Developing a STEAM Strategy for the Boys & Girls Club of Worcester

An Interactive Qualifying Project Report
Submitted to the Faculty of
Worcester Polytechnic Institute
In partial fulfillment of the requirements for the degree of Bachelor of Science

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Date:
May 1, 2018

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Project website link: http://wp.wpi.edu/wcpc/projects/projects-by-term/spring-2018/**steamforbgcw**/

Abstract

The goal of this project was to help the Boys & Girls Club of Worcester (BGCW or Club) implement a sustainable after-school STEAM (Science, Technology, Engineering, Art, and Mathematics) program. Using the *Everything STEM Planning Guide* created by the Boys & Girls Club of America, we completed a STEM Readiness Pre-Assessment, STEM Improvement Plan, and STEM Readiness Post-Assessment. With BGCW staff and active participation of members aged 9-12, we also made immediate improvements through designing and piloting high yield learning activities using the Club's new Lego Mindstorms kits and 3D printer. We created a volunteer guide and recommendations for long-term improvements to help sustain the BGCW's STEAM program.

Acknowledgements

This project would not have been possible without the input and support of the staff of the Boys & Girls Club of Worcester (BGCW or Club) and the members of the Worcester Polytechnic Institute (WPI) community. The staff of the BGCW were welcoming and helpful throughout the project. Our Professors Scott Jiusto and Creighton Peet provided insight and guidance during the project. Lastly, we would like to thank all the members of the BGCW for making this project enjoyable and rewarding.

The following people provided their assistance throughout the project and we would like to thank them for their contributions.

The Boys & Girls Club of Worcester

Bolaji Ojo – Education Coordinator

Liz Hamilton – Executive Director

Joanne Fowling – Director of Operations

Teju Richardson – Human Resources Manager

Worcester Polytechnic Institute

Laura Robinson – Librarian

Shari Weaver – STEM Education Center

Stephan Barthold – Volunteer at the Boys & Girls Club of Metrowest and WPI student

Executive Summary

Introduction

American students have fallen to the middle of the pack internationally in science and math learning, with relatively few pursuing careers in Science, Technology, Engineering, and Mathematics (STEM) fields (US Department of Education, 2014). After-school programs are unique environments with the opportunity to introduce STEM in creative and engaging ways, including by adding in art to create "STEAM" programs. By implementing key teaching concepts such as activity before content (ABC), divergent thinking, and cooperative learning (Eisenkraft, 2003; Hunter-Doniger & Sydow, 2016; Kelly & Zhang, 2016), these programs can make a major impact on how students develop. The Boys & Girls Club of America (BGCA) is a national organization that strives to provide an inclusive and helpful atmosphere for its members. The mission of the BGCA is, "...to enable all young people, especially those who need us most, to reach their full potential as productive, caring, responsible citizens" (BGCA, 2017 p. 6). The Boys & Girls Club of Worcester (BGCW or Club) is the local affiliate working to get its members more engaged in STEAM subjects and activities. The BGCW already has several resources, such as a new 3D printer and Lego Mindstorms kits that can be utilized during STEAM activities. Even with the new technology that the Club has acquired, however, there is still a stigma against STEAM among the members. Overcoming this stigma was one of the main challenges that came with integrating STEAM into the Club. Another challenge was the Club not having enough people power (staff and volunteers) to adequately support a robust program. Our team collaborated with the staff at the BGCW to develop a sustainable STEAM strategy at the Club, focusing on the members from ages nine to twelve active in the Club's Learning Center.

Background

STEAM is a strategy that focuses on building a relationship among all component subjects (STEAM Education, 2015), especially through a hands-on approach that teaches the subjects in unison (Hom, 2014). There are, however, several challenges to STEAM. Many students are not interested in STEAM subjects because, for a variety of societal factors many consider these subjects too difficult or unrelatable (Sithole et al., 2017; van Tuijl & van der Molen, 2016).

