outcome of each center was known and predictable. In addition, there were no mistakes because there were no specific goals or outcomes to reach. The children never received any feedback on the product they were creating; therefore, they did not feel the need to achieve anything. For the children, it was thirty minutes period of play and at the same time to abide by the class rules.
Children must be put in a state of confusion or frustration in order for them to find solutions and to understand that they are learning from the struggle. The children did not care if they got something wrong, because they never realized that the mistakes they make are crucial for their learning. The children know that their point of reference is the teacher or any adult in the room, but the teacher was seldom free to assist the children and there was no room for mistakes. The teacher become more available during the last ten minutes, before clean up time.

One out of the three C6 indicators, I2 “do the learners know who or what they can refer to if they have a problem?” was seen, which resulted in a score range of 0.67. Had I1 and I3 been seen more often, the scores would have increased and helped the children become better problem solvers. The children did not understand why something went wrong, nor did try to find a solution for their problem. It was obvious that they did not know that every time they struggled they were learning in the process, because it was easier for them to give up. Yet, they knew whom to refer to when they had a problem.

*Digital world* (C8) comes in third place with a global average of 1.29 on a scale from 0 to 3. This criterion had only one indicator. That indicator was only visible on Thursdays since digital technology was used one day a week. The results provided a pattern of zero or three. On Tuesdays, the score was zero and on Thursdays, the score was three. The high range of three reveals an inconsistency in the observation of the indicator.

In a nutshell, it is obvious to conclude that the KG1 classroom did not meet all of the criteria of constructionism. A few important aspects need to be included to improve its status. For example, a makerspace must have an element of challenge, design
thinking, and testing. The tasks cannot be too “free” without setting goals and without any guidance. The motivation level must be increased and group challenges should be assigned to the learners to complete and share their learning in the end.

The centers can remain as “play based”, however the engagement should be planned purposeful play. Children at this age are creative and can come up with original ideas, but they need to be given the chance to show off their inner creativity. This is made possible when children are exposed to challenges or problems (learning invitation) that will spark their interest to ask questions and go further by researching solutions.

4.2.5 Role of the teacher and the learner in the Makerspace

In parallel to the observing the behavior of the children, the observer also monitored the teacher and learners’ roles with another checklist (Appendix B). This checklist was used during six sessions and was filled in the same manner as the previous one (Appendix A). Ticks were placed on the checklist in intervals of ten minutes whenever the attribute was observed. Again, the checklist was reproduced in Excel to study the frequency of the attributes. Notes were also taken whenever a tick was not appropriate, or when a clarification was needed to support the attribute. The results were quantified in the same way as for the previous checklist with scores of “1” or “0”. The same technique was applied to quantify the results.
Table 3

Role of the learners

<table>
<thead>
<tr>
<th>Role of the learners</th>
<th>Take ownership of their learning (LA1)</th>
<th>Ask questions, research and explore (LA2)</th>
<th>Become an expert at a certain skill (LA3)</th>
<th>Are active creators (LA4)</th>
<th>Are natural collaborators (LA5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session 1 (S1)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Session 2 (S2)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Session 3 (S3)</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Session 4 (S4)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Session 5 (S5)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Session 6 (S6)</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Average for each attribute</td>
<td>1.33</td>
<td>0.17</td>
<td>0</td>
<td>1.33</td>
<td>1.83</td>
</tr>
</tbody>
</table>

The five attributes for the role of the learners, refer to Table 3, that the observer was looking for were: taking ownership of their learning (LA1), asking questions, researching and exploring (LA2), becoming an expert at a certain skill (LA3), being active creators (LA4) and natural collaborators (LA5).

The attributes LA1 “Take ownership of their learning” and LA4 “Are active creators” had an equal global average of 1.33, on a scale of 0 to 3. This was expected because when a child takes ownership of the product he or she is creating there is always an opportunity for creativity. Piaget and Papert view children: “as the builders of their own cognitive tools, as well as of their external realities. For them, knowledge and the world are both constructed and constantly reconstructed through personal experience.” (Ackermann, 2001) Piaget and Papert’s view supports that children are active creators and use their imagination to try and discover new concepts, especially when given the right means. Finally, the learners were active creators, except for the fact that they
tended to produce basic products and sometimes with no purpose. The learners took ownership of their learning, but not during all of the thirty-minute time frame.

The attribute LA5 “are natural collaborators” had the highest average of 1.83 on a scale from 0 to 3. This attribute is linked to LA1 and LA4 discussed earlier. The learners were natural collaborators when they needed something, they knew how to work together but not for a long period. Being collaborators is what helped them construct new knowledge.

Throughout the six sessions of observation, a few children asked questions to improve their product (LA2). The second attribute “Ask questions, research and explore” was observed once in the first session, which resulted in a low average score of 0.17, on a scale of 0 to 3. The learners asked each other questions in session 1, but never deeply investigated or researched the situation. It is possible that the children were not trained or no one ever modeled to them what they could do in a state of struggle. To increase the average of LA2 is simple, the teacher could place herself in a state where she is faced with a problem and each time demonstrate a different solution. Some solutions could be to ask a friend or a teacher, refer to a book or even looking at the product from a different perspective.

Due to the nature of the learning environment, the learners did not become experts at a particular skill (LA3), which is made clear with the repetitive zeros in Table 3 Role of the learners, under the corresponding attribute. This could be due to the short observation period or because the children were not held responsible for what they were making during this period. This would require more in depth interview with the children and more planning on the part of the teacher.
Table 4

Role of the teachers, facilitators, assistants

<table>
<thead>
<tr>
<th>Role of the teachers, facilitators, assistants</th>
<th>Teachers’ role attributes (TA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Are mentors (TA1)</td>
</tr>
<tr>
<td>Session 1 (S1)</td>
<td>0</td>
</tr>
<tr>
<td>Session 2 (S2)</td>
<td>0</td>
</tr>
<tr>
<td>Session 3 (S3)</td>
<td>0</td>
</tr>
<tr>
<td>Session 4 (S4)</td>
<td>0</td>
</tr>
<tr>
<td>Session 5 (S5)</td>
<td>0</td>
</tr>
<tr>
<td>Session 6 (S6)</td>
<td>0</td>
</tr>
<tr>
<td>Average for each attribute</td>
<td>0</td>
</tr>
</tbody>
</table>

When observing the role of teachers, facilitators and assistants, (refer to Table 4) the researcher was looking for the following teacher attributes: mentor traits (TA1), connecting learners with experts (TA2), learner traits (TA3), preparing authentic engagements (TA4) and always available (TA5). During the course of the observation, only two attributes out of five were visible as seen in Table 4. It was noticed, from the excessive amount of zeros, that the teacher did not interact with the children nor was she involved in what they were “making”. She was only available when she was not working with another child.

The KG1 classroom teacher was always physically present (TA5) in the classroom (TA5) but not always available to support the children’s learning during “center time”. The fifth teacher attribute “was always available” received an average of 1.33, on a scale of 0 to 3. In a maker-centered classroom, the role of the teacher is to monitor the making that takes place during “playtime” and to follow up on the children’s
plans to guide them in the right direction. From what was observed the teacher’s role in this particular KG1 class was to make sure that every child was in a center, that the noise level is acceptable, and that each child’s class work is complete. The teacher or facilitator had a say in which center the child could choose. For example, if the teacher noticed that a child has visited the same center on consecutive occasions, then the teacher would direct the child to another center to experience a new skill. However, there is no assurance that this child will produce something in the new center. At first, the child might observe or communicate with the other children in order to build confidence to play with the tools.

A common scene was repeatedly noticed throughout the observation period, it was that of the teacher sitting with one or more children at a time. Those children would have been absent and needed to catch up on missed work. The teacher rarely interfered in the making or learning that takes place during center time. She was seldom involved in what the children were making, nor did a child ask for her assistance during “free play” time. During the observation period, the centers remained the same. New centers are introduced at the beginning of new units, every six to eight weeks.

The second teacher attribute (TA2) was “can connect students with other experts”, this attribute’s average score was 1.17, on a scale of 0 to 3. This reveals that at least once per sessions, the teacher was able to pair a child with another child or an assistant in the room whenever he or she needed specific guidance. However, an expert does not always have to be another human, it could be a book or access to a digital device where a child could find the answers to his or her questions.
The teacher or the assistant never showed characteristics of a learner (TA3) or a mentor (TA1). Both teacher attributes were never observed; therefore, their average scores were a 0 on a scale of 0 to 3. It was noticed that the children were kept busy until it was time to clean up or time for the next period to begin. The teacher never took the time to sit at a center and discuss a product with its maker.

Another attribute that was never observed was “Prepare authentic learning engagements” (TA4), which also resulted with an average score of 0, on a scale of 0 to 3. It was observed that the learners were more active in the learning environment than the facilitator, but with no benefit. Unfortunately, for the children, the teacher never prepared authentic learning engagements during the “free play” time. Instead of preparing challenging engagements for the learners, the teacher used the time to focus on the incomplete work with certain children. The children were engaged in the first half of the “center” time, but towards the end, they were not motivated to make anymore. The tasks were repetitive and there was no element of surprise. There must be more planning on the part of the teacher.

4.2.6 Summary of the findings of observations

The observations conducted in the KG1 classroom were based on three checklists with different purposes. The first one allowed the researcher to explore the physical learning environment in order to detect the tools and materials available as well as their safety. It was learned that the space could be better equipped if it had more digital devices or items that are not familiar to the children. The addition of digital devices is encouraged to develop the children’s thinking and problem solving skills. The arrangement of the tools is adequate for the children of that grade level.
The second checklist was used to study the conduct of the children in the space. The results revealed that the children learned by doing and the act happened naturally. They used the tools available with ease and were in control of their projects. However, the outcomes were predetermined and the children were never challenged to produce a purposeful product. The tool that was developed to observe the children’s conduct in the Makerspace (Appendix A) highlighted that a lot of the indicators were not present at the time of the observation. Maybe the indicators were not applicable as an assessment tool for the chosen age group. It is a valuable tool, however, it could be used as a pilot to and be modified for another study.

Lastly, with the third checklist, which focused on the role of the teacher and the students, it was clear that the children were more active than the teacher. Nevertheless, this situation led the children to give easily and get bored. Moreover, the teacher had minimal interaction with the children, which defeats the purpose of a makerspace.

4.3 Maker-Centered Instructional Unit in the Grade-2 class

The maker-centered instructional unit entailed a diagnostic assessment made up of two tasks, and an activity spread out over five days, which targeted all the phases of the engineering cycle. The tasks and activity followed the engineering cycle, which will be the basis for the analysis. The phases of the engineering cycle are: define the problem, brainstorm, draw, build, test and modify. A detailed account of the implementation of the diagnostic assessment and the activity will be described along with the anecdotal notes that the researcher collected. Next, a content analysis of the “Making Journal” (Appendix F) that the students used to document their learning during the activity will follow. Finally, a quantitative analysis of the data collected with the evaluation rubric
(Appendix G) during the diagnostic assessment and the activity will conclude the analysis of the maker-centered instructional unit. The maker-centered instructional unit aimed to answer the fourth research question: what impact does a maker-based instructional unit have on the learning of grade-2 students and what are the challenges actually faced?

The students who took part in the instructional unit were assigned a code in order to remain anonymous and to track their progress. The students were numbered from one to twenty-four. This code was noted on the students’ recording sheets, making journals and evaluation rubrics. At the end of the instructional unit, all of documents were sorted for each student (i.e.: student 1’s papers were put together then student 2 and so on).

4.3.1 Diagnostic Assessment

The individual diagnostic assessment presented to the students consisted of two thirty-minute tasks. Two distinct tasks were chosen to ensure that the students could complete at least one. The two tasks were purposefully chosen in order to observe the different steps or the processes that the students will follow to solve the challenges to accomplish the goals. The diagnostic assessment was used as a pre-test tool to identify the students’ prior problem solving and making abilities.

