DEVELOPING MAKERSPACE FOR WAHAHA INTERNATIONAL SCHOOL

An Interactive Qualifying Project Proposal
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By
Bruno Schardong
Matt Vindigni
Seungho Lee

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Report Submitted to:

Robert Mullins and Grace Yang
Wahaha International School

Hansong Pu and Joseph Sarkis
Worcester Polytechnic Institute

Abstract

Wahaha International School (WIS) wants to implement a makerspace that can be used by students and the local community. Our goal is to provide recommendations on the layout and equipment for the makerspace, along with any other useful information for operating a makerspace. To achieve our goal, we worked with students from Hangzhou Dianzi University to interview makerspace owners, do virtual and onsite tours, research articles online, create and distribute surveys, and hold focus groups with the students of WIS. From these research methods, we were able to provide the sponsor with detailed floor plans, a list of equipment that will be useful for all grades K-9 at the school, and recommendations to help grow the potential of the makerspace once it is built.

Executive Summary

The current educational trend around the world revolves around a curriculum based in Science, Technology, Engineering, Arts, and Mathematics (STEAM). STEAM education emphasizes on a collaboration between the sciences and the arts to teach students skills like detail-oriented work and creative problem solving (Land, 2013; Segarra et al., 2018). These skills are currently being sought after in the workforce all over the world. From 2012 to 2016, around 35% of all online job vacancies posted as non-STEAM in the UK required skills or knowledge related to STEAM education (Grinis, 2019). Additionally, among the five largest firms in China, four firms work in the science or technology field (Wikipedia, 2020); however, China faces difficulty to maintaining students' interest in STEAM education due to the exam-oriented educational system. Moreover, students experience difficulties when put into the STEAM workforce because they feel that they do not gain any real-life experience through exams (Kirkpatrick & Zang, 2014, 38). In order to overcome this issue, the Chinese government has built makerspaces and changed school curriculums to more project-based teaching systems in order to motivate students. The Chinese government believes that the renovation of the system and mindset should start from the current workforce and slowly implement it to students.

Like the name implies, project-based learning uses activities and projects to teach students; the idea is that if students apply what they are taught in class through real world examples and projects, they will gain a better understanding of the materials and concepts. Students are intended to develop skills such as teamwork and creative problem solving by applying what they learned in class to complete their projects (Ng & Adnan, 2018). Project-based learning is a good medium for teaching STEAM education, and in a study comparing various teaching styles it was found that, "The project-based learning method had 30% more effect on the science achievement of students" (Karaçalli & Korur, 2014, p. 8). However, without access to the proper learning environment and materials, their ability to learn and innovate is limited. Fortunately, schools such as Wahaha International School (WIS), are working on implementing makerspaces into their buildings to give students access to the necessary space and materials for them to innovate, create, and learn more effectively.

Simply put, a makerspace is a place for people to learn and express their creativity. Its purpose is to provide its users with the right materials and tools necessary to innovate, work on projects, and make discoveries. Makerspaces provide a space for students to practice building and provide them a place to practice the skills and concepts taught in STEAM education classes. Our sponsors at WIS asked our team to help them develop a STEAM centered makerspace with a purposeful design where students can work together, express their creativity, and expand their learning experiences at their own pace. The goal of this project was to design a set of budgeted makerspace floorplans for our sponsors to choose from and reference when constructing their own makerspace. During this project, our team broke down our agenda into a set of objectives for both the planning and design phases of the report.

There are two main objectives in the planning phase:

- Identify Key Elements that Lead to an Effective Makerspace
- Determine Education Values of WIS Community and their Opinions on Makerspaces

And there are two main objectives in the design phase:

- Design and Develop Multiple Iterations of Floor Plans and Equipment Lists
- Consolidate our Designs and Data into a Final Report

First, in order to identify key elements of effective makerspaces, our team researched published documents on successful makerspaces, interviewed people who had extensive experience in building makerspaces, and toured local makerspaces online. Due to constraints caused by COVID, our team was unable to conduct interviews or tour makerspaces in person; however, we used the technology that we had available to continue conducting them virtually. Additionally, students from Hangzhou Dianzi University (HDU) visited local makerspaces in China since they were not limited by COVID in the same way that the WPI students were.

Through interviews, our team learned about the importance of having a maker community and what impacts that community has on determining the effectiveness of the makerspace. A maker community is composed of the staff and volunteers which maintain the

space and the makers that use it. If the staff and participants do not use or like certain materials or machines within the makerspace, then they serve no purpose. We learned that to design an effective makerspace, we needed to meet and know the interests of its new maker community. Additionally, throughout the research, interviews, and tours our team compiled a list of the various materials, projects, and equipment found at each makerspace. We found that many of the makerspaces used a combination of high-end materials – like 3D printers and laser-cutters – along with low-end materials – like LEGOs and cardboard – in order to match the skillsets and maker needs of different age groups. Another concept that came up was the importance of ease of accessibility and organization. People needed to be able to move around safely and have a place to store their projects to work on later.

Second, to determine the education values of the WIS community as well as their opinions regarding makerspaces, our team held weekly informative meetings with our sponsors, sent out surveys to the WIS community, and held focus groups with WIS students. We held weekly meetings to share our findings and progress with our sponsors, to learn more about how they intended to use the available space, and to find out what materials the school already had available. Surveys and consent forms were sent out to participating students and parents using a website called Qualtrics. We would later use the information gathered from the surveys to determine the educational interests and priorities of the WIS community when designing our floorplan options. Additionally, since the WPI students could not go to WIS to conduct the focus groups, students from HDU conducted them in our place to learn more about what makerspace activities and fields of STEAM most interested the future maker community of WIS.

During the surveys and focus groups, we found that students showed interest in activities that were more carefree or involved group collaboration. During focus groups, most students chose activities that allowed for creative freedom or things that could be done at their own pace. For example, there was a trend of creativity, innovation, and diversity found in the parent surveys which was also represented in the focus groups. Some things we found from the focus groups conducted by HDU students is that the students enjoyed the idea of teamwork or group activities: when the WIS students were asked what they would like to do with their friends, the majority decided on LEGO robotics from a list of activities.

Finally, during our design phase, the group worked on compiling, sorting, and interpreting data gathered in order to develop various floorplan options for our sponsors at WIS before consolidating them for the final report. During this time, we reviewed the data collected and looked for similar lists of equipment and activities amongst our interviews, virtual tours, and document research. Next, we looked through our surveys and focus groups to see what topics of STEAM interested the community to see what their needs might be. We compared equipment lists and user needs in order to come up with a couple of different designs for our sponsors and spoke with them twice a week in order to perfect our final designs at a faster pace.

Our team suggests using one of the proposed floorplans when developing the makerspace in WIS. The tables and equipment are spaced out so that students may move about freely to do their work. This area also works as a collaboration space where students can work together on projects and designs. If WIS is interested in having a LEGO robotics team, this might be a good space for students to work together and build a sense of teamwork within the maker community. Our sponsors showed interest in having a hydroponics section, and students showed an interest in learning a bit about hydroponics during the focus groups. With that in mind we suggest implementing a small section of vertical hydroponics planters. The laser cutter and 3D printers are more advanced tools for older students to practice using higher-end equipment, while the lower budget equipment like cardboard, scissors, etc. are intended for much younger students to use creatively. Having a variety of different tools and materials available means that they will have something for all different ages of students to work with and create a legacy of makers from a young age. We would also advise the addition of a green screen and camera for students to use. Not only is video making popular amongst children, evident by the latest trends in apps such as Tiktok, but it also becomes a great learning experience for students to get more involved with the computer skills required for video editing.

We tried to suit the sponsors' needs, because they will be the one physically implementing the makerspace in Wahaha International School. However, the recommendation is also targeting the students and parents of WIS. Since WIS is a private international school, we thought that it is important to hear the opinions of both students and parents. Students will take classes in the space, so it is important to know about their insights and thoughts on the

makerspace. Thus, the deliverable is primarily targeting the sponsors, but it is also for parents and students to view.

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1.0 Introduction

1.1 Modernization of China and Education

China, implementing and reforming the market structure in 1979, has been the fastest sustained expansion by a major economy in history. The International Monetary Fund (IMF) forecast China's economy to exceed America's economy within 10 years (Silver, 2020). Major companies, businesses, factories, political systems, and more played a major role for economic growth.

Like other East Asian countries, China directed their education to be exam-oriented, resulting in the outbreak of an extremely competitive education battlefield. Exam-oriented education guided students to study for tests, instead of getting hands-on experience for their future. By having an extremely rigorous study schedule implemented since childhood, students naturally lose interest in learning and studying; this means China loses potential future leaders and innovators. Compared to other economically leading countries, China has the least number of Nobel Prize winners, especially in the Science, Technology, Engineering, and Mathematics (STEM) fields (Wikipedia, 2020). Despite the rapid growth in economy, China's growth rate will decrease if there are not enough creative and innovative leaders to lead and develop China. It is evident that China attempts to provide more opportunities for students by replacing exam-oriented education systems.

1.2 STEM

Today, non-STEM jobs are looking for workers with some STEM related skill sets (Grinis, 2019). The rapid growth in technology demands for more innovative minds and the need for workers with STEM-skills will only continue to increase as a result. These workers show a greater knowledge in the workforce and are having a higher aptitude for things such as cost and risk analysis. Currently, most out of high school workers with some knowledge of STEM make more money than those who do not (Carnevale, Smith, and Melton 2011). At the end of the day, STEM education is seen to better prepare students for the workforce and can lead them for higher paying jobs.

1.3 The Maker Movement

The maker movement has led to the creation of many makerspaces around the world. The movement has spread so far because its educational benefits have been widely recognized. The maker movement is about inspiring creativeness and innovation. Students can participate in the maker movement through the makerspace, which has become essential in involving students in the STEM education approach. A makerspace is a place where people can work on projects with the assistance of technology or tools. Students who utilize makerspaces can learn the skills that are needed to serve in the workforce.

1.4 Project Goal

While the demand for modernized education and a strong STEAM workforce continues to grow, not enough students have access to the resources. Wahaha International School (WIS) desires to implement a makerspace into their facilities to help cultivate future leaders and innovators. Our goal is to assist WIS in their mission to implement a makerspace, usable by its students and the local community. The final deliverables will contain a floor layout of the makerspace along with a list of recommended equipment.

In the next section, we will cover the background information collected on the project topic, and in section 3, we will go through our methodology in detail. In section 4 we will discuss our findings, and in section 5, we will give our recommendations to the sponsor. Section 6 will conclude our report.

2.0 Background

In this section, we will cover background information relevant to the scope of this project. We will first begin by discussing what a makerspace is, and what they are meant to accomplish in a school setting. Next, we define STEAM and STEAM-based education as well as their purpose in makerspaces, and the workforce. Finally, we present China's views and approaches on implementing STEAM education and makerspaces. We provide an overview of the new maker movements and policies in China and emphasize the Chinese government's initiatives toward the makerspace.

2.1 Introduction to Makerspaces

STEAM and project-based learning are essential elements to the modern educational approach. These elements are practiced in an educational setting called the makerspace. To begin our project, we needed to first understand makerspaces. A makerspace is a place for students to create and explore. These spaces are the center of the maker movement, a movement started circa 2006 when the first ever Maker Faire was hosted. The maker faire is described as "Part science fair, part county fair, and part something entirely new" (About maker faire, n.d., para. 1). The Maker Faire showcases various creations meant to inspire those who attend to believe that they too can create. The maker movement is focused on bringing out the curiosity in students to enhance their problem solving and innovative skills. As technology and education develop, makerspaces are becoming an essential part of the classroom.

2.1.1 About Makerspaces

What is created in a makerspace is up to creator's imagination. It is a space in which users can utilize resources, provided by the makerspace, to express their creativity. A common misconception about makerspaces is that they are full of new-age technology. However, makerspaces are not defined by the technology in them, some makerspaces will have 3-D printers, some have LEGOs, and others might have both. Students are encouraged to aim for the stars as they bring their ideas to fruition.

2.1.2 Makerspaces and Student Involvement

Making learning meaningful is a challenge that educators face. With a new class of kids each year, educators must adapt to different learning styles. Hands-on experience is a powerful learning style that promotes involvement, and retention of the skills or knowledge learned (Bidokht & Assareh, 2011). A collection of interviews was conducted by researchers Harron & Hughes with makerspace employees and volunteers. In one interview, an interviewee stated, "Kids light up when they are allowed to create", and another stated that makerspaces "help kids come out of their shell" (Harron & Hughes, 2018, p. 8).

A selling point to having a makerspace is engaging the students who strive through hands on experience and collaboration. Makerspaces help with student involvement and inclusion, key factors to having a thriving student community. A study on the inclusiveness of makerspaces at the Georgia Institution of Technology showed that student involvement was often barriered by four factors: anxiety from a lack of experience, a lack of knowledge about the equipment in the space, a fear of alienation, and an assumption that makerspaces are only for engineering students (Noel et al. 2016). All these barriers lead to not understanding makerspaces, and who uses them. To ease students into what seems to be an intimidating space, programs can be offered that teach students how to use makerspace equipment. At a school with roughly 14,000 undergraduate students, 100 new students per week were recorded attending the makerspace as result of these introductory programs. For example, to increase female participation in the makerspace, Georgia Tech hosted an event called "Ladies night at the Invention Studio". Over 300 RSVPs were received for the event, and the number of female Prototyping Instructors (makerspace educators) has gone up since the first "Ladies night at the Invention Studio" (Noel et al. 2016). Hosting a variety of themed events can help introduce individuals to the makerspace.

2.1.3 Learning through Failing

Makerspaces are places for students to learn, but they also serve as places for students to fail. An important lesson that makerspaces teach students is to learn from failure. One of the teachers from the previous study by Harron & Hughes (2018) stated that they tell their kids, "it's better if you mess up a couple of times because whatever you end up with is going to be so much better if you do." (p. 10). "It is crucial to… allow students to make their own mistakes and find

their own solutions… Students who learn how to fail early on will find few limits and a deep sense of confidence." (Kurti & Fleming, 2014, p. 4). Failing early on and seeing that it is still possible to succeed is great for a student's confidence, allowing them to take more risks and be innovative.