When teaching STEAM subjects, three key concepts have been found to optimize learning for students. They are Activity Before Content (ABC), divergent thinking, and cooperative learning. ABC is a method developed by Arthur Eisenkraft, PhD, of UMass Boston (Bybee et al., 2002) in which students are first engaged in an activity and then the material they are supposed to learn from the activity is presented afterward (Eisenkraft, 2012). Divergent thinking is the concept of exploring various solutions to a problem (Hunter-Doniger & Sydow, 2016). This concept is pivotal to creativity because it allows students to look at a problem from multiple angles and think of novel solutions. Cooperative learning can be incorporated in STEAM and involves placing students in groups to accomplish a task as a team (Gillies, 2016). When conducted correctly, cooperative learning can foster positive group interactions and direct the team in their findings. Cooperative learning simultaneously teaches the subject matter, important social skills, and a sense of respect for peers.

These concepts were central to designing a STEAM program for the BGCW which provides a safe after-school environment for children around Worcester to participate in various activities that interest them. The Club is open to children ages 8-18 and offers programs in several different areas, such as athletics and the arts.

Methodology & Results

To develop a successful STEAM strategy and stimulate member interest in STEAM activities, we collaborated with the staff of the BGCW on a set of objectives based on the *Everything STEM Planning Guide* of the Boys & Girls Club of America (Fowlkes et al., 2017). This document contains systematic guidance on how to create a STEM program that can be evaluated and enhanced over time. The guide also works well for assessing STEAM because the same ideas generally apply. The first objective was to use the *Everything STEM Planning Guide's* "STEM Readiness Assessment" to evaluate the Club's STEAM program at the beginning of our project across five key categories (Table 1). The assessment found that the Club is primarily at the foundational level and with a little work, could move to intermediate.

Table 1: STEM Readiness Pre-Assessment Total Scores

	SCORE:	LEVEL:
TECHNOLOGY	4 out of 5	Intermediate
SPACE	1 out of 4	Foundational
POLICIES	1 out of 3	Foundational
PROGRAMMING	1 out of 4	Foundational
STAFFING	2 out of 11	Foundational
TOTAL	9 out of 27	Foundational

For the next objective we utilized the "STEM Improvement Plan" from the *Everything STEM Planning Guide*. We collaborated with several staff members on the Improvement Plan to understand which improvements were feasible. Through consideration of the results from the STEM Readiness Pre-Assessment, priorities were agreed upon and immediate improvements implemented in four of the five program categories including:

Technology and Hardware

- Assembled 3D Printer
- Prepared and Assembled Lego Mindstorms Kits
- Fixed Smart Board

Space

- Optimized Learning Center for STEAM Activities

Programming

- Lego Mindstorms: Developed, tested, refined, and documented a Race Track Activity and a Programming Activity
- 3D Printer and TinkerCAD: Created tutorial videos for TinkerCAD and conducted a 3D Printer Drawing Activity

Staffing

- Created a Volunteer Guide to assist with running the Learning Center and STEAM activities
- Team members served as volunteers at the Club with STEAM backgrounds

After implementing these immediate improvements, we performed the STEM Readiness Post-Assessment to see how the improvements affected the BGCW's STEAM program rating (Table 2). The post-assessment showed that with volunteers who have STEAM experience, a dedicated space, and increased time allotted to the program, the BGCW's STEAM program went from the foundational level to the intermediate level.