Twenty-two students took part in the individual, two-task diagnostic assessment (Appendix D). For first task, the students had to create a paper airplane that would fly the farthest possible. In task 2, the students had to build a tower made out of straws and tape that could withstand the weight of three tennis balls. The diagnostic assessment was administered in the following manner. The teacher began by orally introducing the challenge. Then, the students defined the problem by explaining the task in their own words on the recording sheet (Appendix D). Next, the students brainstormed and drew
their idea(s) on the recording sheet as well. The students were provided with the needed material to proceed and to create the model they drew. Later, the students tested their product, on their own, to make sure their creation matched the requirements. This step led the students to make appropriate modifications and to retest their product. At the end of the thirty minutes, students shared their product in front of the group. Finally, the observer recorded the students’ newly gained knowledge during an oral group reflection.

Since two tasks were prepared for the diagnostic assessment, this process was repeated twice. Once both tasks and the group reflections were completed, the students were solicited to write an individual reflection on the recording sheet (Appendix D). During the reflection phase, the students were encouraged to express the knowledge they gained from both tasks and to address any problems they faced.

In the meantime, the observer’s role was to go around among the students to document the making process of both tasks in the form of anecdotal records. The tasks were done in two different sessions to give time for the students to think about what they made. Furthermore, the group reflection sessions were also recorded in writing by the observer. During the group reflection, the learners shared what they learned and how they benefited from these tasks and from working with their peers.

The observation notes collected during each phase of both tasks of the diagnostic assessment, along with the group reflection done at the end of each task will be displayed. The notes are presented following the phases of the engineering cycle against which the students were evaluated throughout the instructional unit. More information will follow about the rubric and its implementation.
4.3.1.1 Diagnostic assessment: Task 1

At the beginning of task 1 (Appendix D), the teacher explained the task orally and displayed an infograph of how to make a paper airplane on the interactive board to guide the students who needed support. In this phase, the students have to define the problem. Although it was an individual task, it was noticed that many students formed groups and assisted each other to build their airplanes.

The learners understood they had to create a paper airplane that could fly the farthest and communicated that to the teacher. Now, the students had to brainstorm ideas of how they would go about creating their paper airplane. It was also clear that many of them had the prior knowledge of how to build a paper airplane. However, as the students built the planes, no one stopped to think about the second requirement of the task, which was to make the plane fly the farthest possible. This was detected once the students started to test their paper airplanes.

Next, on the recording sheet (Appendix D), the students drew and colored the design for their paper airplane, in the dedicated area.

![Figure 1](image)

Figure 1 *Samples of students’ brainstormed ideas*

Figure 1 shows samples of drawings that the students drew individually before they built their products. The large majority of the sketches were similar and looked like the ones pictured above. This suggests that while the students were drawing their ideas
(after brainstorming), they were not thinking of their final product. They wanted their
drawings to look pretty. They did not understand the necessity of connecting this phase
to the building phase of the cycle. Only a few students drew figures that resembled their
finished product.

After the students drew their initial designs, it was time for them to build. The
students who had prior-knowledge about how to build a paper airplane built it by
themselves. The others relied on each other and on the displayed image. A few asked for
the teacher’s assistance. In this case, the teacher would focus their attention to the
infograph on the interactive board or guide them to come up with a better solution. The
teacher continuously encouraged the students who faced difficulties by pointing (on the
infograph) at the step they are at in the building process.

A common scene was perceived of student folding papers, comparing against the
infograph and to their classmates design. However, the students needed to refer to their
drawing and that was never observed. This explains that the students did not understand
that the two previous phases were connected to the building phase.

After the students made their paper airplanes, it was time to test them. The
teacher posed questions to make sure that the students understood the point of testing
their product. Every student replied that the purpose of testing his or her plane was to see
how far it would fly.

At this point in the making process of task 1, the teacher stuck a piece of brown
masking tape on the ground to point to the learners where they must stand to test their
paper airplanes. As the students tested their products, they realized that their planes were
flying at least 2 meters in length. Some made slight modifications to their paper airplanes
by cutting the back end or bending the front part of the plane then tested again. The students actually took the initiative of fixing their plane without prompting from the teacher. Although the students modified their products, the results were not as they expected. Yet, they were motivated to reach the farthest distance possible; the students were competing to build the best airplane. Many worked together and gave each other feedback to fix their planes.

For the final testing stage of task 1, the students stood on the testing tape on the ground, one at a time, and let their planes fly. Where the plane landed a new piece of tape would be placed on the ground with the name of the student. This step was taken to help the students reflect on what went well and what didn’t go well with their plane.

By the end of task 1, there was a common noticing among the students; they remarked that while they were testing their paper planes, the planes travelled a longer distance. However, at the time of the final test, the planes did not go too far. The farthest plane travelled one meter and one plane flew backwards. As a result, the teacher asked them for some clarification of why they thought they all faced a similar issue. These were some responses given by the students. Some students noticed that: “Some people were shooting wrong with a lot of force and strength. You need to throw it gently. Like this”, and they showed how it was done. They also deduced that the “airplanes are different, big and small sizes” which might be a cause for the short flight distance. Consequently, the students realized that “while we were testing our planes, they bumped into things in the class and got destroyed so we fixed them” causing some defects in the paper airplane. Some voiced, “Some of the planes were not made well.” Finally, after
the task ended, a few students noticed “Some of us got our planes mixed up with others while testing.” Thus, the students were disappointed.

4.3.1.2 Diagnostic assessment: Task 2

Task 2 (Appendix D) began by the teacher giving an oral explanation, but this time an image of the final product was not shown to the students, in order to activate their creativity. However, the confusion was clear on the students’ faces, it was clear that that they were not sure about how to proceed. Ten straws were distributed to each student to build a tower that could withstand three tennis balls. The students asked a few questions to make sure they understood the task, such as “do the balls have to go on top of the straws? Does the tower have to have a certain shape?” They also wanted to know if they could cut the straws, obtain more straws and tape, or use other materials.

The students understood that they needed to build a tower out of straws and tape, which could withstand three tennis balls, but they faced difficulties to imagine the tower clearly in their mind. At this point, the teacher needed to draw an example, using short lines to represent the straws, on the board. The students were allowed only ten straws and a 50-centimeter piece of tape. They could ask for more tape, but only ten straws were given to make the task more challenging. Soon they realized that by cutting the straws they could have more pieces.

In task 1, the planes they drew did not look like the ones they created. It was the same case when the students drew their towers for task 2. Several students copied the example tower that the teacher drew on the board. Some tried to make their own tower design. The rest of the students drew some sticks next to each that did not resemble a tower (refer to figure 1).
When building their towers for task 2, the students immediately started to cut the straws without considering their plan. By the end of this stage, none of the towers looked like what the students originally drew. Next, the students started to put the tower together without taping the straws to see how it would look like. Someone noticed that they didn’t need tape; they could fit the straws inside each other by cutting a small slit on the side of the straw. During the building stage, the students were continuously reminding each other of the requirements, especially the one that the tower should withstand the weight of three tennis balls.

Task 2 needed more than 30 minutes and a lot of guidance from the teacher to complete. The students were too excited and too loud at the brainstorming stage. Then when the task became clearer, they started to focus and quieted down. Many students asked for more tape to fix their tower after they tested it. Many faced difficulties to make their tower stand up straight. Only two people collaborated and gave feedback to each other about their own projects. In the end, only one tower out of 22 withstood the weight of three tennis balls.

The majority of the task 2 products the students built did not fit the requirements; their products were not strong enough to hold the weight of three balls. Only one tower survived the weight of the three tennis balls. Only 12 out of 22 students built towers that were acceptable and close enough to the requirements. The rest of the students wanted to play with the straws and make sounds by blowing into them.

When the teacher noticed that the students had some problems building or modifying the product, she gave guiding questions such as: How will your model stand?
Did you try to put the tennis balls on top of your tower? Are you going to start over? What should you do differently this time?

When task 2 was completed, the students had few things to say. One student said: “This activity was fun to make, I liked testing the tower, I loved the tower because I got to build my own.” Another compared both tasks and revealed: “The plane was easier to make, my tower broke with the balls, and I kept trying again.” After reflecting on his product, a student believed: “I had to make the tower straight and strong enough for the balls”.

After the final test for task 2 was done, the teacher showed the students pictures of possible solutions of constructed straw towers. The expected outcome became clearer in their mind and some students tried to recreate it at home.

4.3.1.3 Reflection on task 1 and 2

From the group reflection, it was clear that from kindergarten onward, students are generally not trained to solve problems or come up with purposeful solutions. This result is directly linked to the observations that were done in the KG1 classroom. When the students are not given the opportunity to “think outside the box” or when they are not challenged at an early age, it might be difficult for them to complete a maker activity without the support of a facilitator at the age of eight.

These testimonies below showed that after two STEM tasks the students were able to take ownership of their work. They were determined to complete the tasks because of the empowerment their teacher had granted them. The reflections below are examples of reflections written by the students at the end of the diagnostic assessment. These reflections express the students’ different perspectives or understanding of the tasks.
The reflections in figure 2 show that the students were aware of the mistakes they needed to amend and that they had started to develop a maker mindset. As Dougherty (2013) explained, a maker is a person who is committed, asks questions and who learns from their mistakes. The students learned that problems are unavoidable and how to overcome them by suggesting solutions on how to improve their model. They identified the problem with their plane was that they threw it with a lot of force, that is why it did not reach the required goal. Their towers were not strong because of the layout of the straws in their design. However, they didn’t have the time to try those proposals or modification ideas in the classroom. One student, in Figure 2, focused on the attitude of a maker in his reflection. He discovered that a maker should not give up and must keep trying new ideas based on the outcomes of the testing phase. This student has also become a problem solver by addressing the fact that designing a model is not easy and that commitment and perseverance are a must to get the job done.

These reflections tie in directly with Papert’s eight big idea of constructionism. From these reflections we can detect the criteria of learn by doing (C1), hard fun (C3),
learning to learn (C4), taking time (C5), and you can’t get it right without getting it
wrong (C6). At the end of the diagnostic assessment, which is made up of two tasks, the
students began to display signs of creating or constructing their own knowledge and a
positive attitude. This attitude is what allowed the students to understand that every time
they struggle they are learning in the process.

The students were curious and investigative when using the materials to come up
with new ideas. They relied on each other to gain new knowledge to be able to make
what they want. The students enjoyed building the catapult with the materials provided
and they were focused and determined to succeed in the fun challenging activity. They
also expressed a positive attitude when interacting with the material and with each other.
The learners were motivated and willing to apply the necessary effort to complete the
activity.

The students turned into active learners once their plan was clear to them. They
took charge and ownership of their learning. This empowerment that was bestowed upon
the students made them more committed to the catapult they were creating.

The learners made their own decisions when faced with problems and took
responsibility for their learning. They looked at why something went wrong and they
knew who or what they could refer to if they have a problem.

Since there was no follow up to this activity, there was no way of determining if
the students will transfer and apply this knowledge to a new situation. In addition, we
could not identify if the learners discovered that every time they struggled they were
learning. These two points needed further testing.
4.3.2 Maker-centered activity based on the engineering cycle

The activity was developed based on the observation notes collected in the KG1 classroom combined with the elements of a unit prepared by Wetsby (2016). Wetsby’s resource was purchased from an online platform where teachers share resources they create. The author granted permission for her product to be used for this study. Wetsby’s unit is based on the fairytale of “Red Riding Hood”. The students had to create a solution, in the form of a catapult to aid Little Red to deliver the basket of cookies to her grandmother’s house. The challenge was that, the basket of cookies had to fly over the forest to reach grandma’s house. The objective of the activity was for the students to define and solve a problem by designing and then creating a purposeful solution. Those are the phases of the engineering cycle on which the evaluation rubric (Appendix G) was based, which will be discussed later.

Included in the unit created by Wetsby (2016) is a “Making Journal” (Appendix F). The journal is meant for individual use. It is made up of eight pages including the cover sheet. For the purpose of this study, only six pages were chosen (including the cover page) to target the objectives. The journal was used a documenting tool. The students wrote about the process they went through to produce their group catapult. This “Making Journal” will be analyzed at a later stage.