2.1.4 Self-Directed Learning

There are two main styles of learning, lecture-based learning, and self-directed learning. With lecture-based education, students learn about material that is determined by the lecturer. In self-directed learning, the student gets to decide what they learn. The main difference in these two styles, is that self-directed learning gives the students an opportunity to tailor their learning experience to their interests. "In 90 days, students forget 90% of everything they have been told" (Bidokht & Assareh, 2011, p. 2). To increase student retention, different educational practices have been adapted. Two such methods are self-directed learning, and project-based learning; methods that are designed to help students develop knowledge and skills using projects that reflect problems in the real world. Makerspaces are designed to allow students to create, using technology to aid them in the process.

The STEAM (Science, Technology, Engineering, Arts, Mathematics) approach to education is well suited for makerspaces because they are flexible and self-directed. "Projects are most meaningful when they are student-driven" (Cooper, 2014, p. 7). Makerspaces can and should be used in many ways. For example, in an article about a school makerspace, "Two students have become the 3D printer experts… One of these students is more of an engineering type, while the other is more of an artist." (Kurti & Fleming 2014, p. 4). This middle school took a hands-off approach to their makerspace, and two very different students collaborated and taught themselves how to 3D print in ways that were meaningful to them.

In a different study, two elementary school groups, one taught using the school's current lecture-based style and the other with project-based learning, were compared in a scientific study. The groups were given a pretest on scientific aptitude, then after their teaching was complete, they took another science aptitude test where the project-based learning method had 30% more effect on the science achievement of the students and retention of the material.

Makerspaces combine self-directed learning and project-based learning into one, giving students a great educational opportunity to become lifelong learners.

2.1.5 Difficulties of Sustaining a Makerspace

Makerspaces, being as important of a tool as they are, are not seen in every school because they are difficult to sustain and maintain. There is a stigma with makerspaces that expensive new age technology is needed to design an effective makerspace. However, there is more thought that must go into designing a makerspace than placing high-end technology in it. Makerspaces, when open to a large student body, can consume a heavy number of resources. This can be very expensive for even a wealthier school. The difficulty in designing the makerspace is finding a balance of cost, reusability, and expandability in the tools.

For example, Drawdio is a maker kit, as seen in Figure 1, that allows students to make electronic sounds with their pencil lead. This kit is great in practice, it teaches students about electricity and circuitry all with just their pencil and some paper.

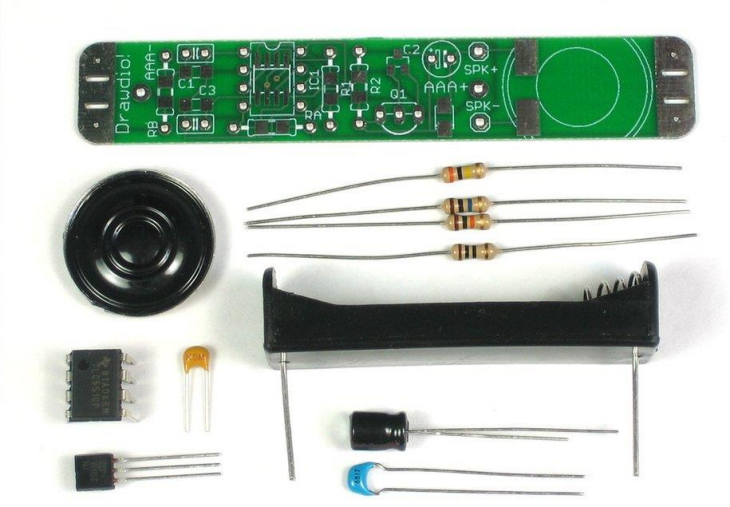

Figure 1 Example of Drawdio Kit

However, the kit is priced at $17.00, and it is single use. This means that in a 20-person class, $340.00 are spent for something that cannot be reused, or expanded on (Fontichiaro, 2016). If the makerspace wants to host a workshop that utilizes kits such as the Drawdio kit, they can have participants sign up for the class and charge them the money it cost to buy the kit. A more reasonable resource for a makerspace to invest in would be something like LEGOs,

microcontrollers, or Arduinos. These can be purchased once and used many times. Students can take control of the tool and decide what they want to create with it, leading to a more engaging and satisfying experience for the student.

2.2 Importance of STEAM Education

We hope to improve Wahaha International School through the addition of a proper maker space that builds on values of STEAM education; however, to understand the significance of STEAM education, one must first understand what STEAM education stands for and its purpose in makerspaces.

2.2.1 What is STEAM Education and why is it Important?

STEAM is an acronym that stands for Science, Technology, Engineering, Arts, and Mathematics. In the modern era, STEAM education, sometimes known as STEM education, is valued because it incorporates important skills necessary for today's workforce. The difference between STEAM and STEM, is that STEAM has the addition of the arts. The purpose of STEM-based learning is to teach students how to be more innovative, organized, and detail-oriented through classes that emphasize the importance of skills such as the sciences (Segarra et al., 2018). Over time, researchers have discovered that the addition of the arts in STEM curriculum further improves the growth of creativity, visual organizational skills, and detail-orientation of students, thereby turning STEM into STEAM (Land, 2013; Segarra et al., 2018).

Segarra's article, *STEAM: Using the Arts to Train Well-Rounded and Creative Scientists*, touches upon how the integration of the arts brings out the expected yields from the sciences. For example, STEM classes such as mathematics or natural science focus on teaching students to identify and understand the world around them through problem-solving and observation. Visual arts such as drawing and painting are considered open platforms to express and practice creativity, close observation to detail, spatial intelligence, and pattern recognition (Segarra et al., 2018). Segarra's study mentions how these cross-disciplinary courses complement and enhance each other's teaching when combined.

Combining the information above, makerspaces are a great platform for educators to engage students in various activities due to the wide variety of resources and equipment available, which is beneficial to balance all elements of STEAM education.

2.2.2 STEAM Education Prepares Students for the Workforce

With recent increased modernization, the dependency of STEAM in the workforce has increased. From 2012 to 2016, around 35% of all online job vacancies posted as non-STEAM in the UK required skills or knowledge related to STEAM education (Grinis, 2019). Many of these non-STEAM jobs required knowledge on coding programs such as C++ and Python or asked for other skills associated with STEAM education like "detail-oriented". If students learn some of these skills in high school, they will graduate with a highly desired skill in the workforce and/or be better prepared for higher education.

A STEAM-based curriculum helps students acquire higher paying jobs. According to a 2011 study, STEAM majors tend to make about $300,000 more in their lifetimes than other majors (Carnevale, Smith, and Melton 2011). In the US, "75% of high school graduates employed in [STEAM] jobs earn above the median for their education level, compared with 40% of high school graduates employed in non-[STEAM] jobs," (Bozick et al, 2017). Not all of these are likely to be directly involved in invention; however, in the modern era where computers and machinery are everywhere, the ability to navigate technology, perform detail-oriented tasks, and implement new ideas becomes vital.

The impact of STEAM-based education comes not only from the skills that it is supposed to teach, but also from the routes it takes teaching them. Project-based learning and self-directed learning, as shown in Figure 2, can be the foundations of implementing a STEAM-based education. Students are intended to develop skills such as teamwork and creative problem solving

Figure 2. Example of Project-Based Learning

by applying what they learned in class to complete their projects.

Research with elementary school students in Malaysia found that they were able to integrate real-life applications of basic knowledge, skills, and values found in STEAM through simple project-based tasks given to the children (Ng & Adnan, 2018). Through simple tasks such as figuring out how to build a Chinese yoyo, young children displayed retention in concepts of measuring size, shape, and symmetry. Although this is a development of small STEAM skills, it shows that even at a young age, students can be taught concepts and values from STEAM through project-based learning (Ng & Adnan, 2018). In Australia, a more complex application of project-based learning with a collaboration between high schoolers and college students. In this project, students in STEM and Arts collaborated to design a series of "Species Hotels" that act as both public artworks and as a method to increase awareness of endangered species in Australia (MacDonald et al., 2019). Teaching students through project-based learning can be improved using makerspaces by providing locations to work. Being able to work together on a project in a communal space helps with the purpose of learning teamwork and collaboration in group projects.

2.3 China's Approach on STEAM Education and Makerspace

The most popular educational trend around the world is STEAM education. Most large and prominent companies in China base their business on science and technology. Among the five largest firms, four firms work in the science or technology field (Wikipedia, 2020). State Grid Corporation of China, the largest firm in China and second largest firm in the world, is a firm that has a massive national infrastructure business for electricity in 2019 (Wikipedia, 2020). However, China faces difficulty to maintain students' interest in STEAM education due to the extremely exam-oriented educational system. Moreover, students experience difficulties when put into the STEAM workforce because they do not gain any real-life experience through exams (Kirkpatrick & Zang, 2014, 38). In order to overcome this issue, the Chinese government built makerspaces and changed school curriculums to implement quality-oriented education and motivate students. The Chinese government believes that the renovation of the system and mindset should start in the workforce then slowly transition to the students.

2.3.1 China's approach to cultivate an Entrepreneurial Mindset

An easy way to solve motivational issues facing China is to cultivate an "Entrepreneurial Mindset." Entrepreneurial Mindset is a terminology introduced to China due to the release of a new policy called "mass makerspace. (Xue, 2018)" This policy states that a maker culture is ideally positioned to help China cultivate an attitude of self-making and self-entrepreneurship, helping to democratize innovation. The Chinese Minister of Science and Technology, Wan Gang(2015) commented, "…we need to better transfer academic research into commercial products; science should serve our economy… open source and open hardware can help realize this innovation strategy. We encourage crowdsourcing and mass entrepreneurship in society so that resources are better distributed." Since the introduction of this initiative, the Chinese government has funded local governments to set up makerspaces, incubators, and labs not only in companies, but also in middle and high schools, to train China's next generation of entrepreneurs. They imagine the policy will resolve unemployment issues and shortage of makers (Lindtner, 2016).

2.3.2 Integration of Libraries and Makerspaces

The Chinese government suggested the construction of a makerspace in local and school libraries. Libraries are accessible to people nearby despite their social or economic status. School libraries are operated by teaching staff, volunteers, and paid instructors. Some school libraries also have 3D printing and modeling technologies in makerspaces for students to use. They also offer wooden crafts centers more often than other library makerspaces (Cao et al., 2020).

Contrary to all the benefits and trends of makerspace, libraries face difficulties financially and academically when integrating with a makerspace. The very first problem is budget limitation. Librarians aspire to provide the best, hands-on experience for students. Despite the aspiration, lack of tools and equipment from limited budgets can be an obstacle for the implementation of makerspace (Li et al., 2018). To overcome the problems, graduates from China and America provided potential solutions for the integration of libraries and makerspaces. From the new policy of Chinese government to cultivate the "Entrepreneurial Mindset", Chinese governments supply funds for local and school makerspaces. For school libraries, there will be enough investment from campus, institutional, and the Chinese government's funds to hire

educators and purchase equipment for the makerspace. For the lack of professional instructors, they provided a solution: arrange with the library staff to develop additional training programs to address the problem of a lack of instructors (Cao et al., 2020).

2.3.3 Makerspace in Wahaha

With the current trend in China, Wahaha International School (WIS) asked Worcester Polytechnic Institute (WPI) and Hangzhou Dianzi University (HDU) students to design a floor plan and create equipment lists for a makerspace. WIS is a non-profit, English-language immersion international school established in July 2015. WIS students consist of Kindergarten to 9th grade, with approximately 260 students. Having 39 faculty members, WIS have a 1:7, faculty to student ratio. This shows that WIS wants the students' education to be more personal, because having a lower faculty to student ratio will allow instructors to focus more on individual students. WIS has a motto: "Curiosity and Courage, Appreciation and Accountability, Resolve and Resourcefulness, Excellence and Enthusiasm." Through a makerspace, WIS not only wants to provide STEAM education, but also motivate students with curiosity and courage to explore with the resources that makerspace provides.

3.0 Methodology

The goal of our methodology is to create a detailed floor plan, and a recommended equipment list for an effective makerspace that will fit the sponsor's needs. Our sponsor wanted our makerspace to have aspects of STEAM education, as well as follow environmentally friendly practices. The implementation of the makerspace will engage students in hands-on project-based learning, shifting away from the exam-oriented learning style that has dominated schools in China. Through various collection tools used by students from WPI and HDU, we developed a procedure (see Figure 3) that allowed us to engage the students and parents of WIS in the design process of our floor plans. Our methodology has four objectives throughout the planning and design phases.

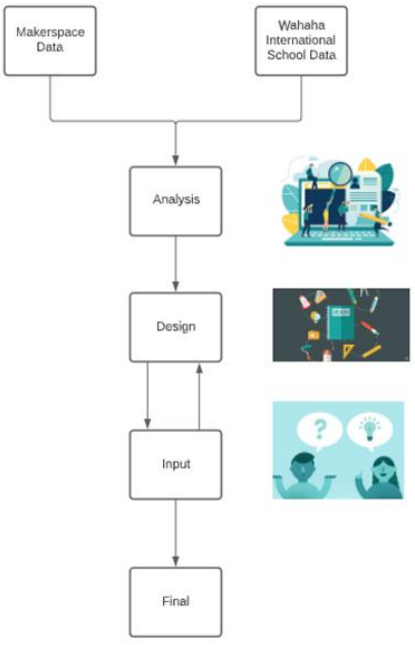

Figure 3. Methodology Flowchart

There are two main objectives in the planning phase:

- Identify Key Elements that Lead to an Effective Makerspace
- Determine Education Values of WIS Community and their Opinions on Makerspaces

And there are two main objectives in the design phase

- Design and Develop Multiple Iterations of Floor Plans and Equipment Lists
- Consolidate our Designs and Data into a Final Report

In the planning phase, we hoped to collect data about the key elements of makerspaces and the educational interests of WIS. In the design phase, we wanted to turn the data we collected into a detailed floor plan and equipment suggestion list. A brief overview of the research methods used in the methodology can be seen in appendix A. This section of the paper will describe the details of the four objectives and explain the research methods selected for obtaining information to successfully achieve the goal.