Table 2: STEM Readiness Post-Assessment Total Scores

Criteria	Description	Score	Max
	Technology & Hardware	**4**	**5**
Wi-Fi	Sufficient broadband is available to provide for all programming, all administrative and some members' needs	**2**	**2**
Technology	A variety of computing devices are available, with a sufficient number to support programming and individual member needs	**2**	**2**
Management	Club has not completed the Technology Assessment in the Club Technology Planning Guide or created a plan for tech infrastructure improvements	**0**	**1**
	Space	**2**	**4**
Dedicated	Club dedicates a space for STEM at least four hours per week	**2**	**3**
Other	Club does not leverage other program spaces for STEM and integrates STEM into other programs	**0**	**1**
	Policies	**1**	**3**
BYOD	No Bring Your Own Device Policy	**0**	**1**
Mobile Technology	Internet safety education is part of programming	**1**	**1**
Wi-Fi	Members' personal devices are not incorporated into STEM programming	**0**	**1**
	Programming	**2**	**4**
Hours	Deliver STEM programming at least three hours per week	**2**	**3**
Variety	Does not run advanced STEM programs, characterized with longer dosage cycles (i.e. APP LAB, FIRST Robotics, etc.)	**0**	**1**
	Staffing	**5**	**11**
Programing Staff	No part-time STEM program staff coordinator	**0**	**3**
Technology Staff	No part-time technology staff	**0**	**2**
Volunteers	Use volunteers with backgrounds in STEM at least monthly	**3**	**3**
Training	Provide at least three annual oppurtunity for staff to participate in STEM-related training	**2**	**3**
	Total:	**14**	**27**

Once the immediate improvements and post-assessment were completed, we reflected on the improvements and discussed with staff, and drew the following insights designed to help future staff members and volunteers improve and operate the STEAM program.

Insights Regarding Running the STEAM Program

- Staffing and space are the top priorities for the STEAM program to become sustainable.
- Staff wants to start with one hour dedicated to STEAM per week and build from there.
- The Club's Fenway Room is not an option for dedicated space for the STEAM program.

Insights Regarding Lego Mindstorms

- The STEAM activities using the Lego Mindstorms kits incorporated well the three key concepts.
- Members like building and controlling the robots.
- Members get excited about controlling the robot and sometimes are rude to their peers while waiting for their turn.
- Members like programming the robot and enjoy completing challenges with the robots.

Insights Regarding the 3D printer and TinkerCAD

- The STEAM activities using the 3D printer and TinkerCAD incorporated well the three key concepts.
- Video tutorials for TinkerCAD will most likely work better than written tutorials.
- It does not work well if multiple members use one TinkerCAD account.
- Members should not operate the 3D printer themselves.

Insights Regarding Facilitating STEAM Activities

- Members work better on activities that have a common goal rather than a competition.
- Members usually work better together in small groups than large groups.

Insights Regarding BGCW Staff and Volunteers

- The staff and volunteers work hard to make sure the members have a safe and supportive environment to come to after-school.
- The BGCW would benefit from more staff members.
- The BGCW staff have been trying to fund a full STEAM program for several years.

Recommendations for Long-Term Improvements

The BGCW is in the process of developing a successful STEAM program for its members. The technology and hardware components of the program are excellent and the other categories of the "STEM Readiness Assessment" and "STEM Improvement Plan" can improve significantly. The team compiled several recommendations as the Club continues to develop its STEAM program. The recommendations are primarily for increasing staffing levels and volunteer contributions to the Learning Center:

Recommendations for the Learning Center

- Determine a specific time and structure for the STEAM program.
- Clarify volunteer expectations while in the Learning Center.
- Reaffirm the Learning Center purpose and rules with members.

Recommendations for BGCW Staff

- Hire a part-time dedicated STEAM staff member.
- Regularly review volunteer program performance at staff meetings.
- Form a stronger, ongoing connection with WPI.

Conclusion

This project aimed to develop a sustainable STEAM strategy for the BGCW and to stimulate member interest in STEAM activities. Many of the members do not have the same opportunities as children growing up in wealthier neighborhoods. The BGCW would like to level the playing field and provide opportunities in STEAM for its members. We hope the STEAM activities at the BGCW will inspire members to pursue their passions, be it STEAM or something else. We also hope that the STEAM strategy implemented at the BGCW will be sustained and further developed with new activities that cater to member interest.