The activity was spread out over five days for a maximum period of 60 minutes per day. The activity focused on each of the 6 phases of the engineering cycle, with “defining the problem” and “brainstorming” combined on day 1. At the end of each of the five days, a whole-class oral reflection took place to give the chance for the students to express their ideas orally in a more systematic way.
For the activity, the students worked in groups of four; this permitted them to interact with each other and to solve problems collaboratively. The constructionist theory does not only support the idea of making with a purpose, but a key and essential component is social learning. In addition, each student was responsible for recording and documenting their own learning journey in their making journal throughout the activity. The making journal is similar to the recording sheet used in the diagnostic assessment (Appendix D). It is also organized to target the six phases found in the evaluation rubric (Appendix G) that was used throughout the instructional unit to evaluate the phases of the engineering cycle. The evaluation rubric ensured that the maker-centered unit targeted the same phases. The students’ making journals, the researcher’s anecdotal records, and students’ oral reflections were analyzed. A content analysis of the making journals will follow the observer’s anecdotal records.

4.3.2.1 Analysis of the anecdotal records

The observer recorded the following notes during her observation of the activity that followed the diagnostic assessment. The notes are presented chronologically from day 1 to day 5 with each day focusing on a skill.

Day 1, define the problem and brainstorm. The teacher read the story of “Little Red” to the students as they listened attentively to predict the ending of the story. To make it more meaningful and relevant, and for the students to have a deeper connection to the characters, the students illustrated the sequence of the story to demonstrate comprehension. They created their own endings for the story using their ideas. Each student had a different outcome to their story depending on how they solved the challenge.
Next, the task was explained to the students. They had to build a catapult, in groups, that would help Little Red get the basket of cookies over the forest to her grandma’s home. The students were introduced to the materials they could use and given instructions about how and when to record their experiences in the sections of the making journals. Before the group work began, each student brainstormed possible designs individually in their journal for the catapult. They were free to draw or write their ideas or do a combination of both. The purpose was for the students to put their ideas on paper. It was noticed that the students were facing difficulties and hesitated to draw a catapult that would be made with the materials provided. Many students commented: “So we have to make a slingshot?” This is when the teacher decided to display, on the interactive board, pictures of catapults made with popsicle sticks, because the students had conflicting thoughts about their form.

Day 2, draw the idea(s) and materials needed. The students were divided into six groups of four students. After the groups were chosen, the students shared their brainstormed ideas with their group-mates. The goal was for the students to collaborate and to use their ideas to unanimously reach a final design. They had three options, which they were made aware of: 1) Create a completely new design, 2) Combine brainstormed ideas together, or 3) Choose one of the four designs proposed. At this point in the unit, the level of enthusiasm was high and so was the motivation.

Day 3, build the design. In groups, the students got the materials they needed to build their catapult from the table of materials. While building, the students faced a common problem that they needed to solve. The problem was that the catapult was not working as they had predicted. The cookie was not going high enough above the forest
to reach grandma’s house. Each group was provided with a paper model of the forest in order to have a unified distance and height for all groups. The students immediately modified their models by incorporating additional materials or by changing the original design of the catapult.

At this point in the activity, the students voiced the following concerns:

1. “The catapult is hard to make it stand and sometimes when you try to make the catapult work it breaks. Not everything is easy, but we’ll try again.”

2. “It takes time to build. Try your best until you get it right. We decided on one idea and we felt a bit happy.”

3. “Not all the designs succeeded. We tried to make a triangle with cardboard to support the catapult. We wanted to come up with another idea but not all members accepted. There was a conflict in the group.”

4. “It was so hard so we tried different ideas and failed. It will not work all the time.”

5. “I learned that it’s not like magic. You need lots of work and coordination and to collaborate. I was excited.”

6. “You can’t just start a project, you need to plan and be organized.”

7. “I felt it was complicated. The first time it wasn’t clear, then we started to work together and it was better.”

8. “It was fun although we didn’t build what was expected. So, I learned that we needed to take turns and to listen and to let everyone add an idea.”

9. “It was hard, and we could have worked better as a team. In the end we made something that works.”
Day 4, test the model. The teams were finalizing their design/product and testing their final model. On this day, some team members started to argue, but all the conflicts were resolved except for one team. In that team, each member built their own catapult and showed little collaboration among its members. Catapults started breaking because of the repeated and excessive testing. On this day, students were given time to fill out the pages of their making journal to document their learning journey.

Day 5, modify the model. After the testing session, the groups were given 10 minutes to make final modifications to their designs in order to share and present their work in front of the class. During the presentations, this is what the observer noticed:

- Some students tried the catapult a few times before succeeding. The height and distance of the catapult needed to be adjusted for the cookie to pass over the forest to reach granny’s house.

- Five of the catapults looked like seesaws and the sixth looked like a boat. It was a seesaw in a sandbox and it performed some of the time.

- Most groups had to slam hard on their catapult with a lot of pressure for it to function properly. One group had to press lightly on the popsicle stick to do the job.

- It was noticed, by the students, that there are different solutions to the same problem. The students also concluded that it is important to keep trying and better to work as a team.

Following the five days, a group reflection took place with the twenty-four students to derive their ideas about the process of building the catapult as a team. The learners shared these few statements:
1. “We felt worried and excited to do something unique, not like the others. We are glad we succeeded. We felt it was not hard anymore because we kept on trying.”

2. “We felt that we were rushed and that we did not have enough time. It was hard to think of a new solution when our first idea didn’t work.”

3. “We were excited when we started. We succeeded, but two members of our team didn’t cooperate with us.”

4. “At first, we were arguing over whose idea to use. It took us too long to make a decision and to start working. We ended up combining our ideas and the catapult worked.”

5. “We made three catapults, but only one worked.”

6. “The catapult we created yesterday broke. So we needed to make a new one and it was a better model. The new one worked perfectly.”

4.3.2.2 Analysis of the Making Journal

The purpose of the making journal (Appendix F) was for students to individually record their ideas, work through challenges and make improvements, and to reflect on the collaborative process. It is made up of six pages including the cover page, which contained prompts to guide students to write, sequence their ideas and reflect on their progress. Five analysis criteria were depicted in the journal, which are: attitude, planning, metacognition, challenges and motivating action. From those criteria emerged themes, which were the basis of the content analysis of the making journals. The themes were uncovered from the answers that students provided to the questions posed on the pages of the journal. The researcher read all the answers and, as a theme arose, it was noted under the analysis criterion to which it corresponded. In addition, each theme was
tallied to identify the frequency and recurrence of specific themes across the answers.

**Attitude**

The analysis criterion of attitude reflected on the feelings that the students had towards and during the activity. The most common themes found under the attitude criterion were “happy” and “excited”. “Happy” was spotted 58 times in the twenty-two journals. While “excited” recurred 25 times. However, not all students expressed the same positive sentiments at all times. The students shared feelings from both sides of the spectrum as revealed by figure 6. Four students indicated that they were nervous, five felt angry and three were sad at some point in the process of creating the catapult. It is clear to say that all the students had a positive attitude toward the activity, which helped them persevere and overcome challenges along the way.

**Planning**

Figure 3 is page three of the students’ making journal. On this page, the students were given the chance to think of the process they had to undertake to build their catapult as a team and to note their feelings for each step of the process. This graphic organizer aided the students with the last step of the engineering cycle, which is to modify the product. This tool allowed the students also to reflect...
on each decision they had taken and to notice the benefits and drawbacks of each step they took.

As the activity progressed so did the challenges, which forced the students to reflect on their plan. When studying page 3 of the “Marking Journal” which targeted planning and attitude, two trends became equally apparent. The first trend was that eleven students used the phases of the engineering cycle to explain their plan in brief. For example: build, draw, make, and try. The second trend, the other eleven students explained what they did step-by-step with a lot of details. They mentioned the materials they used and how they used the materials to create their catapult.

**Challenges and metacognition**

The analysis criteria of challenges and metacognition were combined because when you are faced with a challenge this coincides with a struggle or a problem. To overcome this problem a person needs to solve it by thinking about your previous ideas and thoughts. This is where metacognition comes in and the reason why the analysis criteria of challenges and metacognition were studied jointly. Figure 4 or page 5 in the making journal, allowed the students to identify what they
learned from their challenges and what they did to solve it.

Eight out of twenty-two students mentioned the idea of collaboration, they realized that in order to succeed they cannot work alone. They needed the help of other learners for the product to meet all the requirements. In addition, students expressed feelings of frustration as they were progressing through the activity. The main source of frustration was because the team’s product did not operate as planned from the first time. Eight students addressed the later as a problem they had to solve. Hence, three students understood that nothing works the first time around and that being committed to your work is the key to overcoming frustration. Finally, the last theme is change. Change was noticeable when the students were asked about what they would do differently if they were given the chance to repeat the challenge. Here many students came up with smart solutions or upgrades to their current model. An example was: “Make the design more stable and not to push so hard and to use less tape.” Other mentioned that they would use different materials while other understood that their behavior, the unwillingness to listen to one another, was the source of the problem. This connects to the analysis criterion of metacognition that shows that students have started to develop the skill of thinking about their thinking.

Motivating action

At the end of the activity, the students were asked about their favorite part of the activity. The common motivating factors that the students provided in their answers were: Presentation, group work, not giving up, and building. The most prevalent theme was group work. The students had fun and learned a lot from each other. The students enjoyed the chance of working together as a team and they learned that their hard work
did not go to waste. The teacher empowered the students and gave them the chance to show off their learning by presenting their final product. Presentation was the second most common motivating factor that the students mentioned. The themes of group work and presentation gave students the confidence to build a purposeful model and at the same time the courage to speak about it in front of their peers. In Figure 5 are two examples that support the two most common themes.

Figure 5 Students’ reflection on their favorite part of the activity

Not giving up was the third most common motivating factor. The students realized that in order to succeed, the members of the group must communicate in a positive manner. Building the catapult was the least motivating factor. This shows that the students preferred working together than actually creating something.

4.3.2.3 Analysis of the evaluation rubric based on the engineering cycle

The use of the evaluation rubric will be explained and the scores will be analyzed to identify whether the students have adopted the phases of the engineering cycle when completing the instructional unit. Three tables and a graph were created for the analysis.

The anecdotal records collected by the researcher were guided by an evaluation rubric (Appendix G) based on the engineering cycle that makers must exhibit. Those phases are: defining the problem, brainstorming solutions, designing the model, building
the model, testing the model and modifying the model (NGSS, 2013). Each student was evaluated against the same rubric by the observer. The evaluation rubric was used to evaluate the students at the end of task 1 and then again after task 2 of the diagnostic assessment. Lastly, the students were evaluated with the rubric once the activity was completed. This was done to ensure that the engineering cycle was highlighted throughout the instructional unit. This tool was added to guarantee the validity of the results.

Data were gathered from the students’ recording sheets/journal, the observer’s anecdotal records, and the group reflections held at the end of each task, and the evaluation rubric. The students’ recording sheets and making journal were designed to aid the researcher to identify the six phases she was observing to facilitate the analysis process. The alignment between the diagnostic assessment and the activity was done to coincide with the evaluation rubric (Appendix G) that each student was evaluated against at the end of each part of the instructional unit. While observing, the researcher kept those six phases in mind to jot notes about the students.

Three tables and a graph were created on Excel with the data collected from the rubrics to compare the students’ results at different parts of the instructional unit. Table 5 provides the scores the students received for the six phases of the engineering cycle for both tasks of the diagnostic assessment. Table 6 includes the average scores of task 1 and task 2 as well the scores for the activity. The data of Table 6 were used to create Figure 6, a graph that compares the scores. Finally, Table 7 presents the average scores for each student for task 1 and 2 of the diagnostic assessment for each phase of the engineering
cycle and the scores for the activity at each phase of the engineering cycle. The tables and figure will be analyzed in that order.

Table 5 focuses on the development each student achieved throughout the phases of engineering cycle over the course of the diagnostic assessment. The student codes (student 1 to student 22) are the column headers. Students number 23 and 24 were omitted from this table because they were absent on the days the tasks were completed. The first column displays the six engineering phases and in front of each phase are two cells, one for task one and the other for task two. The next columns show the score (1 to 5) that each student received for each of the six engineering phases for each of the tasks of the diagnostic assessment. Three additional rows were added at the bottom of Table 5. The first row is the combined score each student got for task one and the second row is the total score for task 2. Next, the average of the total scores of task 1 and task 2 was calculated and it is found in the last row of the Table 5. The last column of Table 5 represents the class average scores for task 1 and task 2 for each phase of the engineering cycle.