3.1 Planning Phases

3.1.1 Objective 1: Identify Key Elements that Lead to an Effective Makerspace

As seen in Figure 4, our first objective was to identify what goes into an effective makerspace. We wanted to learn about the basics of makerspaces before recommending anything to our sponsor. For this, our research revolved around three main points for gathering data and analysis:

1. Makerspace equipment and sustainability
2. Examples of makerspace activities and makerspace teaching methods
3. Makerspace design

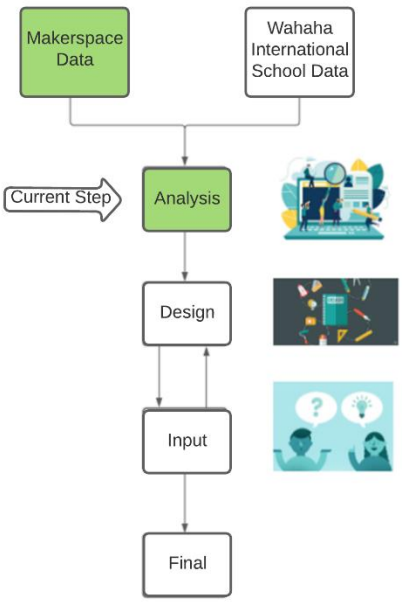

Figure 4. First Step in Methodology Flowchart

Our suggestions were more useful because we strived for a strong understanding of these three main topics. We researched studies on makerspaces, interviewed makerspace employees, and did virtual onsite tour visits to get personal experience with makerspaces. Each research method

contributed to our understanding, and the combination of all our research allowed us to provide evidence-based suggestions to our sponsor.

Content Analysis

Our first research method is content analysis of makerspace publications and studies. Content analysis is the studying of documents and articles. This was useful to us and our project because we had to deliver evidence-based suggestions and plans to our sponsor on effective makerspace design, but our team did not consist of any makerspace experts. We needed the necessary background information before starting our design phase. When we conducted our content analysis, we structured it into two phases: the preparation phase, and the organization phase. (Elo, et al., 2014).

To get started with content analysis we analyzed the Destination Imagination website, a STEAM education program that our sponsors mentioned we look at for inspiration. We investigated what types of programs they use, and why they are effective. We also read through the literature as part of the content analysis. For the organization phase, we compiled the information gathered on all three research topics onto one document and listed any important notes or similarities observed in the articles. The biggest challenge with content analysis of makerspace articles was dealing with untrustworthy or biased articles. To overcome this, we researched studies using trustworthy academic sources in the Gordon Library database.

Interviews

Our second research method is interviewing. Interviews helped us gain a better understanding of what one experiences inside a makerspace at an employee or volunteer level. This type of information was useful because we were able to shape our suggestions and design plans around the experiences of others. To conduct our interviews, we needed to first determine who to interview, and then create an interview plan.

According to Roberts (2020), an interview plan is a tool that interviewers can reference while they are conducting their interview. Interview plans consist of an opening section, an open-ended question section, and a conclusion section. The opening section consists of a greeting,

some warmup questions, and a verbal consent agreement. The open-ended section contains questions designed to pull information from the interviewee. We based the questions on our three main research points listed in the objective introduction. The conclusion section is a section where we thank the interviewee for meeting and talking with us to wrap up the meeting. The outline in appendix B is what we used to help guide our interviews. The open-ended section contains the main questions as well as probing or follow up questions. Probing questions are useful when the interviewee does not answer the question as fully as we expected, or if there is further information to be gathered. Both open-ended questions and probing questions can be improvised during the interview if appropriate. Before we collected and used any data from our interviews, our methodology got approved by the institutional review board (IRB), and we collected written consent from the interviewee (Appendix C).

Interview Sampling

To determine who we would interview, we used a purposeful sampling strategy. The individuals chosen for interviews had extensive experience working at a makerspace. For our study, we chose to interview the Technocopia makerspace, the New England (NE) SciTech makerspace, and Destination Imagination. Both Technocopia and NE SciTech have programs for youth groups, which let us get real examples of how youth makerspaces are organized. Destination Imagination was a program mentioned by our sponsors, they envisioned their makerspace to incorporate the arts in a similar way Destination Imagination incorporates the arts in their program. We reached out to five other makerspaces, but we only got responses from the three listed above.

Conducting Interviews

We conducted the interviews during the COVID pandemic and followed our school's safety guidelines by using Zoom, a video conference software. To organize a virtual interview, we had to reach out to the makerspace and confirm a date and a time. After deciding when the interviews would take place, we sent them a URL to our Zoom meeting room, along with a consent form asking for permission to record and use their responses from the interview in our report. Once this was done, the interview was ready to be held. Organizing the interviews ended up being the biggest obstacle for this research method. We initially had the lack of responses

from e-mails we sent out. After getting our responses and attempting to schedule a time for the interview, there was difficulty communicating with one of the three interviewees. To resolve this issue, we had to send out additional e-mails until we got a response. Once the issue was resolved and we sat down for the interview, everything ran smoothly.

Onsite Research - Initial Plan

The third research method we intended to use to gain a better understanding of the key elements of a makerspace was onsite research. Onsite research is collecting data in-person as a participant or observer. In terms of our project, this consists of going to an existing makerspace in person, and sign-up for either a tour, or a workshop. The value of going to a makerspace in person is getting experience first-hand. Like interviews, gaining personal experience is important because it gives us a better understanding of what to suggest in terms of makerspace activities, equipment, and designs.

Onsite researchers will take descriptive field notes, jotted field notes, or reflective field notes. Descriptive field notes are notes that describe the setting, events, objects, behaviors and interactions in detail. Reflective field notes are notes that put the researcher into relation to the environment, for example, the researcher's reaction or experiences with the environment. Jotted field notes are notes taken by the observer immediately after observation (Johnson, 2017). For our data collection, we planned on taking descriptive and jotted fieldnotes. To do this, we designed a data collection table for when we or the HDU students visit a makerspace. The data collection table will contain areas to enter information based on different categories. The data collection table in appendix D is what the onsite researcher will fill out during their visit.

We visited the Foisie Innovation Studio on campus at WPI, as well as other local makerspaces. However, the future is unclear in terms of availability to visit local makerspaces in person. The biggest obstacle currently for onsite research is the pandemic, which is restricting our travel. To overcome this obstacle, we asked the HDU students to visit makerspaces near or in Hangzhou and report back to us with their experience, pictures, and videos. Virtual tours are also an option for our team at WPI. The experience will not be the same as going in person, but it may be the only alternative.

Onsite Research – Revised Plan

As result of the COVID pandemic, WPI has banned all in-person research off campus for any school related projects. For onsite research, we continued by sitting in on virtual tours as stated towards the end of the initial plan. We took notes during the virtual tour to collect data on the layout of the space, which workshops they offered, which equipment they had, and any additional notes. For the HDU students, they were able to safely visit local makerspaces and gather information, which they later sent to us. The biggest obstacle for our revised plan was to collect all the information we originally wanted through virtual tours, as it is hard to substitute first-hand experience for virtual experience. Luckily for us, the information we ended up gathering plus the information HDU students gathered for us was still useful to our project; it was just different than the information we planned to get during our original onsite research.

3.1.2 Objective 2: Determine Education Values of WIS Community and their Opinions on Makerspaces

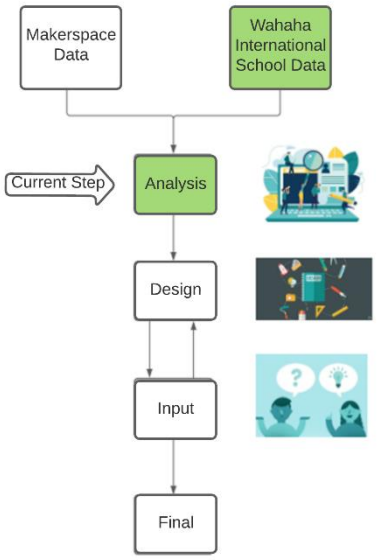

Figure 5. Second Step in Methodology Flowchart

Our second objective was to communicate with people at WIS to learn about the perspectives and needs of people at WIS regarding the addition of a makerspace. Looking at Figure 5. Second Step in Methodology FlowchartFigure 5, we are still in the analysis or planning phase of our methodology. We wanted our final proposal to match our client's needs. Our suggestions will be more beneficial if we have a firm grasp of our sponsor's expectations and specifications. We conducted interviews, sent out our surveys, and hosted meetings with focus groups to obtain necessary information about the people at WIS for our project.

Weekly Sponsor Meetings

In order to make sure that we kept our designs in line with our sponsor's desires and their education values, we met with them weekly. These weekly meetings gave us the chance to ask them directly about their expectations for this project and provided us with an opportunity to gain more in-depth knowledge about Wahaha International School. We used an in-depth interview plan similar to ones mentioned in Objective 1 to effectively gather information from our sponsors during these weekly meetings. These weekly meetings were used to present our weekly progress with our sponsors and they also served as a medium to have longer discussions with them about topics of question outside of merely using WeChat. Under normal circumstances we would have been faced with a language barrier when talking to people from China; fortunately, our sponsors speak English. Although our meetings with our sponsors provided information on their expectations for the project as well as additional information about the school and its wants and needs, they cannot speak for the entire school.

Surveys

Surveys are useful for quickly obtaining information from large amounts of the student and parental population at WIS and are an effective method to gain broad data to help us understand variety of perspectives and interest. It also provides us information to further filter through some of the basic data that we analyze from content analysis and can help better prepare us with a more purposeful and focused dynamic question asking perspectives. To obtain this information of WIS, we decided to survey the general student body and their parents. In the future, students will be makerspace users, so we wanted to know their opinions. We also included parents to be participants of the survey because the parents chose that their kids attend WIS for a good education. For both surveys, we needed them to sign the consent form (found in Appendix E) to match IRB guidelines and the project's ethical consideration, which can be found in Appendix F. During our fourth week we sent surveys to the parents and students at WIS through a secure website known as Qualtrics, where they even had the option to take their surveys in either English or Mandarin. We were able to provide the surveys in both English and Chinese translations thanks to the assistance of our HDU students.

Since our team could not work directly in China due to constraints caused by COVID-19, we faced some unforeseen incidents that required our team to come up with alternatives to our

initial plans for conducting and sending out surveys. Our team ran into accessibility issues while trying to send out permission slips through the students for their parents to sign, which would then allow students to participate in our surveys. We also noticed accessibility issues in terms of getting printed copies of our surveys out to the parents. Our solution to this problem was to set up the online surveys through a known source that we have used for school: Qualtrics. Putting our surveys online made them more accessible to parents and parents alike, which made it easier for us to collect and observe data from those surveys.

The first page informed the students and parents of the study's purpose, that it is a completely voluntary activity, that their participation would not involve us collecting any identifiers, and that in order to participate, students needed to have their parents' signature on the parental survey, giving their consent and permission for the child to participate in our study. The surveys were designed so that if the participant selected that they did not want to consent, they could select that option and the survey would simply end there. Copies of the consent forms can be found in Appendix E. In the parent surveys, we also asked if they would give permission for their children to participate in both the student surveys and the focus groups which can be found in Appendix E. Very simple surveys can only collect data too broad to form proper assumptions or to help build focus group activities (Glasow, 2005). As a result, we created detailed survey questions, shown in Appendix G, to gather their opinions and interest in STEAM and makerspaces. Ultimately, the information we gather will be beneficial to understanding the general perspectives and interests of the student population. Unfortunately, we only received 32 completed responses from parents at WIS, which further limited our available pool of students to survey and ask to participate in our focus groups; however, all things considered, some response is better than no response at all. See section 4.3.3 for more about information gathered from surveys and focus groups.

Focus Groups

Our fourth method was to conduct focus groups with students and parents at WIS to learn about the perspectives and needs of people at WIS regarding the addition of a makerspace. Focus groups are like meetings in the sense that there is a person leading the discussion; however, this method still differs from a traditional interview. Typically, focus groups are discussion groups of

five to seven people, led by an investigator who asks open-ended questions to the group; however, not many students from WIS were available to participate, so our focus groups consisted of one to two students working with an instigator. Focus group members are selected based on certain traits such as age, interests, etc. to understand how those specific people think and react to certain questions and statements. Similar to interviews, the investigator should prepare an interview plan that outlines the prepared questions for the groups. Additionally, it is necessary and ethical to ask the entire group for consent to recording answers and observations during the meeting to be used later as a part of our research. Precaution was required if/when working with children due to IRB regulations. Focus groups benefit the project because they give us the chance to observe group responses and interests of students who attend WIS in a more natural group setting.

One on one interviews do not always display an accurate representation of how the students think and act in a social setting, and since China has a very community structured culture it would be wise to observe the group's thoughts, interests, and opinions rather than focus solely on individuals. Focus group method weaknesses include their dependence on group responses and on being able to bring in all the interviewees at the same time. If one person dominates the conversation, then that skews the data to focus on that one individual's opinions. Also, some focus groups have been known to fail due to an inability to align the participants' schedules. Additionally, we struggled with language barriers and COVID. Fortunately, the HDU student team stepped in as interviewers for the focus groups; however, since focus groups rely on how well the interviewer dictates the question, we had conversations with the HDU student teams to make sure that our questions were similar in meaning in both languages.

We began conducting focus groups during the fifth week of the project, once we received formal consent from the students and their parents. The WIS student focus groups were conducted by the HDU student team, where they presented the students with a combination of open-ended questions and activities such as pile sorting. In pile sorting, the subjects were handed a set of photographs and were asked to sort them into specific categories. The HDU students then asked the focus group subjects to explain why their pictures belonged in the different categories. For example, the HDU students printed out a set of pictures with different activities that they

might do in our space (a 3D printer, a set of colored pencils, a computer, and people working at a table) and the WIS students were asked to pick out the images that they associate most with creativity. A more complete list of what types of activities and how they were conducted during focus groups can be found in Appendix H.

Unfortunately, few students signed up to participate in focus groups; however, rather than breaking down the number of focus groups that we had, our HDU students decided to conduct the same number of individual groups, but with only one to two students per group. This removed the group aspect of information gathering we hoped to attain during this process, but it was better than cancelling the focus groups all together. In the end, we still managed to gather some information from the students using the activities even if the conditions were not ideal. A summary of our HDU student's findings can be found in Appendix I.