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Chapter 1: Introduction

The United States became a global leader to some extent through the hard work of its scientists, engineers, and innovators; however, today few American students pursue expertise in science, technology, engineering, or mathematics (STEM) fields (US Department of Education, 2014). In November 2009, President Obama launched the Educate to Innovate program, prioritizing training teachers in STEM subject areas. The President's priority was for American students to "move from the middle to top of the pack in science and math" (para. 4). One key challenge is that many students, especially underprivileged minorities, do not have access to quality STEM learning opportunities. Some students also avoid these subjects because they are either uninterested or have low self-esteem (Litzler, 2014). Those with low self-esteem may feel that they lack the intelligence to study these subjects. One reason there is a shortage of domestic STEM professionals is many US students lose interest at a young age. The current teaching style for math and science often inhibits students' creativity. Over time, what little interest students had fades. When applying to college, less than 20 percent of students enroll in STEM-related majors (Snyder & Dillow, 2015). It is believed that integrating art into STEM, which becomes STEAM, encourages creativity and engagement and can improve learning (Tillman, An, & Boren, 2015). STEAM education, in both schools and after-school settings, is an area of opportunity for students to become more interested in science and math.

After-school programs are unique environments with the opportunity to introduce STEAM in a creative and engaging way. The Boys & Girls Club of America (BGCA) wants to facilitate integrating STEM programs into local Clubs and has developed the *Everything STEM Planning Guide* to do so (Fowlkes et al., 2017). The guide describes the steps needed to build a STEM program within a Club, and breaks down the program into five categories including technology and hardware, space, policies, programming, and staffing. The Boys & Girls Club of Worcester (BGCW or Club) is an organization contributing to the success of youth in STEAM subjects, however, it has only made limited progress in implementing a successful STEAM program. The BGCW already has several resources, such as a new 3D printer and Lego Mindstorms kits that can be utilized during STEAM activities. Yet, these technologies have so far not been used in STEAM education at the BGCW and there is some uncertainty about how to integrate them into STEAM. There has never been a dedicated space or time for STEAM activities, or a STEAM coordinator, or trained volunteers to conduct these activities. Without the necessary staffing and space, the new and impressive technologies acquired by the BGCW have been unable to be put to good use.

Over the past decade much has been done to understand successful methods of teaching STEAM while overcoming issues such as low self-esteem. Key concepts to keep in mind while teaching STEAM are activity before content (ABC), divergent thinking, and cooperative learning (Eisenkraft, 2003; Hunter-

Doniger & Sydow, 2016; Kelly & Zhang, 2016). Following these concepts can make STEAM more accessible to students and empower them. Another way to increase STEAM accessibility is to provide hands-on activities that stimulate interest. Various local Boys & Girls Clubs, such as in Framingham and Fitchburg/Leominster, have incorporated a STEAM strategy throughout everyday operations. According to a volunteer of the Boys & Girls Club of Metrowest (Stephan Barthold, personal communication, February 12, 2018), Framingham's Club offers a separate program that has themed weeks of hands-on activities. Fitchburg/Leominster's Club takes this even further and requires a STEAM subject to be a daily activity for every member (Boys & Girls Club of Fitchburg and Leominster, 2018). This includes a FIRST Robotics Team for the high school students and a Lego League Team for the younger students.

Although attempts have been made to integrate science and math education programs at the BGCW, the Club still lacks a sustainable STEAM strategy. A WPI project team attempted to implement a STEM program in 2015, however, the program dissolved once the project ended (Bittle, Braith, Hussan, & Sullivan, 2015). That project successfully stimulated interest in STEM by designing a curriculum that catered to students' interests. However, this project was presented to members as a separate program that students had to join, rather than being integrated into the Club's daily routine. Once the project ended, only those students who had worked hands-on with the project team remained enthusiastic about the program. This ultimately affected the program's longevity; the Club's staff was unable to sustain the program long-term.