When all the data were entered, the table was color-coded to facilitate the analysis process. The purpose of the color-coding was to distinguish between the high scores (3 and above) and the low scores (2 and below). Two colors were chosen, red (high) and green (low).

In Table 5, it was noticed that the higher scores (red cells) were more common in the first four phases of the engineering cycle (define, brainstorm, draw and build). This points out that students are not taught to test, review or modify a product they create at an earlier stage in their education. The students are always in a rush to complete the task
and do not take the time to reflect on their product in order to produce the best possible model or to make sure they have met all the requirements. The results also support the fact that this was the students’ first exposure to these kinds of “Maker” challenges.

At a first glance, it is obvious that there are more red colored cells towards the top of the table. This means that those phases are a common practice to the students. The first phase of the engineering cycle is “defines a problem” which is something the students have done before at least since nursery class. It was also noticeable that the second task was more difficult for the students to define. “Brainstorms” is the second phase that the students had repeatedly done over the years, but mainly orally because the green colored cells increased in the “draws” phase. The students needed help with drawing a precise image of the ideas they had brainstormed. The students faced difficulties putting their ideas on paper, especially for task two since it was not clear to them from the beginning.

The last three phases of the engineering cycle are where the students faced the most difficulties. The phases are: builds, tests and modifies. This result explains that they had not been exposed to or asked to build, test or modify a product enough times. The students are used to completing a task and once it is done, they turn it in. They do not take the time to revise or try to improve the content or to the product against the list of requirements. For the phase of “builds”, task one was a success because the students had all made a paper airplane at some point in their life, only six needed support to make the plane.

The score for each phase of the engineering cycle was measured on a scale from 1 to 5. A score of 5 reflects an excellent representation of the criterion required for each
phase of the engineering cycle. None of the students managed to receive a 5 on any phase of the engineering cycle during the diagnostic assessment. This is due to the minimal exposure that the students have to such types of maker-centered tasks.

Table 6, is a simple three row table that displays the average score for each student for the diagnostic assessment and the score for each student for the activity. Using the data of Table 6, a clustered two-column graph, Figure 6, was prepared to compare the performance of each student in the diagnostic assessment and the activity. It was noticed that the students obtained a higher score during the activity; this is due to the collaboration aspect of the challenge and to the separation of the phases over 5 days. The students had more time to reflect on each step of the process and to make the necessary changes. The students were not rushed.

Table 7 was designed to study the evolution of each of each student at the different phases of the engineering cycle during the diagnostic assessment and again in the activity. Table 7 looks similar to Table 5, but instead of the scores of each phase of the engineering cycle for task 1 and task 2, the average scores for each phase for the diagnostic assessment and for the activity are perceived.

After completing two practice tasks and a group reflection session the students' scores improved at each phase of the engineering cycle. The engineering cycle phase, during the activity, where the students showed a drastic improvement was “draws” this is because the students were now better able to transfer their brainstormed ideas onto paper. They could draw a more reliable design of the model that they intended to build. Since the students improved in the phase of “draws”, they consequently did the same in the
“builds” phase. This is because their drawings gave the students a clearer visual image of what they were building.

In addition, the scores during the phases of “tests” and “modifies” have increased. This exhibits that the students have discovered that you cannot get it right the first time. This is a direct link to one of Papert’s eight big ideas; *You can’t get it right without getting it wrong*. The students learned that the struggle they faced during the two tasks of the diagnostic assessment was part of the learning process. They also learned whom they could go to if something went wrong and now they had a small bank of problem strategies, which they could refer to as well.

It is clear that the students’ scores had improved in the activity that was completed after the diagnostic assessment. Each score is out of 30 because there are 6 phases and each phase is rated on a scale of one to five. Students 23 and 24 had the lowest score for the activity because they were absent on the days of the diagnostic assessment. Their scores are very close to the average scores the twenty-two students received for their diagnostic assessment. For those students, the activity was the diagnostic assessment; it was their first exposure to STEM tasks.
Table 5

The score for each phase of task 1 and 2 of the diagnostic assessment

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<th>Class Average</th>
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Table 6
The average scores of the instructional unit

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Figure 6
Graph comparing the average scores of the diagnostic assessment and the scores of the activity

Average score of the diagnostic assessment and activity
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4.3.2.4 Conclusion/analysis of the maker-centered instructional unit

It was noticed that students’ scores did improve and they are now able to solve problems better, but have not yet mastered the STEM skills. They are able to plan their work while keeping the phases of the engineering cycle in mind. It was very clear during the diagnostic assessment and activity that the students always wanted to finish the challenge in the fastest time possible. They did not take the time to reflect on the product they made or even when they tested the model. The students lost interest quickly. If the product did not fit the requirements, they did the minimum effort to adjust it. To fix a mistake, the students, used the trial and error technique, they relied on luck instead of their thinking skills. The students enjoyed the challenges, yet they needed to be more committed and needed to develop the ability to modify the products they create.

Maybe the outcome would have been different if the students were given the choice to come up with a real life problem and given the chance to solve it. However, the purpose of this unit was to study the improvement in student scores over a period of time after being exposed to the engineering cycle and STEM skills. A positive outcome from the instructional unit was that the challenge stuck in the students’ minds and they tried to recreate the tasks and activity at home and even perfected their product. The students were excited to come back to school and share their experiences with the class.

4.3.3 Summary of the findings of the unit

The maker-centered unit was composed of a diagnostic assessment and an activity. The results of the diagnostic assessment proved that the students were never exposed or placed in a problematic situation where they needed to brainstorm, design a plan and test in order to solve the problem. They were never put in a position of
uncertainty where they had to use their problem solving skills and that was obvious due to the low scores the students acquired at the end of two-task individual diagnostic assessment.

After had gone through two maker tasks, the students had a clearer idea of how to tackle those types of challenges. Hence, when it came time for the five-day activity, they were in tuned with the expectations of the task. They were at ease and their scores rose significantly. This demonstrates that learning had taken place.

4.4 Interviews

The purpose of the interviews was to detect two themes: the teachers’ and administrators’ perception of Makerspaces and what challenges they foresee in installing a makerspace in the lower elementary classes. Three sets of interview questions were developed to interview three categories of faculty; administrators, preschool teachers and lower elementary teachers. The answers to the interview questions were transcribed digitally. Then, they were analyzed using color-coding content analysis to identify the aforementioned two themes and any new ideas that could surface. A different color was designated for each theme.

The interviews were conducted in a quiet room at school during the interviewee’s free time. Some interviews took longer than others depending on the person’s knowledge of Makerspaces (between 10 to 30 minutes). Several teachers were in a rush to get back to their class to prepare for their next session, mainly the preschool teachers. This may have affected their way of answering the questions. The content of the interview questions was altered to fit the grade level or position of the person being interviewed. The questions were all open-ended, personal and neutral.
Since the preschool classes already have a maker-centered classroom, those teachers had the least questions to answer. The nine questions (Appendix H) focused on their opinion about the best educational approach, how they implement maker-centered units and whether a makerspace helps students’ learning. The preschool teachers were also asked about the benefits and drawbacks of makerspaces in the classroom, centering more on the challenges. Finally, they were asked why they think maker-centered classrooms do not exist at the lower elementary level.

The lower elementary teachers, who do not have a maker-centered classroom, had to answer the same nine questions as the preschool teachers as well as three supplementary questions (Appendix I). A question related to the benefits they foresee if an educational makerspace was set up at their school and two hypothetical questions, based on whether they would take the challenge to start a makerspace in their classroom and how they would proceed with this challenge, if they agreed.

The administrators only had a few questions in common with the teachers (Appendix J). The bulk of their questions emphasized on the school’s decision-making process, their perception of Makerspaces and what challenges they foresee if a Makerspace is installed at the lower elementary level.

The first question in all three interviews was about their teaching years of experience. The preschool teachers’ experienced were 25 years for KG1 teacher, 12 years for the KG2 teacher and 6 years for the nursery teacher. As for the lower elementary teachers, the first grade teacher had 17 years of experience; the second grade teacher had taught for 25 years and the third grade teacher’s years of experience were 16. The administrators were teachers before they took on the role of an administrator. The
assistant to the director taught for 12 years, while the PYP coordinator had taught for 26.

Both administrators had been in that position for two and one year respectively.

4.4.1 Interview themes

Table 8

*The themes that arose from the teachers' and administrator's answers*

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<td>Perception of educational Makerspaces and its cost effectiveness</td>
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<td>Decision making process for piloting new projects</td>
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</tbody>
</table>

As displayed in Table 8, three common themes were detected among the three sets of interviews. They are: the perception of an educational makerspace, the challenges of a Makerspace in a school setting and the reasons behind the lack of Makerspaces in the lower elementary level. This is the case, because that was the purpose of the interviews and the focus of the third research question for this study. The third research question is: “How do administrators and teachers perceive extending the model of makerspaces to the lower elementary level? What challenges do they foresee?”
New themes arose from the interviews, which will be discussed at a later stage in the paper. First, a comparison of how the three groups viewed makerspaces and the possible drawbacks they envisioned will be shared.

4.4.1.1 Perception of educational Makerspaces

The color red was selected to highlight the answers about the interviewees’ perception of educational makerspaces.

None of the preschool teachers interviewed knew what a makerspace was, but somehow made a connection that a smaller representation of it was present in their classroom. In the preschool classes, the Makerspace is present in the form of centers used for “free play” or to target a certain skill or concept. The preschool teachers recognized that the centers in their classes, which are changed according to the units of inquiry, allow students to be creative by making and producing different products. This making opportunity is presented to the students every day and the students initiate the products they want to create.

The Lower Elementary teachers do not have any formal experience with makerspaces; therefore, they have little knowledge about its form and function. Technology, creativity, transdisciplinarity, learning space, real life learning and construction are ideas that came to the elementary teachers’ mind after hearing the word makerspace. They do not implement maker-centered unit in their classroom, per se, but they did agree that they should. They try to incorporate projects in which students need to create a product, but they do not follow a certain process. This indicates that the elementary teachers are aware of some aspects of a makerspace.
Out of three administrators only two were interviewed. During the phase of data collection, it was impossible to find a suitable time to meet with the director. The questions were emailed to her to fill out and alas; the interview could not take place. Therefore, only the IB-PYP coordinator and the director’s assistant were interviewed.

When the administrators were asked about their perception and the cost effectiveness of makerspaces they had different responses. One of them replied “No idea what it is!” while the other had a lot to say. The latter’s response was: “I would say a makerspace is cost effective and it does not really need high tech tools. Legos, cardboards and other supplies will do, and in case the school decides to have high tech tools, it would definitely push students’ creativity and would help students take charge of their own learning”. Both administrators do not have any previous experience in a makerspace.

In brief, the term Makerspace was somewhat new to the teachers and administrators. The preschool teachers were not aware that part of their classes were maker-centered, while the elementary teacher were very interested in the concept. They all agree that it is important to incorporate it into their classes. As for the assistant to the director, she insisted that a Makerspace would empower the students. Hence, all the interviewees have a positive perspective about Makerspaces.

4.4.1.2 Reasons behind the lack of Makerspaces in Lower Elementary

The three groups of interviewees were asked about the disappearance of Makerspaces at the lower elementary level. This theme was highlighted with the color green.
When the preschool teachers were asked about the reason behind the lack of maker-centered classes at the lower elementary school, they unanimously identified that allocation of space is one major drawback as well as the heavy curriculum.

The lower elementary teachers were also interrogated about the lack of maker-centered classes at their level. They suppose that the disciplines taught at this level do not allow for makerspaces and that there are primary objectives that come first. Money or funding could be another obstacle. Teacher training and classroom size are hindrances too. The room size is not appropriate, “the students get bigger and they have more belongings at this level, and we barely have space to put the current resources”. To integrate makerspaces at the lower elementary level, the curriculum must be revisited and teacher training is a necessity.

The director’s assistant claimed that there is a plan to include a makerspace at the elementary level. However, she advised that grade 3, 4 and 5 students (upper elementary) should have access to it. She also remarked two distinct reasons behind the lack of maker-centered classroom at the elementary school level: “clear learning objectives and space”. The IB-PYP coordinator is not aware of any plans to include a makerspace in the school and had no comments on the reasons for the lack of maker-centered classrooms at the elementary level.