3.2 Design Phase Subsections

3.2.1 Objective 3: Design and Develop Multiple Iterations of Floor Plans and Equipment Lists

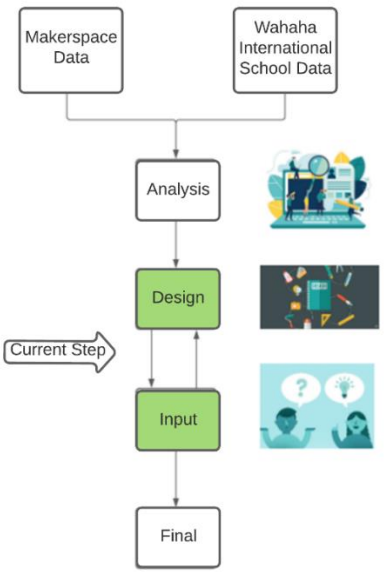

Figure 6. Third Step in Methodology Flowchart

After the data from surveys and interviews were collected, we had to spend sufficient time to analyze the raw data. Surveys from parents and students were analyzed based on their needs and expectations of the school and makerspace. Activities conducted with focus groups provided a general overview of students' interests. Weekly meetings with the sponsors not only shared the deliverables, but also provided detailed comments on questions regarding data collection tools and deliverables. Furthermore, analysis from interviews of local makerspaces provided examples of successful curriculum, workshops, and tools that people use in the makerspace. After the analysis, we began our design phase, as seen in Figure 6. In this phase, we attempted to develop an initial iteration for the makerspace design (Breitinger, 1997).

We utilized interactive feedback meetings (Losada et al., 1990) to present our potential designs to stakeholders and collect feedback to further develop the next iteration. The WPI team met with the sponsors weekly before this meeting to share progress, discuss a to-do list, and ask questions. Weekly sponsor meetings are different from interactive feedback meetings because interactive feedback meeting is more focused on receiving feedback from sponsors on the iterations and deliverables. For preparing an interactive feedback meeting, WPI and HDU teams finished the initial design of the floor layout and equipment list, where sponsors identified potential problems and provided suggestions of the deliverables. We had four interactive feedback meetings during the final two weeks of the project. During the meetings, we learned more about the sponsor's opinions and thoughts on the details of our floor layouts and equipment list, which provided a guideline for changes needed. After applying feedback received from the meeting, we presented the iteration to get final comments from the advisors. We presented by providing slideshows that explained the data collected, the feedback we received, and changes we have made. By doing this, we not only received feedback from the Wahaha sponsors, but also an objective perspective of the design from the advisors. We used the feedback we received to improve our design and tailor it based on what our sponsors want to see.

3.2.2 Objective 4: Consolidate our Designs and Data into a Final Report.

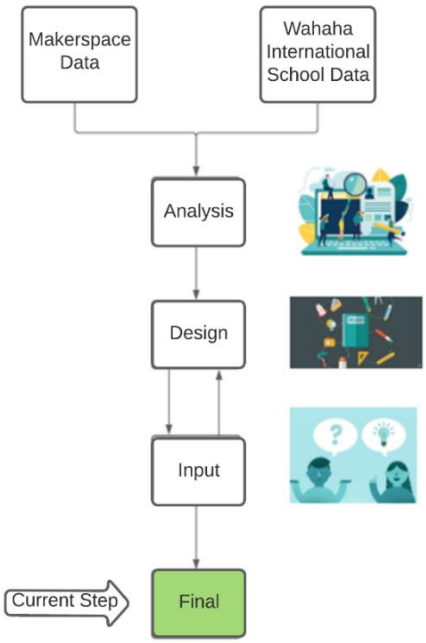

Figure 7. Final Step in Methodology Flowchart

As seen in Figure 7, after our final revision, we began our final step and prepared for our presentation and paper. Our final presentation and document outlined everything we have accomplished through the IQP as well as our interpretation of our qualitative and quantitative data. In addition to the final presentation, we combined all our deliverables with appropriate documentation. We sent the reports and documents to the sponsors to check if any sensitive information remained that they would want us to take out before our final report. We also transferred floor layouts and an equipment list of the makerspace to our sponsors, so that can visually see the makerspace we finalized. By creating easy to decipher deliverables, the project's work will likely gain greater acceptance, and the data collected can be used in future projects. We not only focus on the final documents, but also on the deliverables which contain the products of our research and design processes accomplished with HDU and WIS.

4.0 Findings

During this project, our goal was to gather information about the layout, the design of makerspaces, and the future maker community of WIS in order to assist WIS in their mission to implement a functional makerspace. In this section, we discuss the principals of our floor design, our equipment list, and additional advice regarding running and maintaining the makerspace after implementation at WIS.

4.1 Primary Values of the Floor Layout

To create the floor layout on Figure 8, we considered two main factors: accessibility and organization. Accessibility is important in a makerspace because it promotes collaboration between students and provides access to various tools and equipment. Similarly, organization is also essential in a makerspace because sorting the equipment can save space and time for both the makerspace managers and users.

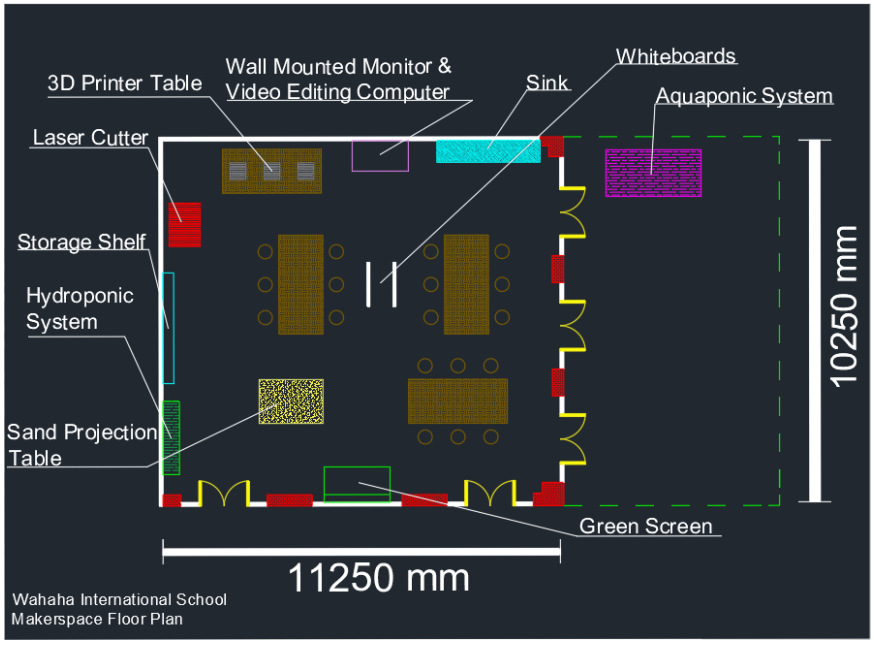

Figure 8 Final Floor Plan Design

4.1.1 Accessibility of a Makerspace

As mentioned above, the accessibility is essential when creating a makerspace. Multiple sources from data collection tools support the claim. During an interview with Kevin Harrington, the co-founder of Technocopia highlighted that "[A] Makerspace is a place to work." As a founder of a major makerspace in Worcester, MA, he believes that makerspace should not limit people in how they work. Accessibility plays a major role to promote this key value of makerspaces. A Makerspace can provide a spectrum of equipment: starting from high-end equipment to low budget equipment. High-end equipment like 3D printers, laser cutters, and circuit cutters require specific skills, but it can help create what students want. The same goes with low budget equipment such as art supplies, green screen, and whiteboards. Having a wide range of equipment, students can use to share and create unique and creative ideas. From researching and analyzing contents on the internet, a published paper describes the six principles in their design of makerspace (Schon, Ebner, & Grandl, 2019). Among the six, one principle is related to accessibility. They emphasize to support idea and innovation development. Having accessible to wide spectrum of equipment will allow students to think differently. One student may create a spoon using 3D printers, while another student may film a short weather report using the green screen.

In the floor layout, we attempted to include variety of equipment in the makerspace. Technocopia's makerspace is approximately 743 square meters, but the space in WIS is only 115 square meters. It is impossible to place all the equipment that Technocopia had in WIS. As a result, we kept track of common makerspace equipment from interviews and virtual tours to provide the best possible experience for students. Space was tight despite only placing the common equipment because there were multiples of the same equipment such as tables and whiteboards. To promote accessibility, we also had to sort out the organization of equipment in the makerspace.

4.1.2 Organization in a Makerspace

Along with accessibility, organization is also a primary principle of our makerspace. From the interviews and virtual tour of local makerspaces, we found out that many makerspaces tend to organize tools and equipment. Technocopia and NE SciTech divided equipment in

different zones, so that similar types of equipment are placed close by. For example, NE SciTech placed their soldering station next to Arduino kits and 3D Printers next to computers. These zones were also visible in the virtual tours. Some things that were emphasized in the tours were digital rooms, the wall of joy, and woodworking. Digital rooms –a section in a makerspace dedicated to video/audio editing, filming, and digital arts– had computers, a green screen, cameras, and an audio booth. The wall of joy was a separate storage area that stored all the small tools and materials, such as: electronics, robotics parts, textiles, construction tools, and more. We realized a lot of makerspaces are organized to be time efficient, space efficient, and reduce confusion. Having separate zones dedicated to a single theme can reduce confusion because similar themed tools will be in the same zone. Adding on, people will not have to move around to look for tools, which also makes it time efficient. Having small tools and equipment stored in a separate zone can make it easier to access and will save space for other tools or tables.

Like other local makerspaces, we decided to divide the makerspace into different zones such as technology, art, aquaponics, and storage. 3D Printers, Laser Cutter, Computer, and other related electronics and tools are placed in the technology zone. Sewing kits, Canvas, and art-related materials are placed in the art zone. Aquaponics are placed outside of the makerspace because there is a water fountain outside, which may be used for hydroponics. Moreover, the sponsor felt that the best place for aquaponics is outdoors.

The WIS makerspace is much smaller than other local makerspaces. Despite dividing it into zones, the zones are not spaced out or large enough to have multiple tools together. This is where the storage area comes in place. We wanted to maximize the space by adding a separate storage zone like the Wall of Joy. If there is not enough space in the storage zone for all the small materials, electronics, robotics, and more, we concluded that the area below tables can be used.

4.2 Equipment List

In order to determine a suitable list of equipment for our sponsors, we relied on a few methods of information gathering. As stated in our methodology, we used a combination of content analysis and information from our interviews and virtual tours. A common theme that we noticed while going over documents that we found online about makerspaces was that many of

them mentioned having 3D printers and some sort of cutting machine. The sources that we found online (see Appendix J) seemed to repeat a very short list of common types of materials or equipment deemed unsafe for children. We chose to rely on the information gathered from our interviews and tours since the makerspaces involved were child accessible, and thus will need to have equipment appropriate for children to use. We noticed that the makerspaces included machines such as 3D printers and laser cutters, the spaces also displayed an emphasis on student driven design and activities. For a more complete list of the compiled similarities found between makerspaces during our virtual interviews and tours, see Appendices K and L. As stated in section 4.3, we learned that encouraging and nurturing maker culture is important for a makerspace. With the lists of materials found around children's makerspaces and information gathered from surveys, we started to compile a list of equipment that we could use to fill the makerspaces that matched that of other makerspaces, and gave students access to potential materials and tools needed in order to work on any projects that they might want to work on.

Technology

Over the past few years, 3D printers have become more and more accessible to the public, and as a result they continue to become increasingly useful to the maker community. People have been using 3D printers for all sorts of personal projects, from making their own figurines and toys to designing custom parts for robots. A piece of advice given to our team by one of the founders of Technocopia was to "make things interesting", for example making a project with a robotic arm into an animatronic. By adding in an element of fun or interest to the project design, children are more likely to want to use the equipment for personal projects and make things. We believe that 3D printers have enough versatility in creative design and can be user friendly enough that students will gain interest in using them to bring to life their own toys and projects. Considering the fact that 3D printing technology is on the cutting edge of industry design, this would additionally give students a new skill that is applicable in the workforce. During our student focus groups, the students mentioned that they were familiar with 3D printers and associated them with creativity. Having an easily recognizable maker-tool that students already associate with creativity might be beneficial for building maker culture or reinforcing it within the space.

Another useful addition to the same tech-space as the 3D printers would be a high-power laser cutter. Precision cutting tools are an effective means to bridge arts and sciences together for personal projects and educational purposes alike. Like 3D printers, precision cutting machines rely on a digitally designed pattern or design created through software and bring them to life in the real world. Laser cutters, like 3D printers, are staple elements in most makerspaces. The design software is simple to teach and if the proper safety procedures are followed, they can be rather safe to use. A majority of the makerspaces that we interviewed or saw through virtual tours had laser cutters and mentioned how they could be used for a wide array of projects from simple keychains to custom earrings and much more. In previous meetings our sponsors have mentioned that they currently own a lower power laser cutter which works on paper, as well as a circuit cutter for paper patterns and cutting vinyl. The addition of a higher-powered laser cutter is the next step to expanding the opportunities to innovate that WIS provides to its students. The higher-powered laser cutters work with a strict set of materials such as specific types of wood and in some cases plastics, which require more power to cut, and could be used to help students cut out larger pieces for projects involving materials sturdier than cardboard or foam.

The sponsors were interested in a makerspace that involves STEAM and bridging the Arts and Sciences. The use of a greenscreen and associated audiovisual equipment would be an excellent means for meeting this goal. While considering various programs that encourage STEAM education – such as Destination Imagination – our team noticed an emphasis on the use of theatrical arts to cultivate and express creativity and design. Using a greenscreen students can utilize the area in order to practice and develop their own creative writing and artistic skills making and recording their own skits; after that, the students can develop their technical skills in a fun way by editing those videos in the computer lab and experimenting with their greenscreen. This setup will also provide more utility to existing features in WIS such as their computer lab, thereby increasing the usefulness of both facilities without needing to allocate more financial resources on additional physical equipment.

Miscellaneous

Not everything in a makerspace needs to be high-end equipment or expensive tools. The purpose of a makerspace is to provide access to the necessary materials that makers need. Often times, especially with children, this purpose can be accomplished using more basic materials like cardboard, foam board, hot glue, and other simple construction materials. A variety of low budget activities can be done using the suggested materials that we have placed in our "crafts" category. For example, designing props and costumes to use alongside the green screen. The idea here is to provide simple materials for students to work on personal and school projects alike in a space where they can actively build what they want as well as brainstorm ideas. Some of these materials may already be available in art rooms but having them available in the makerspace will make it easier for students to bring their innovative ideas to life on the spot. The materials in our crafts section are intended to suit the skills of younger students in grades K-4. Since they are younger, it is important to give them tools that are more appropriate for their current skill level.