The goal of this project was to collaborate with the staff of the BGCW to develop a sustainable STEAM strategy and stimulate member interest in STEAM activities. To achieve this goal we used the BGCA *Everything STEM Planning Guide* to determine the current capabilities of the BGCW and make an improvement plan for the Club (Fowlkes et al., 2017). Some high yield learning activities involving Lego Mindstorms kits and the 3D printer were tested at the club. The hands-on activities we designed matched the interests of the members, in particular those who participate in the Power Hour program, which is a program for students to complete homework for two hours each afternoon (Boys & Girls Club of Worcester, 2018). Integrating STEAM activities advanced the Club's effort to help members grow into well-informed citizens. For the STEAM program to be successful, it is essential that member interest remains high. This was done by working cooperatively with the Club's staff and volunteers to keep everyone at the BGCW interested and engaged in the program. Ultimately, these activities should be able to get more members interested in STEAM and enable them to realize their full potential.

Chapter 2: Background

Implementing a STEAM strategy at the Boys & Girls Club of Worcester (BGCW or Club) requires overcoming a variety of challenges in order to be successful. In this chapter we begin by discussing STEAM programs in general, including what goes into a STEAM program and the challenges that must be overcome. We also discuss pedagogy in the classroom and in an after-school setting specifically. We explore how it relates to STEAM in regards to building self-esteem and the key concepts necessary to implement STEAM activities. The Boys & Girls Club of America is described as a whole to show how some Clubs have made progress in accomplishing what the BGCW would like to achieve. To explain the learning environment in which the BGCW is trying to work we provide an overview of Worcester as a city, its public school system, and the roadblocks low-income students face. Finally, we describe the daily operations of the BGCW, and how a STEAM program might contribute to the Club.

2.1: What is STEAM?

STEAM stands for Science, Technology, Engineering, Arts, and Mathematics (STEAM Education, 2015). STEAM is a strategy that focuses on building a relationship among all subjects. All subjects support one another to demonstrate how the world works. There are several challenges to STEAM that are exacerbated by sociocultural factors and stigma. Many students are not interested in STEM subjects because they are thought of as difficult or out of reach based on societal factors (Sithole et al., 2017; van Tuijl & van der Molen, 2016). Despite these misconceptions, STEAM can be for everyone and students should be encouraged to pursue STEAM careers if they are passionate about the subject matter. This section discusses STEAM strategy, the challenges to STEAM, sociocultural influences, and ways to overcome STEAM stigma.

STEAM originated from STEM, which stands for Science, Technology, Engineering, and Mathematics. Through a hands-on approach the curriculum teaches the subjects in a well-integrated way (Hom, 2014). “The Obama administration announced the 2009 ‘Educate to Innovate’ campaign to motivate and inspire students to excel in STEM subjects” (para. 3). The campaign also trained more teachers to have adequate backgrounds to teach the STEM curriculum due to an increase in student interest. As of 2014, “thirteen agencies are partners in the Committee on Stem Education (CoSTEM)” (para. 4). In addition, the CoSTEM intends to invest in a joint national strategy for K-12 STEM education. With increased funding, STEM engagement and experience can be adapted to appeal to students of all ages.

The STEAM curriculum finds a fun and engaging way to pique the interest of students, while teaching them crucial lessons in relevant subjects (STEAM Education, 2015). The STEAM Education website (2017) states, “The philosophy of STEAM revolves around the concept that STEAM = Science & Technology interpreted through Engineering & the Arts, all based in Mathematical elements” (para. 4).

This strategy is used in both classroom settings and after-school programs. Educators in the program use teaching techniques in their specialized subject to optimize productivity and student learning. “STEAM lessons are built with educators, for educators, who contribute to creating and updating them regularly” (para. 8). Educators choose how to teach topics through the outlined lessons or making up original lesson plans. This freedom gets educators excited about teaching and caters to their students so they get the most out of lessons. Students who go through STEAM programs enjoy learning because “they are almost always investigating things that matter to them” (para. 11). Most lessons attract students’ attention by introducing the topic’s application in the real world. Once interest is piqued, teaching becomes simpler because the student wants to learn, rather than being forced to learn. Students learn at their own pace. The idea behind STEAM strategy is students “[learn] about everyone’s situations and what the world best needs to go forward” (para. 15). Learning will become more efficient and technically advanced with everyone working together.