In a nutshell, all interviewees agreed that the heavy curriculum and space are the foremost reasons behind the lack of Makerspaces at the lower elementary school.

4.4.1.3 Challenges of a makerspace

The theme of challenges was highlighted in light blue and was recurrent in the three sets of interviews.
Maker-centered classrooms do not come without challenges. The preschool teachers expressed that they do face challenges in their makerspaces. Sometimes, depending on the child’s age, guidance is necessary for them to produce an outcome. Other challenges they mentioned are funding and documentation. If the school does not have a budget for the resources, then the makerspace will be limited and not as beneficial to the students. For the assessment of the students to be authentic, the documentation should be continuous to show the learning journey of the learner. Therefore, the number of learners in class must be questioned as well as teacher professional development.

The lower elementary teachers predicted that there could be many drawbacks to setting up a makerspace in a school. First, the schedule must be flexible and allow the students to access the makerspace. Second, teachers must be encouraged and motivated to use the space. A teacher declared: “I would need to work on myself and need professional development to be able to set up a makerspace in my classroom”. Another lower elementary teachers affirmed that permanent technical support and teacher support are an obligation to ensure the sustainability of the makerspace. Lastly, convincing some of the parents that makerspaces can benefit their children’s learning could be another challenge.

Both administrators foresee teacher training and curriculum alignment as major challenges to setting up an educational makerspace at school. To get the faculty and staff on board the school must provide the appropriate professional development to those concerned. Linking an educational makerspace to the school curriculum could be a risk because “if left to each teacher’s whim, it could just become an add-on”. They both agree that for any program to succeed the school must provide the appropriate support.
In conclusion, the three groups of interviewees gave similar answers to the three recurrent themes that ran in the interviews. This showed that teachers and administrators who work at the same school have the same mindset and goals for the school. It is interesting to note that although each person expressed their answer in a different manner, in the end their answers revealed the same thing. They all had a vague idea of what Makerspaces are, but could express possible drawbacks for the space. The curriculum is a factor they all mentioned when asked about the lack of maker-centered classroom at the lower elementary level. The learning that happens in Makerspaces must be authentic to guarantee transfer of knowledge to the real world.

4.4.1.4 Benefits of Makerspaces

The preschool and lower elementary teacher were questioned about the benefits of Makerspaces and their opinion of the best educational approach. Those themes were addressed in the preschool and lower elementary teachers’ interviews.

Only the teachers were asked about the benefits of an educational makerspace. Those answers were highlighted in dark blue. This is what they had to say.

The preschool teachers all agreed that a makerspace helps support the students’ learning, especially when the space supports the learning that is taking place in class. For example, if the students are learning about the change in materials, then a corner in the classroom is reserved just for this concept. They also agreed that makerspaces shape the learners to become better inquirers, problem solvers and permit them to become more creative when producing their own product.

“Definitely help!” the lower elementary teachers had a positive response to whether makerspaces support students’ learning. “It brings out their creativity, and
prepares them for the real deal”. Another teacher added that makerspaces: “will give children the chance to make mistakes in a non-judgmental environment and eventually become proud of themselves and boost their self-esteem”. Essentially, a makerspace would be an added value to the learning of the children.

According to the lower elementary teachers, a school Makerspace can “target multiple intelligences and allow for a creativity outburst”. A second teacher believed that makerspaces would develop the students’ 21st century skills and open new horizons and opportunities for their future. The three agreed and insisted that makerspaces will increase the students’ problem solving skills therefore; they will be able to solve real life problems.

Although it was earlier mentioned that there are challenges in implementing a makerspace at any level in a school, all the teacher assert that a Makerspace has benefits. Those benefits range from the individual to the community. Meaning that when a student is exposed to challenges or problem solving activities, that helps him or her develop their self-confidence and then spread it to the rest of the community.

4.4.1.5 Best educational approaches

The best educational approach, in the opinion of the preschool teachers, varied upon the age group of students the preschool teacher teaches. One teacher stressed that the best approach is “learning through play”, since this is what preschool students do best at that age and she added that “students also learn best by observing and imitating others”. Another teacher described the students as “explorers”. She explained that she prefers a hands-on approach where the learners explore and manipulate their learning environment and can “learn in their own style”. The third teacher asserted that a
problem-based approach is the best because it enhances the students’ thinking skills and the teacher “acts to facilitate the learning rather than to provide knowledge”. In conclusion, each preschool teacher described an approach where the students are in control of their learning and use their environment to learn. To them, the teacher is another learner in the classroom.

The lower elementary educators have a common opinion about the best educational approaches for students to learn, however each teacher used different terms to describe the approach. A teacher strongly believed in constructivism while the others cited the inquiry approach to be the best. When explaining the reason why they chose that approach, they gave similar clarifications: “because it allows students to have ownership of their learning by valuing the process of learning and it also allows creativity and problem solving. It is centered on students’ needs and interests. Principally, the teachers identified a student-centered approach as the best teaching practice.

In brief, both group of teachers agreed that the best educational approach is student centered, based on authentic issues and enhances the students’ thinking skills.

4.4.1.6 Other themes that appeared in the interviews

This wraps up the themes that are common amongst the sets of questions. The following themes sprung out from the lower elementary teachers’ interview and the administrators.

There are themes that did not recur in the three sets of interview questions. They surfaced in the lower elementary teachers’ interview and the administrators’ interview. Those themes were not highlighted with a specific color.

A few questions were added to the lower elementary teachers’ interview that
focused on whether they would accept to make their classroom more maker-centered and how would they begin. Their replies varied. If the lower elementary teachers were given a choice to set up a makerspace in their classroom, two teachers responded positively and were up for the challenge while the other answered: “Currently no, because of space. I would if there’s room for it. I’d be very excited to actually be able to implement it”. To begin their classroom makerspace two teachers chose tools that they were most comfortable with: a 3D printer and reusable materials. The third insisted that she should begin by researching about makerspaces and how they are run in a classroom.

A bulk of the questions compiled for the administrators were to study the decision making process at the school. According to both of the administrators interviewed, the implementation of new projects or proposals must be run and approved by the director. The decision is consequently based on the school’s curriculum requirements, the need to prepare the students for the 21st century and the school’s budget. In general, the projects proposed are not rejected since the students will always benefit. “This procedure is set in place because the school needs to know why certain tools and materials are ordered”. The director is always the reference point and the decision maker.

4.4.2 Summary of the findings of the interviews

In a nutshell, the three groups that were interviewed perceived a Makerspace as a positive asset to a school. The interviewees highlighted many benefits that this space presents to its users, such as empowering students by targeting their areas of interest and developing their self-confidence. Yet, with all the positive aspects, the concept of a Makerspace is only restricted to the preschool classes in the school of study. Many reasons were provided to identify the disappearance of Makerspaces in the lower
elementary level. The heavy curriculum and professional development training were the most common reasons the three groups provided for the disappearance of the Makerspace at the lower elementary level. However, those reasons could be overcome if an appropriate plan is designed.

4.5 Global summary of the findings

The findings of this study revealed the importance of integrating maker-centered classrooms at the lower levels in schools. The observations done in the KG1 classroom revealed that it is not fit to be labeled as a maker-centered classroom. A few important aspects need to be included to improve its status. For example, a makerspace must have an element of challenge, design thinking, and testing. The tasks cannot be too “free” without setting goals and without any guidance. The motivation level of the students must be increased and group challenges should be assigned to the learners to complete and share their learning in the end.

The maker-centered instructional unit implemented in grade 2 did indeed help students become better problem solvers. After being exposed to three maker-centered tasks, the students’ thinking skills improved just by working with their hands and by collaborating with classmates. The teachers and administrators voiced a positive attitude towards Makerspaces. However, without the proper tools, teacher professional training and curriculum a makerspace will end up as an extra science lab in the school, only used a few times a year.
Chapter Five

Discussion

5.1 Introduction

The study aimed to answer four research questions that were part of a case study. The study took place in one school but at two different grade levels. The first two research questions are about the form and function of a maker-centered space in a KG1 classroom and how the space contributes to children’s learning. The next question focused on how the administrators and teachers, of the same school, perceive the addition of a makerspace at the lower elementary level and the possible challenges they predict. The fourth question aimed at studying the impact of a maker-centered instructional unit would have on the learning of grade-2 students.

This exploratory study was two fold. First, a part of the research was based on observations done in a KG1 maker-centered classroom that aided in the development of a maker-centered instructional unit for grade-2 students. This instructional unit was implemented to study the effect that maker-centered activities have on the enhancement of the problem solving skills of 8-year-old students. Next, interviews were conducted to answer the third research question. The purpose of the interviews was to determine the perceptions that teachers and administrators have of educational Makerspaces and to identify, according to them, the benefits and challenges of educational Makerspaces and how they could be overcome.

The four research questions posed at the beginning of the research will be answered according to the study conducted. Questions one and two were based on the
observations done in the KG1 classroom. The next question’s answer was discovered in the implementation of a maker-centered instructional unit in a Grade-2 classroom. The last question was answered after the teachers and administrators were interviewed.

5.2 What are the main features and components of the makerspace in the studied KG1 classroom?

It was realized by studying the data collected with the physical environment checklist (appendix C) that several features and components of a Makerspace were not present in the maker-centered classroom. This includes digital tools and a little guidance provided by the teacher during the morning “free play” time. In the classroom, the children appeared as if they wanted to use everything in sight. The room is large enough for the children to circulate with their projects and with no danger. They are allowed to create whatever they desire with the available tools and materials. The materials are available on open shelves within children’s reach and the children know where to return the materials once they have finished using them.

There are a wide variety of tools and materials in the classroom. The tools that were perceived were mainly of one category, offline and non-digital. Children have access to arts and craft materials; play dough, plastic cooking utensils, puzzles, and books, building blocks made of foam and wood, and reusable materials. Electronic devices are available in the room, but set away from the children. The devices are given to them only when a specialist is present in the class to supervise the children.

On another note, it was noticed, by using the observation checklist for the role of the teacher and student (Appendix B) that the facilitators were not involved in the
creation of the children’s projects. The children worked independently in the “centers” and sometimes turned to their classmates for support. The children are the makers, they are the elements that contribute the most in a Makerspace, however without the proper guidance they may end up making a product that is meaningful to them, but may not have any value in real life. It is always important to look at things through the eyes of the children and not be too quick to judge. They must be given a chance to assess themselves and the product they create.

5.3 How does the makerspace contribute to the learning in the KG1 classroom?

Two checklists were created to study how a Makerspace contributes to the children’s learning. A checklist (Appendix A) examined the conduct of the children in a Makerspace and the other (Appendix B) focused on the role of the children and teachers in a Makerspace. At first, it was obvious that the children and the teacher were busy doing something until the observer took a deeper look at what they were doing, how they were doing it and why they were doing it. After four weeks and eight half-hour observation sessions, it was concluded that the KG1 classroom had a few aspects of a Makerspace but was missing important traits. A very important aspects in a makerspace are planning and modification on the part of the students. Those aspects were non-existent during the observation period. Hence, the KG1 classroom was not a maker-centered classroom and was contributing little to the learning in the KG1 classroom. Meaning that children gained little knowledge from the morning “center time” which they could transfer to other learning opportunities.
The observation checklist of the students’ behavior in a Makerspace (Appendix A) exposed results that were surprising. The children’s actions were studied against Papert’s eight big ideas of constructionism, only seven of which were observed. The criteria Learn by doing (C1) and Hard fun (C3) had the highest scores. This indicates that learning was happening in the class and the children were having fun while learning. However, those are only two criteria out of seven. The five remaining criteria exposed that the tools and materials the students were using were not the proper materials needed to make interesting and meaningful products. As well, the teacher or facilitator did not provide the stimulating modeling about Learning to learn (C4) nor did they support the children’s learning by asking questions or guiding them on the path to success. Making a plan and managing time are two aspects of Taking time (C5), with which the children needed the most guidance. The children were seen giving up at the slightest sign of struggle. It was obvious that the children were not aware that one way to learn is through making mistakes.