Finally, since our sponsor had shown interest in having a hydroponics or aquaponics system and believed that it could be used to teach the students, we investigated possible systems for them. For a hydroponics system, we suggest a vertical hanging unit like the models produced by ZipGrow™. Vertical systems are very space efficient because they use up less floor space than other units. While a homemade system may end up being cheaper, we suggest purchasing a kit, since they tend to look more professional and come with instructions on maintenance. We suggest keeping the vertical hydroponics unit indoors so it can be used to educate students year-round, and to avoid any damage caused by freezing conditions during winter. For aquaponics units, we recommend constructing a media bed aquaponics system outdoors which will not be utilized during winter. What makes aquaponics different from hydroponics is that aquaponics incorporates fish, making the system more sustainable. While hydroponics units will rely on nutrients being added into the water from time to time, the plants in aquaponics systems gather nutrients in the water left by fish waste. We recommend using a media bed system, because they do not need additional filters for solid fish waste, and we recommend housing it outdoors because these systems tend to require more floor space. An aquaponics system is a useful method to educate students about sustainability, biology, and where food comes from through tangible experience. If our sponsors choose to use edible plants, herbs, and fish as listed in the table

below, the aquaponics system can also provide the school with a source of fresh meat and vegetables that can be harvested before winter.

4.3 Additional Recommendations

Over the course of this project, our team interviewed makerspace employees, researched articles, went on virtual tours, sent out surveys, and held focus groups. As a result, we have created some detailed floor plans and a recommended equipment list. However, floor plans and equipment lists cannot convey all the information we gathered. Along with our deliverables, we want to leave the sponsor with insight gained throughout our planning phase of the project. We hope that this information will aid them in their goal of creating a successful makerspace.

4.3.1 The User Makes the Makerspace

Makerspaces are meant to be a tool for the community, and a makerspace can only thrive when it fulfills that purpose. During an interview with Kevin Harrington from Technocopia, he said “Makerspaces are their communities; they come from the community; they are driven by the community; the community decides and lays out what they want”. Since makerspaces are made for the community, the community should influence the space.

In a separate interview with the founders of the New England SciTech makerspace, there was a guitar hanging on the wall in the background of their webcam. When we asked about it, they explained that a local high schooler wanted to make their own guitar, so he came in one day and asked if he could build one from scratch. It was a long project, but with the assistance of the staff and the equipment at the makerspace he was able to complete it. After that, other users of the makerspace were interested in the DIY (do it yourself) guitar and wanted to make their own. In response, the makerspace ordered DIY guitar kits for the users who were interested and asked the high schooler to help lead the program with the experience he gained from his project. This is a great example of the relationship between the makerspace and the user. The user benefits from the makerspace, and then the makerspace benefits from the user. In this case, the high schooler was able to make his guitar, and then helped others make their own guitars after.

While we are recommending certain floor layouts and equipment lists, the space should not be set in stone. There is a symbiotic relationship between the community and the

makerspace, it is important to tailor to the needs of the user because it will help your space and the community grow.

4.3.2 Staff and Volunteering

To maintain and properly utilize a space that has a wide variety of equipment is a difficult task. Having dedicated staff and volunteers is important for the makerspace and its users. Some of the equipment we recommended (such as 3D printers and laser cutters) are high maintenance and not beginner friendly. Having a staff member who is well versed with the equipment in the makerspace is essential for two main reasons.

The first reason is to repair the machine in case it breaks. 3D printers and laser cutters have many moving parts and are costly. Sometimes a piece of equipment can stop functioning properly. Someone who is an expert with the equipment could diagnose and fix the problem, saving the makerspace time and money. We observed an example of this during our interview with New England SciTech. They were saying that one time they had a faulty 3D printer, and they were going to sell the parts on eBay. But then a child saw that they were going to scrap the machine and asked if he could look at it. It turned out that the youngster was very knowledgeable in 3D printers and fixed it within 10 minutes. This may not be an example the sponsors will encounter, but high-end machinery needs to be maintained in order to work correctly. Having someone who knows how to do those things will allow the makerspace to operate smoothly.

The second reason is to help guide the users in bringing their ideas to life. When a user comes to the makerspace with an idea in mind, they might not be aware of how the equipment in the space can benefit them for their specific project. An expert who knows the capabilities of the equipment would be able to point them in the right direction for starting or continuing their project. The staff member should not direct or control the user's project, this would prevent the user from learning more about the equipment and its applications. Having someone who is well versed in the equipment can also be inspirational to others. In both Technocopia and New England SciTech, users who have had help from others in their projects had learned from the experience and decided to help others learn by being a volunteer.

Volunteers are another great way to help run a makerspace. From an organizational standpoint, they are reliable and cost-effective. In Technocopia and New England SciTech, users will volunteer out of passion for the makerspace and its community. This participation not only benefits the makerspace, but also the users. Users will have more people to ask for help, but volunteers will also have the chance to teach others. Learning something and teaching it are very different. A famous quote from Albert Einstein states “If you can’t explain it simply, you don’t understand it well enough”. Volunteering allows users to gain a better understanding of skills they learned by teaching others. The symbiotic relationship can be seen again in this situation; the volunteer benefits from the makerspace by having a place to teach and practice what they have learned, and the makerspace benefits from the volunteer by getting additional assistance in running the space.

Involvement does not have to stop at staff and volunteers. In the makerspaces we interviewed, we have seen examples of different ways the community gets involved with the space. For example, at NE SciTech there are clubs that users can join such as an amateur radio or HAM radio club, an astronomy club, and a robotics club. If a group of users were interested in an activity, they could propose to start a club and use the makerspace as a place to meet and work. These clubs would have a president or advisor that sets up meeting times, designs activities for the group to do, and teaches the club members when they meet. If the club grows to a considerable size, this work can be delegated to different members like a secretary or vice-president. Another example of how a makerspace has gotten additional members involved is by inviting parents to youth workshops. NE SciTech offers child friendly workshops that costs money; the cost is usually reflective of the materials that will be used during said workshop. However, for no additional cost, the child can bring their parent and have them join the workshop. If the community is passionate about making, they will find different ways to get involved and utilize the makerspace. It is the school’s responsibility to help them get involved and grow the interaction between the community and the makerspace.

4.3.3 Existing Interests

As part of our research, we sought out any information on the academic interests of the students attending WIS and their parents. We did this through the form of online surveys and in-

person focus groups conducted by the HDU students. Unfortunately, we received minimal survey responses from the parents and no responses from the students, so there is not much data to analyze from the surveys. We recommend that this detailed evaluation through surveys be completed with future IQP projects or by WIS. Regarding the focus groups, only a small sample of students were involved. The groups consisted of smaller sizes, and there were only students from 5^{th} – 7^{th} grade who participated. With this in mind, we know that the data we are analyzing will not represent most of the school and highly recommend that additional feedback be gathered by WIS or future IQP projects.

In the parent surveys, we asked what they valued in their child's education. The parents seemed to not focus on the grades and academics, but rather they were more concerned about bringing out their child's creativity, having their child experience a diverse environment, and having their child work on their innovation skills. The figure above (Figure 9) visually represents the answers parents gave for what they value in their child's education. The majority of responses fell into the creative and diversity aspect, which we believe means that the parents

want their child to grow from their experiences at an international school, and they want their child to be challenged mentally, having to think outside the box.

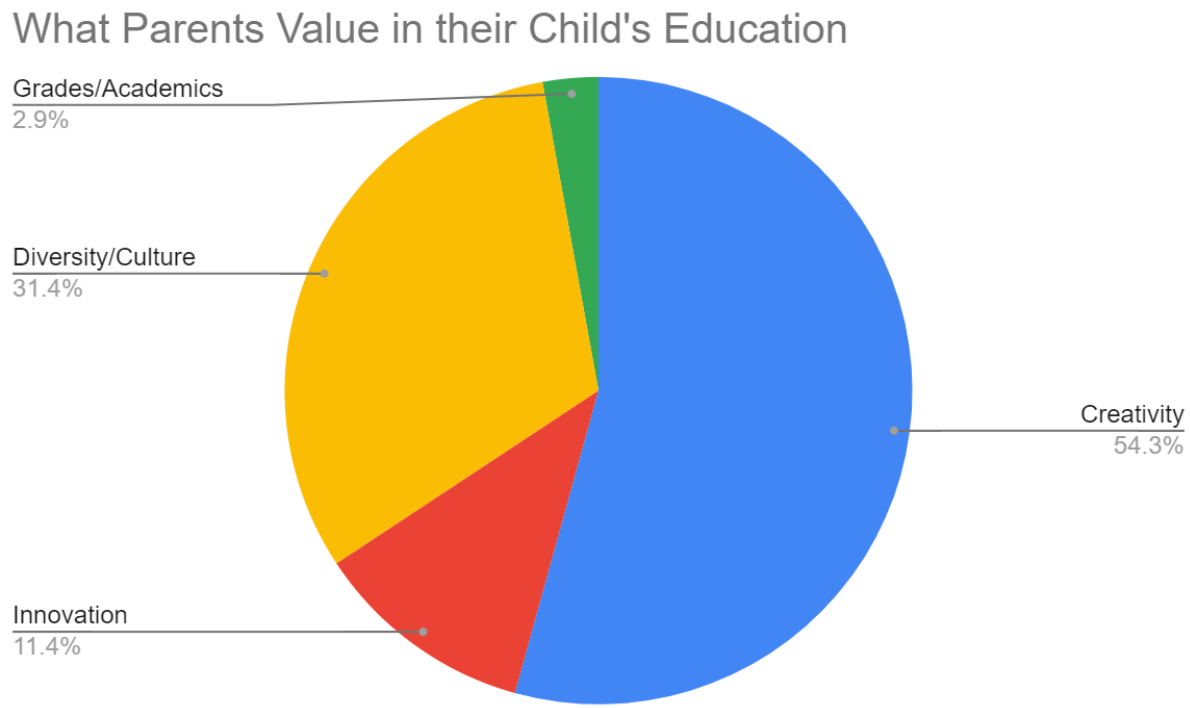

Figure 9 What Parents Value in their Child's Education

The trend of creativity, innovation and diversity found in the parent surveys is also represented in the focus groups. Some things we found from the focus groups conducted by HDU students is that the focus group participants enjoyed the idea of teamwork or group activities as asked in question 4 of the picture sort activity in Appendix I. When the WIS students were asked what they would like to do with their friends (question 4 of Appendix I), the majority decided on LEGO robotics from a list of activities. The reasoning they gave for LEGO robotics was that it requires teamwork, it requires creativity, and it is challenging. Like the parents, it is apparent that the students enjoy being challenged creatively, and they enjoy tackling these challenges with their classmates. What we can recommend from this finding is that activities in the makerspace should inspire creativity and require collaboration. Allowing a certain amount of freedom for the students to add their own ideas into a project is good practice for them, and good to inspire others.

Another important note we found is that when we asked the parents in the survey what they believed their child's favorite subject was, there was not a dominant response. As can be seen in Figure 10, students expressed interest in the topics listed, music being the outlier. When cross analyzing with the focus groups, the data seems accurate.

We can conclude that WIS, at least in the elementary school grade range, is a very diverse school in terms of interests. This means that making the makerspace suitable for everyone will be

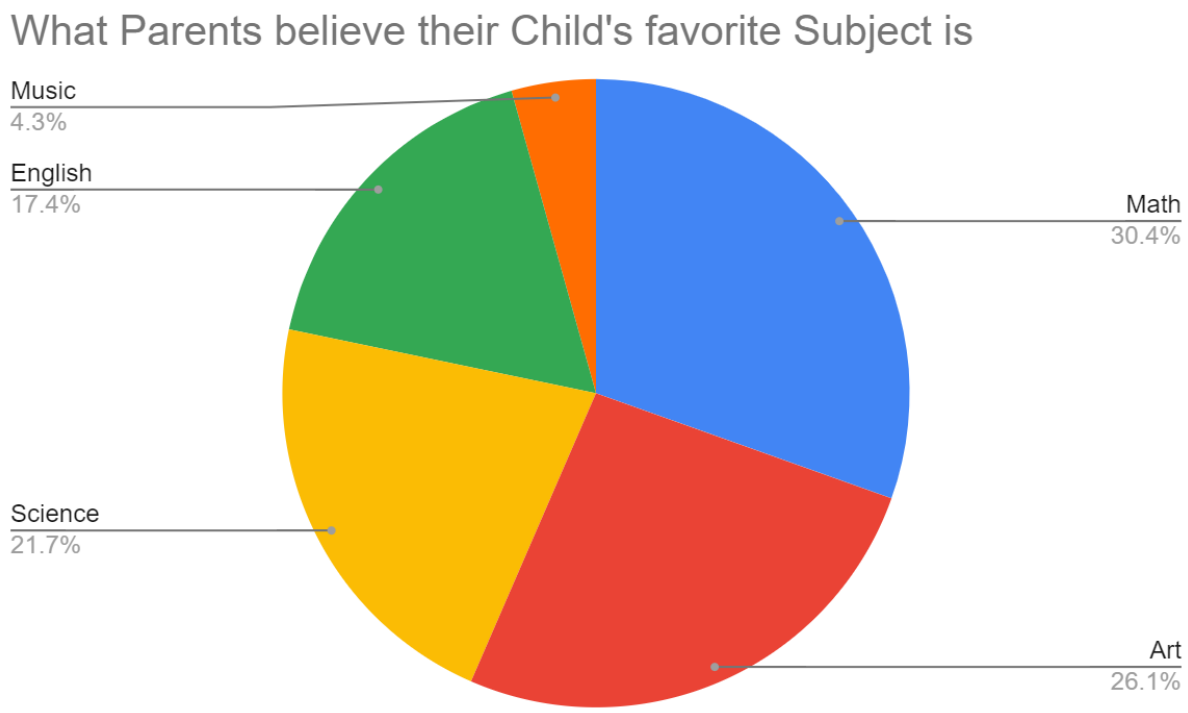

Figure 10 What Parents believe their Child's favorite Subject is

a challenge, not to mention the range of ages that will be utilizing this space. What we recommend is to make sure WIS is changing on a regular basis the types of activities in the makerspace. Something that Technocopia and NE SciTech do is host weekly workshops that people can sign up for. Each week these workshops will change, for example one week could be about laser cutting earrings, and the next week could be about building and programming a robot.