Challenges to STEM also affect STEAM, since the latter is derived from the former. The challenges are summarized in Figure 1.

Figure 1: Challenges to STEAM

The addition of art to STEM has helped alleviate some of the problems, although there are several that still need to be addressed, as shown above. There has been a push to advance STEAM in the United States for several years (Hom, 2014). Students in the United States score lower on math and science standardized tests as they get older, while many students from Singapore, South Korea, and Taiwan continue to be more proficient (National Science Foundation, 2014). There are several reasons students avoid STEM topics. Many students find STEM subjects difficult and boring (Sithole et al., 2017). Some feel they will not understand the material and their efforts will be wasted (van Tuijl & van der Molen, 2016). These attitudes start early in a child's mind and continue as they age. For example, timed math tests in elementary school can lead to math anxiety (Boaler, 2017). These tests could be restructured to avoid anxiety and possibly lifelong negative attitudes towards math. Another reason is that topics are not presented in a way that excites students. This can happen if teachers do not adapt their curriculum to encompass new discoveries within STEM fields (Sithole et al., 2017). By making assignments reflective of current findings within STEM fields, work can become more relevant and intriguing.

Various sociocultural influences contribute to a lack of interest in STEM. According to the American Psychological Association (2018), one influence is a family's socioeconomic status (SES), which is defined as "the social standing or class of an individual or group... measured as a combination of education, income and occupation" (para. 1). If a family has a low SES and lives in a community where most people are in the same situation, the schools generally have fewer resources and capabilities (van Tuijl & van der Molen, 2016). This limits the activities teachers can do with students. In addition, students with low SES often feel they cannot achieve high goals and therefore avoid STEM fields. This decision derives from low self-esteem and limited STEM accessibility. Another influence is gender stereotypes. According to van Tuijl and van der Molen, society places different expectations on males and females that impact their values. Males tend to value "money and power", and females tend to value "family and helping others" (para. 29). Males want to succeed at work to live up to their values, and females want to have careers where they can have time for their families. STEM fields are thought of as demanding and with difficult hours, which leaves little time for family. These misconceptions often turn females away from STEM fields. In addition to the difference in values, research has shown that science is thought of as a masculine field and only women comfortable in this atmosphere should have science based careers. If women do not want to work in this atmosphere, they choose a different career path. These influences contribute to women pursuing jobs outside of the STEM fields.

The stigma against STEM has been firmly implanted by several societal factors, in particular parents, teachers, and the media (van Tuijl & van der Molen, 2016). Nevertheless, there are ways to overcome the stigma that society has built around STEM. One tactic is to try to get parents to change their attitudes about STEM to encourage their children to embrace the challenges of STEM subjects. This encouragement would increase their children's self-esteem and resilience to other social pressures to avoid STEM subjects. A second tactic is for teachers to take an individualized approach to helping alleviate misconceptions about STEM subjects. Every child has a different reason he/she does not like STEM. By working with students individually, teachers can show that STEM subjects are accessible to everyone. A third tactic is to try to change the stereotypes around STEM. Many people picture a mad scientist or someone who looks like Einstein when they imagine STEM professionals. They believe working in STEM means they will have to make several sacrifices to their personal life, such as free time and social standing. There are also stereotypes that women should not be in STEM fields (Sithole et al., 2017). While none of these stereotypes is true, the public's knowledge will need to be improved before more people are interested in STEM fields.