As for the last criterion Digital world (C8) of Papert’s eight big ideas of constructionism, the children were only exposed to it through coding, which was on the agenda of the school. Otherwise, the children have never been in contact with a digital device, which is the language of the future and children must be exposed to this new literacy.

The role of the teacher and the children was studied to identify how they have an effect on the learning in the Makerspace. Using another checklist called Observation checklist of the role of the students and teachers (Appendix B), we were able to answer the second research question from another perspective. Through this instrument, it was
clear that the teacher was always present in the room, but not using her time effectively. She was busy helping children finished incomplete work or making sure that the students have unpacked their bags and placed their belongings in the right place. The children were taking ownership of their learning and being active and natural collaborators, but were not asking questions, researching or becoming experts at a certain skill. For the latter to happen, the teacher has to take on the role of a mentor and show the children that they, themselves, are learners too. Throughout the observation session, the teacher was busy with children who needed to complete unfinished work.

5.4 How do administrators and teachers perceive extending the model of makerspaces to the lower elementary level? What challenges do they foresee?

The interviews with the teachers and administrators exposed the little knowledge they had about Makerspaces, but at the same time, their excitement to learn more about them. Many of them admitted that they researched about Makerspaces before coming to the interview.

In terms of teacher perceptions of educational Makerspaces, it was apparent from the teachers’ answers that they supported the idea. However, they needed guidance about ways to run it in their classes since none of them had any prior experience in a Makerspace. The preschool teachers ran a maker-centered classroom but with no pre-set goal, which defeats the purpose of a Makerspace. When asked to give three words about the makerspace, the teachers could only refer to the tools and characteristics of the space.
None of them mentioned the way learning would happen, or the skills that the students would develop in such a space, because they are not aware of them.

Heavy curriculum and lack of space allocation were recurrent reasons for the lack of Makerspaces in the Lower Elementary classes. The teachers and the administrators agreed that the students at this age needed to focus on reading, writing and arithmetic skills in order to succeed in the rest of their schooling. However, we are unaware of what the future holds, the interviewees are disregarding the 21st century skills altogether.

In general, all the interviewees agreed that teacher professional development workshops and assistance are a must in order to implement a Makerspace in the lower elementary. By assistance, they stressed on the need of a co-teacher that is familiar with the tools available. Another common response that the preschool teachers voiced was the importance of recording the progress of each student, i.e. documentation of the learning. At the lower elementary level, the students begin to read and write, so there is less stress on the teacher to record everything. The students can take on part of the responsibility by documenting their learning in their journal by writing and drawing. Nowadays, with the use of iPads in the classroom the documentation process has become less of a burden. The sessions could be recorded and the teacher can view them later to check if she has missed anything important. Also, at the end of each day, the students could record a video reflection on the iPad which would aid the teacher to keep track of the students’ growth and any misunderstanding they could have developed.

The administrators looked at the challenges from a wider lens. They did agree with the teachers that training would be a priority, but they also believed that curriculum
alignment is also a must. The best learning happens when the content is authentic, so integrating these maker projects into the curriculum in a meaningful manner would be most beneficial for the students. However, curriculum alignment is a continuous job and must be reviewed, regularly taking into consideration the teachers’ feedback.

5.5 What impact does a maker-based instructional unit have on the learning of grade-2 students and what are the challenges actually faced?

Overall, the administration of the maker-centered instructional unit was a success since the students showed improvement in the phases of the engineering cycle by the end of the unit. The maker-centered instructional unit revealed that, with the proper support and guidance, students could make a product with a purpose. However, the results would have been more authentic, had the unit been student-centered and interest driven, in the sense that a student or group of students could have chosen a problem of interest and come up with a workable solution to share with the class.

The research question related to the maker-centered instructional unit had two parts. The purpose of the unit was to study the impact of a maker-centered instructional unit on the students’ learning and to detect the possible challenges that would arise during implementation. By looking at the results, it was shown that the instructional unit had a positive impact on the learning of the students since the students’ scores for each phase of the engineering cycle improved over the duration of the implementation of the unit.

An evaluation rubric was developed to study the six engineering phases. The results disclosed that by scaffolding the students and by exposing them to the engineering cycle, they learn to think about their thinking and come up with meaningful solutions.
The explicit phases of the engineering cycle helped the students organize their ideas to come up with a logical solution.

Challenges of a Makerspace are inevitable as was discovered when administering the instructional unit. First, the second-grade teacher had little prior knowledge or experience in a makerspace. Therefore, the couple of hours of training that were provided by the researcher were not sufficient. More training time and practice would have led to better results. Second, the class schedule is fixed and sometimes it was hard to find a one-hour block of time to continue with the instructional unit. A third challenge was that the teacher had to be alert all the time, she had to be aware of each student or group’s struggles and give them the appropriate support to help them come up with a solution to their problem.

Another challenge was that, although the students were learning, they were confused about the way to use this newly gained knowledge. They were never put in a similar situation before this unit was implemented in their classroom. The students were not able to relate the learning they got from the unit to what was going on in class. This indicates the importance of developing authentic integrated making activities into the curricular content. Lastly, there was no space in the classroom to display the students’ projects.

5.6 Connection to the literature and to the theoretical framework

5.6.1 Connection to the literature

In the observations, the KG1 teacher or facilitator was not devoted to the Makerspace, which had an effect on the products that the students were making. Kurti,
Kurti and Fleming (2014c) stated that the spacemaker does not have to be an expert, but must have leadership qualities and be in charge of the Makerspace. Therefore a teacher who runs a maker-centered classroom must be aware of all the projects being built in the space to support the making process or even guide the students to the correct resources to locate the answers they are looking for.

As mentioned by Kurti, Kurti, and Fleming (2014a), a maker-centered classroom must offer students the opportunity to use the learning environment to develop new knowledge or skills through inquiry with enthusiasm. A learning environment must instigate the students’ curiosity and make them want to discover. Other researchers such as Dougherty (2012), Papert (1991) and Stager (2005) also support this fact about Makerspaces.

In this study, it was discovered from the observations that the students were using the tools without a purpose or a goal. This is the opposite of what a Makerspace is. Just like in Papert’s CLL project in 1999, the students must be involved in long-term projects based on their interest and the project must be meaningful to the students. In a Makerspace, the students cannot be “free” to play around with the tools and produce meaningless products. The products must have a purpose; they must be planned, tested and of course modified. The projects can be completed within a few days or may take months to finish.

The results of the maker-centered instructional unit supports what Waters and Kessler (2015) reported in their study. When students are engaged in their learning and have ownership of it, they will be motivated to explore more possibilities. This visible
change in the students’ skills and attitude directly relates to Hatch’s (2013) Maker Movement Manifesto. The students exhibited all of the nine traits of the manifesto during the maker-centered instructional unit that they were subjected to.

In their study Hira et. al. (2014), discovered four major challenges to deploying a Makerspace in the school setting. They are: standardized testing, teacher training, management of technology, and representation of diversity. The interviews conducted with the teachers and administrators further supported the four challenges. Standardized testing is referred to as “official exams” in Lebanon. Those exams are a burden since they limit the approach to learning to rote memorization. Teacher training is another area of weakness that must be a priority in Lebanon to lift our education system into the 21st century. Technology in schools can be a financial burden, so mainly private schools have the up-to-date technology, but are the tools being used to benefit the students’ learning? In Lebanon, the issue of gender is still a concern. Girls still tend to shy away from STEM based subjects and are encouraged to go in another direction.

5.6.2 Connection to the theoretical framework

This study was based on the constructionist learning theory. It is a theory of learning and design coined by Seymour Papert about fifty years ago. The basis of this theory is problem solving, but the students are always encouraged to go a step further by questioning their thinking. As they solve problems, students make sense of their learning. They learn by inquiring about their learning, asking questions, finding solutions, collaborating, reflecting and criticizing ideas.
This theoretical framework supports the study, especially when the maker-centered instructional unit was implemented. The unit showed the theory in action. The learners were given a chance to work together, question what they were doing and make modifications to reach a certain goal. They needed to think of what they were doing and to improve the product. This theory proved to enhance students’ thinking skills and make them better problem solvers, if properly implemented. The enhancement was measured by using the evaluation rubric (Appendix G). Over the course of two weeks, the students had experienced the engineering cycle three times through three distinct activities. Hence, they were evaluated at the end of each task. By the third evaluation, the scores that the students received for each skill systematically increased. This uncovers that the more students are exposed to such challenges and the engineering cycle the better it will positively affect their cognitive growth.

5.7 Implications and recommendations for teaching and learning

It is important to note that all of the activities conducted, in this study, were never assessed for grading or ranking. This instructional unit was a fun activity done by the students, and to them the unit was not school related. It is possible that this fact is what motivated the students to complete the work with a high level of enthusiasm and learn in the process. In addition, those students did not feel judged, even when they were presenting their final product to the class. On the contrary, the collaborative environment allowed them to listen to each other and to modify their products according to their classmates’ feedback.

In addition to being a mentor or support agent, the spacemaker or facilitator must take the time to create learning opportunities for the students. For example: the teacher
could leave out some new tools on a table and ask the students to explore them and make something they would use every day. Another idea could be for the teacher to setup an experiment that is not complete and ask the students to finish it up and write up a report about the experience. A broken toy could be left in a corner of the room to strike a student’s attention and maybe that student could be committed to putting it back together or use its parts in another project he or she was building. Definitely, this takes a lot of planning on the part of the teacher, but this is how the students’ thinking and problem solving skills will develop.

Studying the benefits and drawbacks of Makerspaces at the lower elementary level is not enough; the sustainability of Makerspaces should also be studied. Teachers should be held accountable for developing maker-centered units but only if they have the proper support. Support can come in different forms, such as support from a co-teacher, someone who is an expert in a specific discipline. Alternatively, teachers could take part in externship programs. In externship programs, the teachers are connected to certain industries to enable them to learn a specific skill that could be brought back into the space and shared with the students. The program would be part of the professional development plans offered by the school where the teacher works. School administrators, teachers and students must all be held accountable for the success of an educational Makerspace.

Teaching outside the physical classroom also supports the sustainability of a Makerspace in the sense that the teaching must be connected to real life. Students and teachers should visit the source of the problem that they are studying to make more sense of the problem. The students must be engaged and committed to their project and
learning. For instance, students could be chosen to take part in a capstone project where disciplines are integrated and students deal with solving real world problems.

The study contributed to the current literature by supporting the importance of exposing students to the engineering cycle at a young age. In summary, design thinking or the engineering cycle must be part of the curriculum. The students could be exposed to one or more projects per month. However, the project must be related to the student’s real life and connect to their interests in some way. These projects would make more sense to the students if they give them a glimpse or target their future way of living. For example, the projects could include self-driving cars, managing rovers on mars or even sustainable energy, which will become more apparent in the coming years. These ideas could be introduced in coding activities or simulations.

Schools in Lebanon could collaborate with outside-of-school Makerspaces and organize local Maker Faires. These Faires could open up many opportunities, not only at the student level, but also at the school or even the national level. The goal of these projects is to solve a problem that people face every day, so why not take advantage of the young generation’s creativity and allow them to spread it all over the country? Lamba Labs – Beirut Hackerspace have recently announced on their Facebook page that the first ever Beirut Mini Faire will be help on February 16\textsuperscript{th}, 2019. This Faire is a collaborative initiative with Make: Magazine.

Another recommendation for teaching and learning is Genius makerspace. It is a combination of genius hour and a makerspace (Cheska, 2018). Genius hour is an hour during the week, set aside for students to choose to work independently on a project of
interest. The Makerspace idea ties in well with genius hour. It is a room where students are given the opportunity to explore their interests and use tools to develop creative projects. For a student to create a product, he or she must be motivated and committed to their project. The best way to motivate the students is by providing them access to a space that offers them limitless opportunities to “tinker and invent, they face challenges that encourage critical thinking and problem solving” (Cheska, 2018).

The purpose of a genius makerspace is not only for students to make a product, but to empower them by allowing them to share their ideas with the community. In her article, *A short guide to Genius Hour makerspaces*, Cheska (2018) provides tips on how to empower students. Cheska (2018) stresses on the importance for the students to be aware of what they are doing and the impact that the project will have on them over a period of time. In addition, students must be given ownership of their project by allowing them to plan and design the process. In addition, the teacher can give some students the job of being a mentor. Lastly, showing off the students’ work is the most rewarding part of the process. This makes the students more confident and proud of their work.