We distributed surveys and conducted focus groups to get a sense of what the student body is currently interested in. Knowing this will help the school design workshops or activities

for the makerspace. The most important part of implementing the makerspace will be how the students are introduced to the space. If the students are offered workshops or activities during class that do not interest them, it will leave a bad first impression, damaging the potential of the makerspace. Remember, the makerspace and the community are one, they cannot thrive without each other.

5.0 Findings and Recommendations

In this section, we provide a simple summary of the findings and discuss the key recommendations from our data analysis. The final deliverables are the floor plans and equipment list, but we made key ideas that we focused on while creating the deliverables. Adding on to the recommendations, this section also shows our final discussion of the report. This section will provide insight and ideas for running and maintain the makerspace.

There were three main themes we focused on while collecting and analyzing data.

- Designing the Floor Plan
- Variety of Equipment: STEM, Art, and Sustainability
- Community and Education

5.1 Designing the Floor Plan

For the floor plan, we mainly concentrated on implementing accessibility and organization into the design. We discovered the importance of these ideas from our interviews with local makerspaces, and our virtual tours. The WPI team had the opportunity to interview three different makerspaces in Massachusetts: Technocopia, New England SciTech, and Destination Imagination Program. One concept that the makerspaces discussed was that the makerspace is a space/community that should promote creativity and collaboration. An effective way of achieving this is through accessibility of tools and equipment in the makerspace. Similarly, from virtual tours, we noticed that makerspaces usually divided their space into different zones to maximize space efficiency. We observed that the zones were made up of types of equipment and tools that work well with each other. This helps reduce the time and energy spent by the users while using the makerspace.

Because WIS is a school with grades ranging from kindergarten to 9th grade, our sponsors wanted to have a variety of equipment that could be used by all students. It was difficult to place all the equipment into the makerspace without cramming it because of the size of the room. As a result, we made two versions of floor plans to give our sponsor an idea of what we believe is possible with the space given.

5.2 Variety of Equipment: STEM, Art, and Sustainability

In addition to the floor plan, we focused on STEAM education, and the variety of equipment while creating the equipment list. We took inspiration from our interviews with makerspaces, online articles, and our focus group activities. One thing we noticed was that all the makerspaces we interviewed had 3D printers. 3D Printers can print out parts needed for project and can also create personal objects that student created using software. We discovered the importance of laser cutters and cricut cutters from online research and focus group activities. Having sophisticated tools is not required for a makerspace. But, since two of the sponsors' goals for the makerspace are to provide a STEAM education experience and prepare students for their future careers, we included these tools to assist students to acquire skills and experience applicable for future careers.

High-end equipment is beneficial to have in a makerspace, but not everything has to be sophisticated. The A in STEAM is Art, which means it is important that a STEAM makerspace to provide not only engineering and technology, but also art. To satisfy the need for arts, we included art supplies, digital cameras, and hydroponics. Students can use the art supplies and cameras to exercise their creativeness. In addition to designing personal objects from 3D printers, students can film an animation through the art supplies and the digital camera.

Although it is no longer our primary goal, sustainability is still a value to consider while implementing a makerspace. After careful discussion with the sponsors about the scope of the project, we figured that hydroponics will be a great way to promote sustainability in the makerspace. With the addition of STEM and art, hydroponics can teach users about natural sciences like biology and chemistry. In short, we have focused on filling the makerspace with a wide spectrum of equipment to satisfy the variety of users at WIS.

5.3 Community and Education

Unlike the floor plan and the equipment list we are recommending, this section is about a non-physical deliverable, advice. From our wide range of data collection methods, we gathered some bits of wisdom. The first is that the makerspace thrives off the community, and the maker

culture in communities thrives off the makerspace. The second is that the makerspace will need staff and volunteers to help run and maintain the space.

We learned the importance of the makerspace-community relationship from our conversations with makerspace owners. They emphasized that a makerspace is built upon the community's interests. To understand the community's interests, we made surveys and focus group activities for members of the WIS community. Despite the lack of responses and representation we got from both research methods, we discovered that more parents valued creativity over anything in their child's education, and that the students at WIS have a variety of interests. We were able to cross reference this information with the data the HDU students collected from the focus group activities with students to validate our survey responses. Getting this information helped guide our decisions when choosing equipment. We tried to pick equipment and design the layout around project-oriented learning. We found this the best way to address the parent's value of creativity in their child's education, and to promote project-based education, a style of project-oriented learning.

The importance of staff and volunteers is to help manage the makerspace by teaching the users how to use equipment, repairing any broken equipment, and guiding the user in their project. Educating the students on proper usage of equipment lowers the risk of equipment breaking and allows them to be more independent in their project. The staff and volunteers should understand the capabilities of the equipment, allowing users to ask them questions on what can and cannot be done with the equipment in the makerspace.

5.4 Recommendations

These themes are key recommendations that we analyzed and found from data collection tools. It is important to recommend deliverables that suit the sponsor needs. With the addition of these needs, we also attempted to introduce recommendations from experts, students, journalists, and participants from our data collection tools. According to experts from interviews and virtual

tours, a makerspace has to promote accessibility and organization. Thus, we separated the makerspace into different zones in our floor plan: technology, collaboration, storage, and more (Figure 11). Collaboration zone helps prepare for future workforce; not only from teaching STEAM skills, but also understanding group work techniques. Efficiency is an important value in business because it is directly related to profitability (*Business Growth: Efficiency vs Effectiveness*). The storage zone also aids students by maximizing the space for makerspace users. Students and participants from surveys and focus groups shared their ideas and recommended certain equipment for the makerspace. From the surveys and focus groups, we have found out that students and participants usually associate makerspace with high-end technology and programming. However, some students wanted to learn more art and stress-free work. To reflect both opinions, we have suggested both high-end equipment for the technology and engineering aspect and budget equipment for art aspect. Since the equipment list contains both ends of the spectrum, it will suit a variety of students, allowing for self-directed learning; students are free to manage and organize projects instead of studying for given subjects and materials.

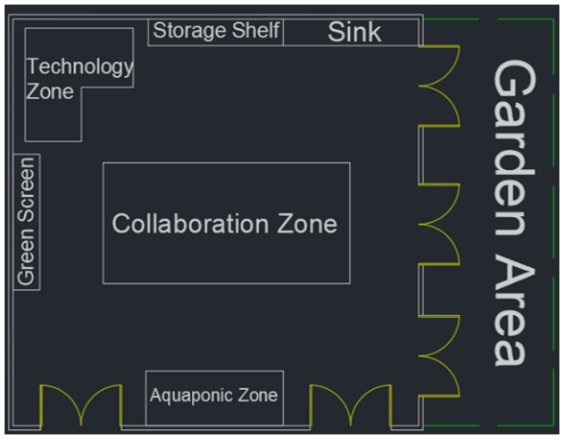

Figure 11 Early Iteration of Floor Plan with Zones

6.0 Conclusion

From this 14-week long project, our final deliverables to our sponsors consist of two floor plan designs, a recommended equipment list, and insightful advice to maintain the makerspace. Our team believes we put forth our best effort to complete this project. However, this does not mean we went without challenges. We had to change some plans in our methodology as we worked on our project due to COVID-19 and other unseen complications. In the future, if we were to work on another similar project, we would change our approach to give us additional time to work on the final deliverable. An example is that we would start our data collection tools earlier. During this project, we collected information using five different research methods. To cover this much ground comfortably, we would have needed to start our data collection at an earlier date to ensure we get adequate responses and have plenty of time afterwards to analyze the data. Another thing we could have improved on is consistently reminding survey participants to complete the survey. For our project, we needed to distribute the surveys for the parents so they could sign a consent form allowing their student to participate in our student survey and focus groups. Unfortunately, we only received around 30 responses from the parent surveys, not allowing us to proceed with our focus groups or student surveys as planned.

In conclusion, we are grateful for this project and the experience it has given us. We believe it has made us more prepared for future challenges once we leave college. We want to thank everyone for the hard work they put in to see this project to completion. Without their assistance, we would not have been able to provide detailed and thought-out deliverables to the sponsors.

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Appendix A

Research Method Table

Research Method	Research Candidates	Justification
Content Analysis	Online articles about makerspace design, teaching methods, and sustainability	Gain an educated background on makerspace design, teaching methods, and sustainability
Interviews	Makerspace managers / staff from local makerspaces (such as Foise and Technocopia for WPI students, and Westlake for HDU students). Our sponsors Mr. Mullins and Ms. Yang	Gain a better understanding of what one experiences inside a makerspace from a student, educator, or designer level. Find out any criticisms people who frequent makerspaces have for their makerspace.
Onsite Research	Local makerspaces (such as Foise and Technocopia for WPI students, and Westlake for HDU students).	Get personal experience with makerspaces.
Surveys	WIS students and their parents	Gather information easily from a large sample size. Better understand student's and parent's values in education.
Focus Groups	WIS students	Gain detailed information from a group of individuals through interview like questions. Group settings may also elicit more information than a one on one interview.
Interactive Feedback Meeting	Our sponsors Mr. Mullins and Ms. Yang	Collaborate with our sponsors and gain feedback on our design plans on a weekly basis.

Table A-1. Research Method Table

Appendix B

WPI Foisie Makerspace / Technocopia Makerspace Interview Plan

Introduction

Overview:

- We are working with Wahaha International Schools to design a makerspace that meets different criteria
- With your permission we would like to record this interview to use as part of our research in our project

Informed Consent:

- Will you allow us to record this meeting and use anything said during this interview in our report?

Build Rapport:

- How long have you worked with your makerspace?
- Could you describe your position, and how you came into position?
- Can you tell us about your makerspace?

Open Ended Questions

1. What is your favorite aspect of your makerspace?
    a. Why?
    b. How does this aspect contribute to the makerspace?
2. What activities or workshops does your makerspace offer?
    a. How often are these held?
    b. Are these workshops effective in growing a community?
3. Can you describe the equipment and resources that your makerspace has?
    a. How often are you restocking on resources, if at all?

4. Can you elaborate on the behind the scenes experience of working for a makerspace?
5. Were you involved in the design process for your makerspace?
    a. If so, what was it like?
    b. If not, can you explain the design of your makerspace and how it affects the user experience?
6. What would you change about your makerspace, if anything?

Conclusion

Closure

- ∉ Ask if they have anything to add.
- ∉ Ask for any useful recommendation of sources to look into.
- ∉ Thanking them at the end, and also send a thank you email after the interview

Review

- ∉ Meet as a team to review notes and information
- ∉ Upload the recording on to the shared google drive

Appendix C

Informed Consent Agreement for Participation in a Research Study

Investigator:

Contact Information:

- Bruno Schardong – beschardong@wpi.edu
- Chris Lee – slee7@wpi.edu
- Matt Vindigni - mrvindigni@wpi.edu

Title of Research Study: Developing Makerspace for WIS

Sponsor: Wahaha International School

You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: The purpose of this study is to gather information from individuals with experience in makerspaces.

Procedures to be followed (Interview): The interview will take around 30 minutes to 1 hour. The interviewer will ask makerspace related questions, the interviewee will answer the questions if comfortable. The interviewee can stop the interview at any point.

Risks to study participants: This is a minimal risk study. There should be little to no risk involved.

Benefits to research participants and others: Participation in the study would help us learn more about makerspaces, and individuals' experiences in makerspaces. This information will help us design a makerspace that meets the needs and interests of Wahaha International School, and the student body.

Record keeping and confidentiality: Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you, but may reference your position or title at your place of work. The interview will be recorded as a mp4 file, and responses to interview questions will be recorded on a Microsoft word document that will be shared amongst the researchers for this study.

Compensation or treatment in the event of injury: This study should not involve more than minimal risk of injury or harm.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact:

; the IRB Manager (Ruth McKeogh, Tel. 508 831- 6699, Email: irb@wpi.edu); the Human Protection Administrator (Gabriel Johnson, Tel. 508-831-4989, Email: gjohnson@wpi.edu).

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

Date: _____

Study Participant Signature: _____

Study Participant Name (Please print): _____

Date: _____

Signature of Person who explained this study: _____

Parental Permission Slip & Informed Consent Agreement for Participation in a Research Study

Informed Consent Agreement for Participation in a Research Study

Appendix D

Onsite Data Collection

Makerspace Name	**What equipment does the makerspace have?**	**What staff do they have working at the makerspace?**	**What equipment is the most popular among the users?**	**What workshops, events, or activities does the makerspace offer?**	**What safety precautions does the makerspace take?**	**How is the makerspace designed?**
Makerspace 1						
Makerspace 2						
Makerspace 3						

Table D-1. Onsite Data Collection Table

Appendix E

Parental Permission Slip & Informed Consent Agreement for Participation in a Research Study

Investigator:

Contact Information:

- Bruno Schardong – beschardong@wpi.edu
- Chris Lee – slee7@wpi.edu
- Matt Vindigni - mrvindigni@wpi.edu

Title of Research Study: Developing Makerspace for WIS

Sponsor: Wahaha International School

You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: The purpose of this study is to gather information about the students' interests at Wahaha International School to help design a makerspace.

Procedures to be followed (Surveys): The survey should only take about 5 to 10 minutes to complete. These are supposed to be anonymous, so please do not write your name on the survey itself. The student just needs to check boxes in order to answer most of the questions.

Procedures to be followed (Focus Groups): You would be participating in a group activity with 4 to 6 other students afterschool for 30 to 45 minutes. A student from Hangzhou Dianzi University will lead the participants in a group activity. During this time, the participants will be asked to either sort pictures, rank items on a list, or will participate in a group discussion. The HDU student will lead these activities and will ask the group of participants questions to explain their decisions.

Risks to study participants: This is a minimal risk study. There should be little to no risk involved.

Benefits to research participants and others: Participation in the study would help us learn about the interests of the students at Wahaha International School, so we can help design a makerspace that meets the needs and interests of the student body.

Record keeping and confidentiality: Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you. Data will be recorded on a Microsoft word document that will be shared amongst the researchers for this study. Surveys are intended to be anonymous, and in focus groups, participants will be recorded as: participant 1, participant 2, etc. There is limited confidentiality in the focus groups because we cannot control what participants will do outside of our study, and there is a chance that the participants will recognize each other since the school is so small.