2.2: Pedagogy in the Classroom and in After-School Programs

Pedagogy is defined by Merriam-Webster (2018) as, "the art, science, or profession of teaching" (para. 1). There are certain teaching methods that work well regardless of grade level. For instance, infusing art with math and science allows students to think creatively while also reinforcing art (Tillman, An, & Boren, 2015). One middle school teacher had her students design biomes and build organisms that lived in their biomes (Herro & Quigley, 2016). The students used their creativity and science skills to design the biomes and artistic skills to construct the organisms. Bronson and Merryman argue the push for STEM subjects in school has increased students' intelligence but decreased creativity (Hunter-Doniger & Sydow, 2016). This creates an issue when students compete for jobs because employers want well-rounded individuals who can think outside of the box. However, integrating art across STEM subjects allows for more creativity and student engagement in the classroom. There are several teaching methods to integrate STEAM subjects, including cross-disciplinary integration (Quigley & Herro, 2016). When teachers engage students by incorporating are throughout STEM subjects, the students do better in STEM subjects (Dwyer, 2011; Kelly & Zhang, 2016).

There are a few ways subjects can be taught together. One method is cross-disciplinary integration where a subject is looked at from the perspective of another (Quigley & Herro, 2016). This is the foundation for moving STEM to STEAM (Dwyer, 2011). Cross-disciplinary integration with art works well as it encourages children to think creatively and outside the normal realms of schoolwork. Working with art also does a better job at teaching students about the benefits of paying attention and focusing on individual tasks. This focus and attention has been proven to carry over to other subjects. The integration of art across subjects in schools has shown positive results (Dwyer, 2011). Students who participated in art integration programs felt encouraged and more capable of tackling topics they previously felt discouraged and overwhelmed by. Statistically, schools that introduced this integration also found that these programs had lower student dropout rates than what was typical.

While integrating subjects is an important teaching tool, so is student engagement. Engagement becomes a more important issue as students move into secondary education (Kelly & Zhang, 2016). The student-teacher relationship is a key factor to success in the classroom. Support from teachers contributes to student engagement, more so in secondary school than elementary school. The support for students can come from other sources as well. For instance, a student-mentor relationship could have similar benefits outside the classroom as it could inside. A supportive atmosphere also improves behavior and is an effective way of reaching at risk students. A good method to engage students is problem-based learning with relatable, real world problems (Quigley & Herro, 2016).

2.2.1: Key Concepts to Consider When Introducing STEAM Topics

Several key concepts should be considered when STEAM topics are introduced to students. These concepts can be used when students participate in activities to learn the material being presented. They include the Activity Before Content (ABC) approach, encouraging divergent thinking, and utilizing cooperative learning. These concepts can be used throughout formal education and in an informal setting, such as an after-school program. When students are participating in STEAM activities, the key concepts should be evident so the students learn effectively.

ABC Learning – Activity Before Content

Activity Before Content (ABC) is a method developed by Arthur Eisenkraft, PhD, of UMass Boston (Bybee et al., 2002). Dr. Eisenkraft works at the Center of Science and Math in Context (COSMIC). COSMIC's mission statement "is to advance high quality teaching and learning in science and math for all students at K-12, undergraduate, and graduate levels" (para. 1). 5E consists of 5 stages: Engage, Explore, Explain, Extend/Elaborate, and Evaluate. The Engage stage gets students involved and excited in what is to come while allowing the instructor to assess prior knowledge. The Explore stage lets students gain understanding on their own, while the Explain stage allows the instructor to teach content students missed. The Extend/Elaborate stage allows students to return to earlier segments with their new-found knowledge, and the Evaluate stage gives the instructor feedback on the students' learning. This method is commonly accepted and utilized by teachers.

Dr. Eisenkraft (2003) is the main driving force for changing 5E to 7E. The shift from 5E to 7E is shown in Figure 2.