### 5.8 Limitations

Limitations in any study are unavoidable. In this study, one limitation is the small sample size and the sample being limited to one single school in Lebanon, which does not allow for the generalizability of the results to other schools. The sampling is only limited to two age groups of students, which also cannot allow the generalization of the results to students from other class. Other preschool classrooms should be observed to compare how the maker-centers are run in different classrooms.
Another limitation of this study is that five days are not enough to notice a change in the students’ problem solving skills. The maker-centered activity could be considered as a pilot and built upon in a future study. A solution for this could be to give the students a second chance, a couple of days after the end of the unit to review their products again and to make final modifications to their product. By giving them a second opportunity, the teacher would be better able to detect improvement in students’ problem solving skills and if their ability to transfer the new knowledge they gained from observing and listening to other students’ projects.

The homeroom teacher who implemented the maker-centered unit was not a maker; hence, she does not have the maker mindset. The teacher had minimal any prior experience in a Makerspace, she was not aware of how to deal with some problems that arose, on the spot, during the instructional unit and many times, she felt confused. Consequently, it is important that whoever is in charge of a Makerspace have the appropriate STEM training or exposure to facilitate a unit properly along with the needed mindset. So in this case, time was another factor that impacted the students’ outcome and process of thinking.

Not being able to interview the director was another limitation that hindered the results of this study. She had valuable information that would have affected the results of the study. The director is responsible for taking budgetary decisions, and implementing changes in the school’s structure and teaching approach. She also needs to ensure academic success by seeking out the best programs and to support the teachers with the best professional development available to improve instruction. Her input would have impacted the results of the interviews at the administrative level since she is aware of all
the major decision that are taken at the lower elementary level. As well, she is responsible for the welfare and success of the students and the teachers’ professional development. In addition, the director is accountable for preparing the budget needed for educational materials for the following school year.

The director, based on the interview questions, could have provided information about the process of decision making at the school. Her perspective on implementing a makerspace at the lower elementary level could have hinted on whether this was a plan for the school. The director would have also shared the challenges she foresees and how she would get her lower elementary teachers prepared to adopt a maker-centered classroom.

5.9 Suggestions for further research

The concept of a maker-centered classroom is new; therefore little research is published about it. This means that there are few reliable sources for instrumentation. Since there is not much research and literature about the implementation of maker-centered classrooms at the lower elementary level, more research about it and with different schools in mind as targets should be part of further explorations.

The question as to why a makerspace reenters the children’s lives in the middle school should be addressed. What are the factors that encourage administrators to make such decisions? A curriculum study could be performed to identify at which points a Makerspace could aid students’ learning.

A Makerspace allows students to develop different skills. Thus, units could be prepared to observe the development of students’ critical thinking, logical reasoning and
other 21st century skills. Visiting other schools’ Makerspaces or out-of-school Makerspaces for comparative purposes could aid in identifying benefits and learning how to overcome drawbacks. Consequently, a larger sample of participants could be reached. No one knows what the future will hold for the next generation of students. The teachers are currently preparing students for the hidden future.

The outcome of the study concurred with the findings that were shared in the literature review and identified that it is necessary to nurture the maker mindset, at an early age, by giving students choice, diversity and a safe learning environment. However, Makerspaces come with challenges as educators are preparing students for the unknown. Therefore, it is best to equip them with a sense of self, a sense of belonging and empower them with the gift to solve problems.
References


Appendix A: Observation checklist of children’s behavior in a Makerspace

Checklist for student behavior based on Papert’s 8 big ideas of Constructionism

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Indicators</th>
<th>0-10 mns</th>
<th>10-20 mns</th>
<th>20-30 mns</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 Learn by doing</td>
<td>Is learning something the students do naturally and find interesting?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Do the learners interact with the content and knowledge directly?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Do the learners find what they are doing interesting?</td>
<td></td>
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<tr>
<td></td>
<td>Are the learners curious and investigating the material that is available to</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>them?</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Do the learners use the tools to come up with new ideas or creations?</td>
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<tr>
<td></td>
<td>Do the learners follow by example (social learning)?</td>
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<tr>
<td></td>
<td>Do the learners use what they learn to make what they want?</td>
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<tr>
<td></td>
<td>Are the learners creating or constructing their own knowledge?</td>
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<tr>
<td></td>
<td>Do the learners have a pre-conceived idea of how their work will turn out?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2 Technology as building material</td>
<td>How the learners use the tools as building material?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Are the learners aware of the function of the tools?</td>
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<tr>
<td></td>
<td>Are the learners encouraged to use the tools?</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Do the learners create their own tools from what is available?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3 Hard fun</td>
<td>Do the learners enjoy what they are doing?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Are the learners focused and determined?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Is what they are making challenging fun or passive play?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Are the learners investigating, exploring or experimenting?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Do the learners show a positive attitude?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Are the learners interacting with the materials and the environment?</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Are the learners motivated and willing to apply the necessary effort to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>achieve the goal?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>Learning to learn</td>
<td>Are the learners taking charge of their own learning?</td>
<td>Are the learners free to start any step they need or do they wait for someone to tell them what to do?</td>
<td>Do the learners take ownership of their learning?</td>
</tr>
<tr>
<td>------</td>
<td>-------------------</td>
<td>------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>C5</td>
<td>Taking time</td>
<td>How do the learners manage their time?</td>
<td>Do the learners manage their own time?</td>
<td>Do the learners make a plan?</td>
</tr>
<tr>
<td>C6</td>
<td>You can’t get it right without getting it wrong</td>
<td>Do the learners look at why something went wrong?</td>
<td>Do the learners know who or what they can refer to if they have a problem?</td>
<td>Do the learners know that every time they struggle they are learning in the process?</td>
</tr>
<tr>
<td>C8</td>
<td>Digital world</td>
<td>Do the learners know how to use digital technology?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Appendix B: Observation Checklist for the role of the teachers and learners

<table>
<thead>
<tr>
<th>Attributes</th>
<th>0-10 mns</th>
<th>10-20 mns</th>
<th>20-30 mns</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Learners’ role attributes (LA)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Take ownership of their learning (LA1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ask questions, research and explore (LA2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Become expert at a certain skill (LA3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are active creators (LA4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are Natural collaborators (LA5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Teachers’ role attributes (TA)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are mentors (TA1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can connect students with other experts (TA2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are also learners too (TA3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepare authentic learning engagements (TA4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are always available (TA5)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix C: Observation checklist of the Makerspace learning environment

Checklist for physical environment based on literature

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Space</strong></td>
<td>Description of the physical environment</td>
</tr>
<tr>
<td></td>
<td>It is a place that the learners want to use?</td>
</tr>
<tr>
<td></td>
<td>Is the set-up inviting for learning to take place?</td>
</tr>
<tr>
<td></td>
<td>Does the Makerspace occupy a specific part of the classroom?</td>
</tr>
<tr>
<td></td>
<td>Are tools spread about the whole classroom?</td>
</tr>
<tr>
<td></td>
<td>Are the tools easily accessible to the students?</td>
</tr>
<tr>
<td></td>
<td>Are the tools well organized by categories?</td>
</tr>
<tr>
<td></td>
<td>Are the tools easily accessible to the learners?</td>
</tr>
<tr>
<td><strong>Tools and</strong></td>
<td>Digital and electronic devices</td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td>Cooking utensils</td>
</tr>
<tr>
<td></td>
<td>Arts and crafts</td>
</tr>
<tr>
<td></td>
<td>Building materials</td>
</tr>
<tr>
<td></td>
<td>Reusable materials</td>
</tr>
<tr>
<td></td>
<td>Offline resources</td>
</tr>
<tr>
<td></td>
<td>Sewing tools</td>
</tr>
<tr>
<td></td>
<td>Power tools</td>
</tr>
<tr>
<td></td>
<td>Printers</td>
</tr>
<tr>
<td></td>
<td>Software</td>
</tr>
<tr>
<td></td>
<td>Recording equipment</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td>Safety guidelines are made visible, through images, and explained to the learners by the teacher</td>
</tr>
<tr>
<td></td>
<td>Instructional Handbook is available for the use of materials (for teachers to refer to)</td>
</tr>
<tr>
<td></td>
<td>Children friendly tools</td>
</tr>
</tbody>
</table>

Additional notes:
Appendix D: Diagnostic Assessment

STEM Challenge Design

You have two tasks to complete. The first task is for you to create a paper airplane that will fly the farthest possible. In the second task, you will need to build a tower made out of straw and tape which can withstand three tennis balls. Good Luck!!

<table>
<thead>
<tr>
<th>Define the problems:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) __________________________</td>
</tr>
<tr>
<td>2) __________________________</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Criteria:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Your paper plane must travel for the longest distance possible.</td>
</tr>
<tr>
<td>2. Your straw tower with tape must withstand 3 tennis balls.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Materials &amp; tools:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A4 paper</td>
</tr>
<tr>
<td>2. Straws</td>
</tr>
<tr>
<td>3. Masking tape</td>
</tr>
<tr>
<td>4. Tennis balls</td>
</tr>
</tbody>
</table>

Airplane

Tower

Reflection: (test and modify)

_________________________________________________________________________________________________
_________________________________________________________________________________________________
_________________________________________________________________________________________________
_________________________________________________________________________________________________
_________________________________________________________________________________________________
Appendix E: Maker-centered activity – Unit plan

Title: Little Red Riding Hood – Cookie Catapult Challenge


Grade Level: Grade 2  Subject: STEM  Duration: 5 days

Unit Objectives:
1. Identify a problem
2. Brainstorm solution(s) for the problem
3. Collaborate to design one solution
4. Create the solution using the materials provided
5. Test the product and make necessary modifications
6. Reflect on the process

Essential Questions:
* Can students design a simple solution to a problem and reflect on the specified requirements for success?

* Can the students generate and compare multiple possible solutions to a problem?

* Can students plan and carry out tests to modify their product?

By the end of the activity, the students will understand:
- There may be different solutions to the same problem
- We learn from our mistakes,
- Problem solvers must think outside the box
- Collaborate with the people around you
- Test and modify your product

Materials and Resources:

Cookie (or something to represent a cookie), tape, toothpicks, cardboard, glue, scissors, elastic bands, string, straws, popsicle sticks

Daily plan:

On day one, the teacher will provide a positive atmosphere in the class and introduce the task. She will explain the purpose of the five-day activity. In addition, the teacher will announce the required materials that the students can use to produce the product. In groups, the students will proceed to read and act out the fairy tale “Little Red
Riding Hood”. Then in their making journal, the students will individually define the problem and brainstorm idea(s) for the catapult. The session will end with a group reflection session.

The session on day two will start with a quick recapitulation of the previous day. The students will get back into their groups and share their brainstormed idea(s). This will be the basis of their collaborative design for the catapult. They have the choice of creating a new design together or to combine their ideas. They may come up with several new designs. These designs will be drawn in the making journal. The session will end with a group reflection session.

During the third day of the activity, the students will begin to create the product using the provided materials. As they create their design, they will also test it and make modifications to improve their catapult. In the process, they will have to make a note of the amendments they make to their product in the making journal. The session will end with a group reflection session.

On the fourth day of the activity, each group will be given five minutes to present their catapult and share information they believe is important for the rest of the students to learn. After the presentations, the students will complete the last pages of their making journal, and then the session will end with a group reflection session.

Finally, on day fifth day, the students will fill out a self-assessment checklist to make sure they have gone through all the phases of the activity. The students will also individually assess their actions during the four previous days and write about their favorite part of this challenge. Along with that, the students will orally reflect on:

5. How they felt about collaborating with others
6. How they dealt with the frustration during some of the activity
7. What do they think they learned from the activity
8. What would they change about this activity and why?