Compensation or treatment in the event of injury: This study should not involve more than minimal risk of injury or harm.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact:

; the IRB Manager (Ruth McKeogh, Tel. 508 831- 6699, Email: irb@wpi.edu); the Human Protection Administrator (Gabriel Johnson, Tel. 508-831-4989, Email: gjohnson@wpi.edu).

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

Date: _____

Study Participant Signature: _____

Study Participant Name (Please print): _____

Parent Signature: _____

Parent Name (Please print): _____

Date: _____

Signature of Person who explained this study: _____

Appendix F

Ethical Consideration

Basic Needs

Before each information gathering session, be it an interview, survey, or focus group we will remind the applicant of their basic rights that are covered and how these are intended to be minimal risk. All cases are intended to be recorded without recording any identifying information about our participants. Their participation should be strictly voluntary, and they are free to leave at any time. These information gathering methods are designed to imposed minimal risk to our participants. We will remind them of this before they participate and each method may have its own way of recording the participant's consent, the primary method being a written signature stating that they understand their rights as a participant and that they consent to participating for the sake of our research.

Additional Needs – Children

All children will need to also need the written consent of one of their parents before they can participate in any of our activities. As minors, we need to gain additional consent from their guardians. One possible method to gain their guardian's consent is to have the children who want to participate take home a copy of the paper explaining what the activity their child wants to do as well as their child's rights both as a participant and as a minor. Additionally, if the children are participating in focus groups, we will have to inform them about the limited amount of anonymity that we can guarantee. Since other students would be participating at the same time for this group interview, they are other witnesses that we technically cannot guarantee will be as confidential since we have les control over what the participants say outside of our activity.

Appendix G

Survey Questions

Parent Survey

1. What grade is your student?
    1. K-9
2. What do you value the most in education?
    1. Innovation
    2. Grades/Academics
    3. Creativity
    4. Diversity/Culture
3. What do you want your child to pursue their career in?
    1. Engineering
    2. Politics
    3. Business
    4. Medical
    5. Laws
    6. Other
4. What do you think your child's favorite subject is?
    1. Math
    2. English
    3. Art
    4. Science
    5. History
    6. Music
    7. Other
5. What do you think of project-oriented learning? (Learning and receiving grades based on projects instead of exams)
6. Do you like the school's current curriculum? Why?
7. Do you know what a makerspace is?
8. What comes into your mind when you first think of makerspace?

Student Survey

- What grade are you in?
- Do you participate in any afterschool activities? If yes, please list them:
- What do you like to do for fun?
- What are some of your favorite classes?
- Do you know what a makerspace is?

- Rank the following from best to least (1=best; 6=worst): Music, Theatre, Robotics, Science, Computer class, Art

Appendix H

Activities for Focus Group

Picture sort

- The moderator starts this task by handing out sets of photographs to the students. After the pictures have been passed out and each student has a set, the students are then asked to sort out the ones that they think match a description given. One each student makes their pile of photos that they think matches the statement given, they each go around one by one mentioning why they thought that their photos belonged in their pile. For example, we might print out a set of pictures with different activities that they might do in our space (a 3D printer, a set of colored pencils, a computer, people working at a table, etc.) and the WIS students would be asked to pick out the images that they associate most with creativity (Colucci, 2007).

Ranking

- In this task, participants generally receive a list of terms, written on cards or on a whiteboard, to rank according to a specified dimension; for example, from the most likely to the least likely, from the most accessible to the least accessible, or from the least dangerous to the most dangerous. A different ranking task could take the form of a paired comparison (Colucci, 2007)

Choosing Among Alternatives

- Participants are offered various alternatives and are asked to discuss the advantages and disadvantages for each of them and select the one (or two, three) that they believe is the most appropriate, useful, and so on. They can also describe why they made that choice. Instead of alternatives being predetermined by the researcher, these can be produced by the participants (Colucci, 2007).

Instructions of Focus Group Activities

Picture Sort

Instructions: You will start off by handing out the sets of photos to each of the children. Each child should get one copy of each photo. When you ask the kids the questions, give them about a minute after you ask each question to come up with their answers. When you have the students give their answers, have them go around in a circle, each sharing both their decision and their justification.

"Each of you will be given a set of photographs of different tasks. I will hand out the photos, and ask you all to show me the photos that you think best answer the questions that I will ask you. Once everyone has chosen their answers, I will ask you all to explain why you chose your answers."

Which of these are the most creative?
Which of these are the most exciting to you?
Which of these would you be interested in learning how to do?
Which of these would you do with your friends?
Which of these are the least interesting?

Ranking

NOTE

C refers to the one conducting the focus group

Words that are italicized are instructions for the conductor

Setup

You will need…

A whiteboard or a print out of each list

Whiteboard is preferred

A device to record data

Laptop, pen and paper, etc.

Introduction

C will introduce themself, and ask the participants to introduce the participants. During introductions C should ask an icebreaking question to ease the participants into the study.

An example would be,

"Let's all introduce ourselves and share a hobby we have. I'll start, my name is [your name], and I like to [your hobby]

The question can be determined by C

If you have access to a whiteboard

C: "I am going to write a list of terms on the board and ask you to rank them in two different ways. After you rank them, I will ask you to explain your answer."

If you don't have access to a whiteboard

C: "I am going to hand out a list of terms and ask you to rank them in two different ways. After you rank them, I will ask you to explain your answer."

Procedure

List 1

Write List 1 on the whiteboard / Give the participants List 1

List 1:

Arts

Science

Technology

Mathematics

Engineering

C: "As a group, take a couple of minutes to rank list 1 from least useful to most useful"

After the participants finish ranking the different items, record their answers.

Ask these two questions. Record their responses to each question. Try to get everyone to talk

C: "Explain your reasoning for the list you made"

C: “Did the group have any trouble creating the list?”

C: As a group, take a couple of minutes to rank list 1 from least interesting to most interesting

After the participants finish ranking the different items, record their answers.

Ask these two questions. Record their responses to each question

C: “Explain your reasoning for the list you made”

C: “Did the group have any trouble creating the list?”

List 2

Write List 2 on the whiteboard / Give the participants List 2

List 2:

Build a paper bridge

Create a 3D model of a building

Create a circuit that turns a lightbulb on and off

Create a program or function that sorts a list of numbers

Make a functional bottle rocket

C: As a group, take a couple of minutes to rank list 2 from easiest to hardest to complete

After the participants finish ranking the different items, record their answers.

Ask these two questions. Record their responses to each question

C: “Explain your reasoning for the list you made”

C: “Did the group have any trouble creating the list?”

C: As a group, take a couple of minutes to rank list 2 from least to most fun to complete

Ask these two questions. Record their responses to each question

C: “Explain your reasoning for the list you made”

C: “Did the group have any trouble creating the list?”

Conclusion

C will thank the students for their participation and time.

C will offer to answer any questions the participants have

Choosing Among Alternatives

Set Up:

- A device to record data
    - Laptop, Paper, Phone, or other
- A paper for students to write down their thoughts(Optional)
- Whiteboard and board markers

Introduction:

- This activity will give ideas of what students prefer and expect indirectly. The questions are not directly related to makerspace or education, so students will be able to freely discuss the advantage and disadvantage of each option for each question. Students will discuss among groups freely about advantages and disadvantages then decide the best answer/alternative for the question.

Procedure:

1. Form random groups. Three to four students per group
2. Write the first question and the options for the first question:
    1. Question: What would you like to do in class
        1. Building a comfortable chair
        2. Designing a robot car and compete
        3. Build a village with Minecraft
        4. Building a robot to rescue people
        5. Fun science experiments: demo-volcano, instant freezing, and more
        6. Grow plants together. Watch how different attributes impact the plants

3) Give 5 to 10 minutes for discussion. Each group will share their opinions (advantages and disadvantages for each options and choose the best answer.

4) Record the answer, then write the second question and the options:

1) What would you rather not do in class?

a. Group Activities

b. Read books

c. Take tests

d. Have Homework

e. Present in front of others

5) Give 5 to 10 minutes for discussion. Each group will share their opinions (advantages and disadvantages for each options and choose the best answer.

6) Record the answer, then write the last question and the options:

1) What do you want to be in future?

a. Engineer that will innovate the Hangzhou Community

b. Businessman who will start a business and succeed

c. Artist that will express their creativity in China

d. Scientist who will win a Nobel Prize

e. Chinese Literature Professor who will dedicate in the learning of Chinese

f. Sportsman who will lead China to win world tournaments

7) Record the answer.

Appendix I
Focus Group Results

Procedure

A total of eight groups of students, ranging in age from 11 to 13, participated in our group discussion. Since the children had to attend class, the discussion lasted about 20 minutes, and some students failed to complete the ranking task 2 part in time. The following is the data recorded by us [HDU students].

Choosing Among Alternatives Activity

QUESTION 1 - What would you like to do in class?

A. Building a comfortable chair
B. Designing a robot car and compete
C. Build a village with Minecraft
D. Building a robot to rescue people
E. Fun science experiments: demo-volcano, instant freezing, and more
F. Grow plants together. Watch how different attributes impact the plants

Group #	Response	Rationale
1	C	I like the challenge, and I have been exposed to other activities after school
2	D	I love Minecraft, which is a very open game. I can do whatever I like without any stress
3	A	I like to sit and rest, so I want to build a chair
4	C	It is interesting and highly operational
5	A	I hope to do something useful and practical
6	C	I can create a new world
7	C	It’s funny to play games
8	C	I can have fun with my classmates

Table I-1. Choosing Among Alternatives Q1 Reponses

QUESTION 2 - What would you rather not do in class

A. Group activities
B. Read books
C. Take tests

D. Have homework
E. Present in front of others

Group #	Response	Rationale
1	D	I don't like to do homework. Sometimes there is a lot of homework
2	D	I hate homework, I want some free time after class
3	C	Exams are stressful and you can't do well under stress
4	D	I don't like to do homework. Sometimes there is a lot of homework for Chinese courses
5	D	I don't like doing homework after class
6	D	Doing homework is boring
7	D	I don't like to do homework
8	C	Exams are too intellectual

Table I-2. Choosing Among Alternatives Q2 Responses

QUESTION 3 - What do you want to be in the future?

A. Engineer that will innovate the Hangzhou Community
B. Businessman who will start a business and succeed
C. Artist that will express their creativity in China
D. Scientist who will win a Nobel Prize
E. Chinese Literature Professor who will dedicate in the learning of Chinese
F. Sportsman who will lead China to win world tournaments

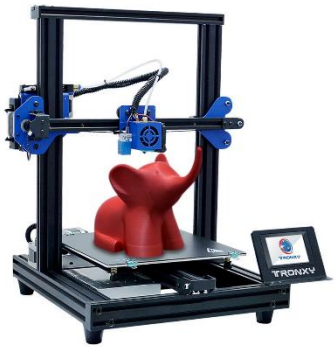
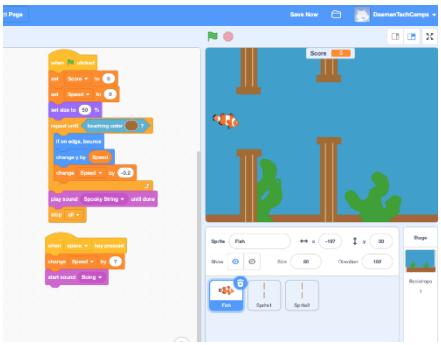
Group #	Response	Rationale
1	N/A	Not sure of which career they wanted
2	F	I am fond of sports and want to win honor for my country. I have a great sense of achievement and honor
3	C	I like drawing, and I wish I could paint creatively
4	C	I want to be a creative artist, but not in China
5	B	I like money
6	A	It's exciting to make a city beautiful
7	A	It is exciting to change the city's appearance

8	B	Creating wealth and achieving success is exciting

Table I-3. Choosing Among Alternatives Q3 Responses

Picture Sort Activity

Images used in activity

ID	Activity	Image
A	Using a 3D printer	
B	Coding a video game	

C	Lego Robotics	
D	DIY Instrument	
E	Hydroponics / Aquaponics	

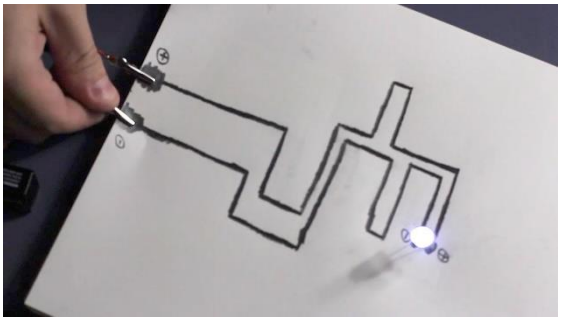
F	Create a paper circuit	

Table I-4. Picture Sort Activity Pictures

QUESTION 1 - Which of these is the most creative?

Group #	Response	Rationale
1	D	I love music
2	A	3D printers are high-end, they look complicated and ideas can be brought to life by 3D printers. There are 3D printers in the school
3	A	It's a very innovative activity. It sounds very high end
4	D	It would be fun to combine it with code
5	C	Because it looks messy and challenging
6	A	It was funny
7	A	I can feel the joy of creation
8	A	It inspires creativity

Table I-5. Picture Sort Activity Q1 Responses

QUESTION 2 - Which of these are the most exciting to you?

Group #	Response	Rationale
1	B	Programming is challenging, and it's fun to create the game you want
2	D	It is easy to make musical instruments. A few rubber bands can make the most simple one. I like music, and there will be different and interesting timbres every time.
3	NONE	They're not very appealing

4	B	The game itself is fascinating, and you learn a lot about programming
5	C	I like playing with LEGOs very much and I can feel a sense of achievement during that activity
6	F	It's a great way to use my talents
7	F	It's exciting to me
8	A	I like it

Table I-6. Picture Sort Activity Q2 Responses

QUESTION 3 - Which of these would you be interested in learning how to do?

Group #	Response	Rationale
1	E	Haven't seen one. It's a novelty
2	A	3D printers are very high-end, cool and trendy. It implements ideas and brings them to real life. You can print toys for yourself if you learn 3D printing
3	NONE	Not interested
4	E	I like the process of raising plants and animals
5	A	Because I wanted to be able to do something interesting with 3D printing
6	E	You can see the plants grow up
7	F	It is funny
8	A	I like it

Table I-7. Picture Sort Activity Q3 Responses

QUESTION 4 - Which of these would you do with your friends?