Assessment
1. Self assessment checklist
2. Reflection question about their favorite part of the activity
Appendix F: Making Journal
### Appendix G: Instructional unit evaluation rubric

<table>
<thead>
<tr>
<th>Criteria</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defines the problem</td>
<td>Student has an exceptional understanding of the problem and could clearly articulate it.</td>
<td>Student has a good understanding of the problem.</td>
<td>Student has a fair understanding of the problem.</td>
<td>Student is not able to define the problem.</td>
</tr>
<tr>
<td>Brainstorms solutions and picks the best one.</td>
<td>Student uses prior knowledge to brainstorm clear, and excellent ideas focused on the problem.</td>
<td>Student uses prior knowledge to brainstorm clear, and adequate ideas focused on the problem.</td>
<td>Student uses prior knowledge to brainstorm an idea that is minimally focused on the problem.</td>
<td>Student uses prior knowledge to brainstorm an idea that is impractical and not focused on the problem.</td>
</tr>
<tr>
<td>Draws the idea and decides on the needed material</td>
<td>Student proposes and designs a plan that excellently aligns with the criteria.</td>
<td>Student proposes and designs a plan that adequately aligns with the criteria.</td>
<td>Student proposes and designs a plan that minimally aligns with the criteria.</td>
<td>Student proposes and designs a plan that does not align with the criteria.</td>
</tr>
<tr>
<td>Builds the design</td>
<td>Student builds a working model that excellently aligns with the criteria.</td>
<td>Student builds a working model that adequately aligns with the criteria.</td>
<td>Student builds a working model that minimally aligns with the criteria.</td>
<td>Student builds a working model that does not align with the criteria.</td>
</tr>
<tr>
<td>Tests the model</td>
<td>Student accurately tests the working model and its effectiveness to solve the problem.</td>
<td>Student adequately tests the working model and its effectiveness to solve the problem.</td>
<td>Student minimally tests the working model and its effectiveness to solve the problem.</td>
<td>Student does not tests the model and its effectiveness to solve the problem.</td>
</tr>
<tr>
<td>Modifies the model</td>
<td>Student excellently modifies the model.</td>
<td>Student adequately modifies the model.</td>
<td>Student minimally modifies the model.</td>
<td>Student does not modify the model.</td>
</tr>
</tbody>
</table>
Appendix H: Interview questions for preschool teachers

Consent to participate in an Interview
Bringing a Maker-Centered Class into the Lower Elementary School

I would like to invite you to participate in a research project by completing the following interview. I am a student at the Lebanese American University and I am completing this research project as part of my Masters Thesis. The purpose of this interview is to examine how administrators and teachers perceive applying/introducing the model of a Makerspace into the lower elementary level, as well to report any challenges they envision. Your answers will not be released to anyone and your identity will remain anonymous. When the results of the study are reported, you will not be identified by name or by any other information that could infer your identity.

Completing the survey will take 30 minutes of your time.

By continuing with the interview, you agree with the following statements:

1. I have been given sufficient information about this research project.
2. I understand that my answers will not be released to anyone and my identity will remain anonymous. My name will not be written on the interview nor be kept in any other records.
3. When the results of the study are reported, I will not be identified by name or any other information that could be used to infer my identity. Only researchers will have access to view any data collected during this research however data cannot be linked to me.
4. I understand that I may withdraw from this research any time I wish and that I have the right to skip any question I don’t want to answer.
5. I understand that my refusal to participate will not result in any penalty or loss of benefits to which I otherwise am entitled to.
6. I have been informed that the research abides by all commonly acknowledged ethical codes and that the research project has been reviewed and approved by the Institutional Review Board at the Lebanese American University
7. I understand that if I have any additional questions, I can ask the research team listed below.
8. I have read and understood all statements on this form.
9. I voluntarily agree to take part in this research project by completing the following interview.

If you have any questions, you may contact:

<table>
<thead>
<tr>
<th>Name (PI)</th>
<th>Phone number</th>
<th>Email address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Iman Osta</td>
<td>00 961 1 786 456 ext. 1287</td>
<td><a href="mailto:iman.osta@lau.edu.lb">iman.osta@lau.edu.lb</a></td>
</tr>
</tbody>
</table>

If you have any questions about your rights as a participant in this study, or you want to talk to someone outside the research, please contact the:

IRB Office,
Lebanese American University
3rd Floor, Dorm A, Byblos Campus
Tel: 00 961 1 786456 ext. (2546)
irb@lau.edu.lb
1. How many years of teaching experience do you have? Which grade level do you currently teach?
2. In your opinion, what are the best educational approaches for students to learn, and why?
3. If I say to you “Makerspace”, what are the first 3 ideas that come to your mind?
4. What is your perception of educational makerspaces or a maker-centered classroom?
   a. Do you know what a makerspace is?
5. Do you implement maker-centered units to support your students’ learning?
6. Do you have previous experience with Makerspaces?
7. Do you believe that makerspaces can help or hinder students’ learning or thinking? How?
8. What do you think are the reasons behind the lack of maker-centered classes in the elementary school?
9. What challenges do you face in the preschool, in regards to the makerspace?
Appendix I: Interview questions for elementary teachers

Consent to participate in an Interview
Bringing a Maker-Centered Class into the Lower Elementary School

I would like to invite you to participate in a research project by completing the following interview. I am a student at the Lebanese American University and I am completing this research project as part of my Masters Thesis. The purpose of this interview is to examine how administrators and teachers perceive applying/introducing the model of a Makerspace into the lower elementary level, as well to report any challenges they envision. Your answers will not be released to anyone and your identity will remain anonymous. When the results of the study are reported, you will not be identified by name or by any other information that could infer your identity.

Completing the survey will take 30 minutes of your time.

By continuing with the interview, you agree with the following statements:

10. I have been given sufficient information about this research project.
11. I understand that my answers will not be released to anyone and my identity will remain anonymous. My name will not be written on the interview nor be kept in any other records.
12. When the results of the study are reported, I will not be identified by name or any other information that could be used to infer my identity. Only researchers will have access to view any data collected during this research however data cannot be linked to me.
13. I understand that I may withdraw from this research any time I wish and that I have the right to skip any question I don’t want to answer.
14. I understand that my refusal to participate will not result in any penalty or loss of benefits to which I otherwise am entitled to.
15. I have been informed that the research abides by all commonly acknowledged ethical codes and that the research project has been reviewed and approved by the Institutional Review Board at the Lebanese American University
16. I understand that if I have any additional questions, I can ask the research team listed below.
17. I have read and understood all statements on this form.
18. I voluntarily agree to take part in this research project by completing the following interview.

If you have any questions, you may contact:

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<td><a href="mailto:iman.osta@lau.edu.lb">iman.osta@lau.edu.lb</a></td>
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</table>

If you have any questions about your rights as a participant in this study, or you want to talk to someone outside the research, please contact the:

IRB Office,
Lebanese American University
3rd Floor, Dorm A, Byblos Campus
Tel: 00 961 1 786456 ext. (2546)
irb@lau.edu.lb
1. How many years of teaching experience do you have? Which grade level do you currently teach?
2. In your opinion, what are the best educational approaches for students to learn, and why?
3. If I say to you “Makerspace”, what are the first 3 ideas that come to your mind?
4. What is your perception of educational makerspaces or a maker-centered classroom?
   a. Do you know what a makerspace is?
5. Do you implement maker-centered units to support your students’ learning?
6. Do you have previous experience with Makerspaces?
7. Do you believe that makerspaces can help or hinder students’ learning or thinking? How?
8. What do you think are the reasons behind the lack of maker-centered classes in the elementary school?
9. What challenges do you foresee if an educational makerspace was set up at your school?
10. What benefits do you foresee if an educational makerspace was set up at your school?
11. If you were given the choice to set up a makerspace in you classroom would you take it? What would your reaction be and why?
12. If you agree to start a makerspace in your classroom, how would you begin?
Appendix J: Interview questions for administrators

Consent to participate in an Interview
Bringing a Maker-Centered Class into the Lower Elementary School

I would like to invite you to participate in a research project by completing the following interview. I am a student at the Lebanese American University and I am completing this research project as part of my Masters Thesis. The purpose of this interview is to examine how administrators and teachers perceive applying/introducing the model of a Makerspace into the lower elementary level, as well to report any challenges they envision. Your answers will not be released to anyone and your identity will remain anonymous. When the results of the study are reported, you will not be identified by name or by any other information that could infer your identity.

Completing the survey will take 30 minutes of your time.

By continuing with the interview, you agree with the following statements:

19. I have been given sufficient information about this research project.
20. I understand that my answers will not be released to anyone and my identity will remain anonymous. My name will not be written on the interview nor be kept in any other records.
21. When the results of the study are reported, I will not be identified by name or any other information that could be used to infer my identity. Only researchers will have access to view any data collected during this research however data cannot be linked to me.
22. I understand that I may withdraw from this research any time I wish and that I have the right to skip any question I don’t want to answer.
23. I understand that my refusal to participate will not result in any penalty or loss of benefits to which I otherwise am entitled to.
24. I have been informed that the research abides by all commonly acknowledged ethical codes and that the research project has been reviewed and approved by the Institutional Review Board at the Lebanese American University
25. I understand that if I have any additional questions, I can ask the research team listed below.
26. I have read and understood all statements on this form.
27. I voluntarily agree to take part in this research project by completing the following interview.

If you have any questions, you may contact:

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<tr>
<th>Name (PI)</th>
<th>Phone number</th>
<th>Email address</th>
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<tbody>
<tr>
<td>Dr. Iman Osta</td>
<td>00 961 1 786 456 ext. 1287</td>
<td><a href="mailto:iman.osta@lau.edu.lb">iman.osta@lau.edu.lb</a></td>
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If you have any questions about your rights as a participant in this study, or you want to talk to someone outside the research, please contact the:

IRB Office,
Lebanese American University
3rd Floor, Dorm A, Byblos Campus
Tel: 00 961 1 786456 ext. (2546)
irb@lau.edu.lb
1. How many teaching years of experience do you have?
2. For how long have you been in this administrative position? What is your role and what are your responsibilities?
3. If I say to you “Makerspace”, what are the first 3 ideas that come to your mind?
4. What is your perception of educational makerspaces or a maker-centered classroom?
   a. Is it cost effective? Why or why not?
   b. Do you believe makerspaces would better allow students and teachers to achieve the learning objectives? In what ways?
5. How does the school decide on the implementation of new projects or proposals? What is the basis for that decision? What are the policies?
6. Do you have previous experience with Makerspaces?
7. Are the teachers allowed to run a maker-centered classroom without the consent of the administration? What if they need to order tools and materials?
8. Is there a plan to include a Makerspace at the elementary level?
9. Do you advise having a makerspace at the elementary level? If so, at which grade levels?
10. What do you think are the reasons behind the lack of maker-centered classroom at the elementary school level?
11. What challenges do you foresee if an educational makerspace was to be set up at your school?
Appendix K: Facilitation Field Guide

[Facilitation Field Guide diagram]

- **Facilitation Goals**
  - **Spark**: Initial interest
  - **Sustain**: participation by following the learner's ideas
  - **Deepen**: understanding through making connections

- **Practices**
  - Welcome people and invite them to the space
  - Introduce the activity and set the mood for the interaction
  - Value tentative ideas, "mistakes," and wrong directions
  - Support their process in moments of failure and frustration
  - Guide people to go a little bit further than they could on their own
  - Surface connections between projects and links to outside learning experiences

- **Techniques**
  - Smile and introduce yourself
  - Orient learners to the available tools and materials
  - Offer a place to start working
  - Meet them at eye level when explaining or modeling
  - Show examples that demonstrate a variety of thinking
  - Suggest a prompt that generates possibilities
  - Observe learners for a bit before jumping in
  - Ask questions about their process
  - Listen to their ideas
  - Restate statements or questions
  - Offer new materials or tools
  - If you don't know the answer, work together
  - Give learners suggestions instead of directions
  - Show enthusiasm about their ideas

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Appendix L: Photos of the KG1 classroom

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<thead>
<tr>
<th>The main features and components</th>
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<tbody>
<tr>
<td><img src="image1.jpg" alt="Image 1" /></td>
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<td><img src="image2.jpg" alt="Image 2" /></td>
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<td><img src="image3.jpg" alt="Image 3" /></td>
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<tr>
<th>The KG1 students in their learning environment</th>
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<td><img src="image5.jpg" alt="Image 5" /></td>
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