Group #	Response	Rationale
1	C	It requires teamwork and it is challenging
2	C	With LEGO, you can build what you want, you can realize the fantasy through LEGO. You can build something with your friends, you can build airplanes or you can imagine the hero plot. It's cool and fun

3	A	I can print things with friends
4	C	It requires teamwork and challenges
5	F	Good for doing it with friends
6	C	You can have a robot fight
7	C	It is funny to have a robot battle with friends
8	C	It stimulates the interest in creativity

Table I-8. Picture Sort Activity Q4 Responses

QUESTION 5 - Which of these are the least interesting

Group #	Response	Rationale
1	A	I've used one before
2	E	It's boring, it takes a lot of time just looking at plants
3	B	It's too difficult and complicated
4	F	I feel bored about it
5	B	It's complicated and boring
6	D	I am not interested
7	E	I don't like aquatic animals
8	D	I don't like music

Table I-9. Picture Sort Activity Q5 Responses

Ranking Activity

List 1:

A. Science
B. Technology
C. Engineering
D. Arts
E. Mathematics

List 2:

A. Make a bottle rocket
B. Create a circuit that turns a lightbulb on and off

C. Build a paper bridge
D. Create a 3D model of a building
E. Create a program or function that sorts a list of numbers

Task 1 - Rank List 1 from least useful to most useful

Group #	Response	Rationale
1	B, C, D, E, A	I think they are all important
2	D, C, B, A, E	Art is not very practical Technology can implement ideas. If you can use technology well, there will be more good things Everyone says science is important. Science produces technology and engineering Math is used in life. Science, technology, and engineering all use math
3	D, C, B, A, E	Art just cultivates one's sentiments Relative to science and technology, engineering is not very innovative Science can produce technology Science can make life smarter and more convenient Math is used in all aspects of mathematical life
4	E, B, A, C, D	I want to be an artist, so art is very important
5	D, C, B, A, E	Art is not very practical Engineering has low technical content Technology can build a lot of useful things Science has a lot of creative ideas Mathematics is the foundation of all science and technology
6	N/A	Didn't finish
7	N/A	Didn't finish
8	N/A	Didn't finish

Table I-10. Ranking Activity Q1 Responses

Task 2 - Rank List 2 from least to most fun to complete

Group #	Response	Rationale
1	D, A, B, C, E	N/A

2	N/A	Didn’t finish
3	N/A	Didn’t finish
4	D, A, C, B, E	N/A
5	N/A	Didn’t finish
6	N/A	Didn’t finish
7	N/A	Didn’t finish
8	N/A	Didn’t finish

Table I-11. Ranking Activity Q2 Responses

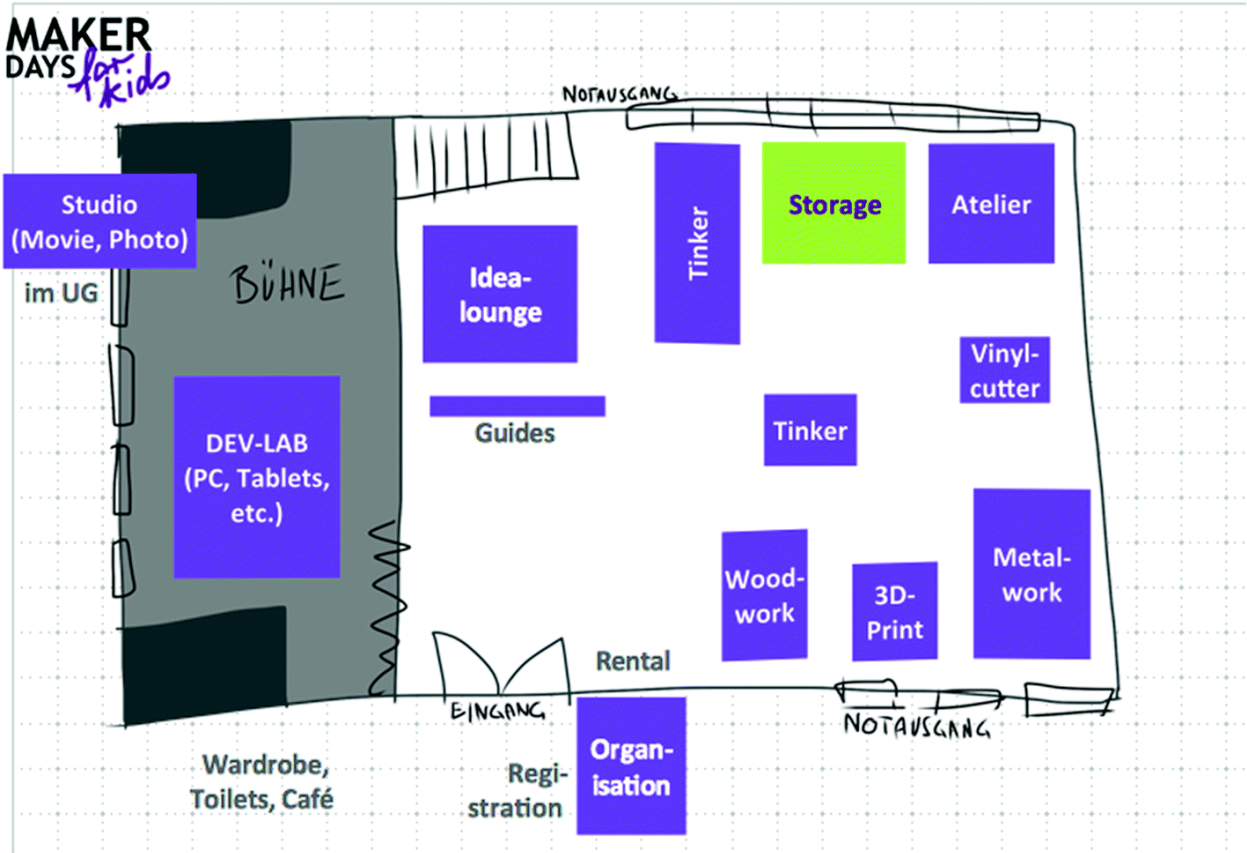
Appendix J

Content Analysis Findings

Materials Suggestions

- Accessible Whiteboards (on wheels?), but this seemed to be for more of a planning/doing work thing rather than strictly making
- 3-D printers were frequently listed.
- Saw different types of cutting materials, be it laser cutters or saws, but I'm not sure how important that would be for the kids
- Usage of LED's was mentioned a couple of times. That would be useful for any coding or robotics
- Legos and other building blocks were mentioned

Space Suggestions



- Concept: Idea Lounge

Sources

https://digital.wpi.edu/show/z029p5040

- In this project, the team determined which equipment they needed in their space, and then developed safety protocols and a layout based on the equipment they chose.
- On page 36 they use a table to compare and contrast different pieces of equipment and what they can do
- On page 69 they show their final recommended layout, after their recommended layout, they list recommendations for the sponsor if they want to alter the layout.
- In the case of this project, they didn't have much space to work with. Their equipment was large so their layout was very restricted by their equipment.

Schön, S., Ebner, M., & Grandl, M. (2019). Designing a Makerspace for Children – Let's Do It. In Educational Robotics in the Context of the Maker Movement (Vol. 946, pp. 3–15). Springer International Publishing. https://doi.org/10.1007/978-3-030-18141-3_1

- In this study on designing an effective makerspace for children, they used 6 principles in their design
    - Realize an open and low-threshold offer
    - Foster participation of children
    - Support idea and innovation development
    - A self-organized competence development concerning new media and ICT (Information Communications Technology)
    - Design a gender sensitive setting
    - Select tools and software that children could continue to use after a period of time
- Example of initial floor plans in section 3.4 "Designing a Makerspace Location"
- Some design considerations
    - Where are the outlets?
    - If the internet is an issue: Where can you install a router?
    - What are low-cost options to mark certain spaces
    - What furniture and equipment do we need?
    - What do we already have?

Steele, K., Blaser, B., & Cakmak, M. (2018). Accessible Making: Designing Makerspaces for Accessibility. International Journal of Designs for Learning, 9(1), 114–121. https://doi.org/10.14434/ijdl.v9i1.22648

- This paper is about designing a makerspace that enables people with disabilities to utilize the space.
- Some questions they used for reflection on the design of the makerspace are…
    - What are the most accessible features of this space?
    - How might we improve this space?
    - What are two things you would tell someone who was creating a makerspace to maximise accessibility?

- After designing a space, they had a group of people with diverse abilities tour the space they created.
    - Note: A person in a wheelchair really enjoyed that almost everything (chairs, tables, machines) were on wheels because it made it easier to move around. However, a person who was vision impaired disliked the feature because they like to make a mental map of the space, and if stuff can move around easily, then their mental map will always have to change.
- List of recommendations on page 7

27 makerspace materials & supplies. (2016, January 25). *Makerspaces.Com*. https://www.makerspaces.com/27-makerspace-materials-supplies/

Main Idea: There are supplies that will be helpful.

- Legos
- Scratch
- Raspberry Pi
- Arduino
- VEX Robotics
- Minecraft

It's a blog promoting different perspectives and options for makerspaces. May not be as credible compared to scholarly articles, but it is good to take it as a reference

http://steps-centre.org/wp-content/uploads/MC-report_final.pdf

Main Idea: Most makerspaces are not sustainable. Imaginative, flexible, and open-ended support is needed for sustainability of makerspaces. Sophie Thomas, manager from RSA Great Recovery, spoke about creating a circular economy. Janet Gaunter, co-founder of Restart Project, suggested repairing and working with broken electronics.
Interviews and information collected from trustworthy individuals.

Smith, A., & Light, A. (2017). Cultivating sustainable developments with makerspaces | Cultivando desenvolvimento sustentável com espaços maker. *Liinc Em Revista*, *13*(1). https://doi.org/10.18617/liinc.v13i1.3900

Main Idea: Discussions with researchers problematized different sustainabilities, which do not align well with economic and social values. Makerspace strengths lie in the encounters they create and the ensuing cross-fertilization of ideas. Can work with local communities to work with 'waste' materials from local productions and consumption activities. Makerspaces can convene activities to attract the suppliers of such materials into thinking creatively.

Appendix K

Interview Findings

Main Points

- Community builds the makerspace
    - Listen to what the users want to create, then buy supplies to help them
    - Need to create a makerspace based on the needs of the community
        - If the community does not need a makerspace, no need to build it.
    - The Modern Makerspace Movement leads to industrial revolution on a building-scale.
- 3D Printers and Laser Cutters seem to be the most essential tools of makerspaces (maybe more of a high school level makerspace)
    - With 3D Printers and Laser Cutters, you can achieve a lot in terms of making.
    - May encounter limitations, but probably not with kids.
- If you have a piece of equipment in a makerspace, you must have someone who is very experienced at using that equipment on your team.
    - Repairs are expensive, you need to know the limitations of what a machine can do for when someone wants to make something
    - May also need a supervisor for kids to teach them how to use certain tools (not dangerous ones but simple ones)
- Makerspaces are a place to work, not just a place for equipment and tools
    - Make sure there is adequate space for the user to work and collaborate, as well as space for the equipment
    - Having a break area may be useful, when working on a project, it is natural to want to take breaks.
    - After making a creation, it may be open source for other students to build or use.
- Let the kids learn and do the work
    - Emphasis on letting kids lead their own projects and interests
    - Emphasis on volunteers helping to maintain the makerspaces (student leadership)
    - Concept of first teaching the kids how to use the tools/facilities, and then giving them the space to do what they want and create on their own (some supervision, but at the end of the day, the students are the ones making/working on their own projects)

Examples of Creations that we've seen

- Animatronic baby yoda stuffed animal
- Snowman made from laser cut wood materials (doesn't have to be laser cut) and LEDs for buttons and a nose that light up
- An electronic magic 8 ball (that's not in the shape of a ball)
- Battlebots (tiny combat robots, often made of spare parts)
- A guitar made from scratch
- Flashlight that shines the big dipper (a wooden cover that has laser cut holes in the shape of the big dipper is placed over the light, the light was an LED)
- Name Tag with LED lights to emphasize their names.

Some equipment / tools that we've seen

- 3D Printers
- Laser Cutters
- Woodshop tools
    - Drill press, rotary saw, drum sander, etc.
- Soldering Stations
- Sewing Kits
- Laptops → for elementary students for scratch and basic programming
- CAD packages.

Appendix L
Virtual Tour Findings

Main points
- Makerspace should be organized in a manner that promotes productivity
    - Layout of equipment in relation to each other should be considered
    - Amount of open space should be considered
    - Storage of materials and the user's accessibility to them should be considered

Layout
- Storage
    - All smaller things were organized into bins and boxes
    - Boxes were placed next to walls with labels on them
    - Shelves on the wall for space efficient storage
    - Corrugated cardboard boxes
- Organization
    - Dividing the makerspace into sections
    - Dedicated section for picking up finished 3D prints and laser cuts
- A lot of open space
- Space is well decorated and has fun themes
- Tables in center of space for collaboration
    - Some have computers
- Equipment that is used often together is placed together

Equipment
- **Laser Cutter**
- Construction blocks / pieces
    - **Legos**
    - Build a marble run track
- Soldering Iron
- Sewing machines
- **3D printers**
    - They had specific filaments
- CNC routers
- Woodworking tools
    - Scroll saws
- **Robots**
    - Ozobots
- **Computers**
- **Green screen**
- Vinyl cutter
- TinkerCAD
- Doodle 3D
- Audio booth

- Digital cameras
- Textiles
- Construction materials and tools

Activities

- Soldering Circuits
    - Make a circuit to power a lightbulb
- Make paper shadow puppets
- Laser Cut String Art
    - Use laser-cut designs to weave and embroider
- LEGO challenges
    - Build anything that is taller than you
    - Build anything that can support the weight of a robot
    - Build an animal or creature
- Make an ornament using a laser cutter
- Make 3D shapes using toothpicks and mini marshmallows
- Program robots to move around
- DIY DJ Booth
    - In the example given, they used spoons and forks as conductors and had them wired up to a launchpad. The kids would then ground themselves and when they touched a fork or spoon a signal would pulse and trigger a sound on the launchpad.
    - Kids can change the sounds on the launchpad to compose their own music
- Using thingiverse to download or upload models for 3D printing