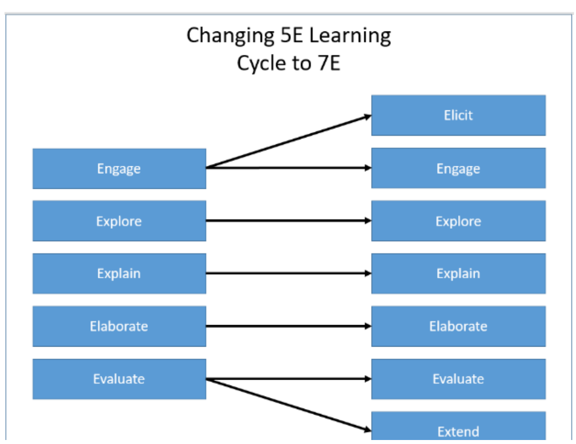

Figure 2: 5E and 7E Models

After working with 5E and researching its strengths and shortcomings he proposed several changes. First, he split the Engage section into Elicit and Engage. Second, he rearranged the Extend/Elaborate and Evaluate stages into a set order of Elaborate, Evaluate, and Extend. He found that many teachers start an activity without an understanding of the students' prior knowledge. The mind can work in several ways and the conclusion a student arrives at to explain a phenomenon could differ from what an instructor intends. Thus, it is important to elicit prior knowledge from the students. Dr. Eisenkraft also found many teachers opted for the Elaborate phase rather than Extend. Teachers typically assigned problems and examples that moved into specifics on the subject. The problem with this is that students have a difficult time connecting subjects to real world experiences. This connection is called the "transfer of learning," and to help with this, Dr. Eisenkraft encourages making the Extend stage a permanent fixture in the process to connect to real world applications. This is visible in many college level textbooks as many include transfer of learning examples after covering major concepts or at the end of chapters.

While these methods might work well for formal education, they are too in-depth and thorough for after-school programs (Eisenkraft, 2012). The main ideas of 7E can be summed up with the term ABC, or "Activity Before Content." This phrasing alludes to a simplified strategy to accomplish most of the 7E method. Dr. Eisenkraft has recently been pushing to simplify 7E to this, when necessary, as it conveys the idea in simpler terms. ABC is a helpful approach to use when designing STEAM activities and programs in an after-school setting.

Divergent Thinking

In addition to ABC, STEAM activities should also incorporate divergent thinking, which is the concept of determining various solutions to a problem (Hunter-Doniger & Sydow, 2016). This concept is pivotal to creativity because it allows students to look at a problem from multiple angles and think of novel solutions. An example of divergent thinking is when students were asked to use their knowledge of Athens, Greece, to hypothesize how society would adjust if the marketplace was demolished (Kousoulas, 2010). The students were asked to brainstorm as many ideas as possible. This question utilizes divergent thinking because students are being asked to develop several solutions to a hypothetical problem.

Divergent thinking also strengthens other skills, such as handling stress and social situations (Hunter-Doniger & Sydow, 2016). Several studies on this topic have concluded that divergent thinking decreases as people age. For instance, George Land and Beth Jarman (2012) conducted a study that showed divergent thinking declines as children grow up. They gave a test to five, ten, and fifteen-year-old children that measured their level of divergent thinking. The five year olds scored significantly higher than the ten and fifteen year olds. The ten year olds also scored higher than the fifteen year olds. This evidence demonstrates that as children grow up, they are conditioned to discredit their divergent thinking skills. However, these skills will assist them in the future, especially when they begin looking for jobs because many employers want their employees to think outside the box (Hunter-Doniger & Sydow, 2016). Therefore, it is important that divergent thinking skills are practiced at a young age and encouraged throughout a child's development.

Cooperative Learning

Studies conducted in the late 1980's found that in learning environments that encourage competition or individual goal-setting students performed nearly identically in terms of how much they benefited from these environments (Gillies, 2016). There was, however, a learning environment that was better: one that encouraged students to work together and learn as a group. This is called cooperative learning, and it is a pillar of effective education.

Cooperative education can be incorporated in STEAM activities as well. It promotes learning by placing students in groups to accomplish a task as a team (Gillies, 2016). Placing students into groups breaks subjects down into easily learned sizes, while the blanks are filled in and taught at the appropriate educational level by the peers in the team. When instructors are involved correctly, they can foster positive group interactions and direct the team in their findings. If the group works well together, the instructor can foster discussions that cement what they have learned on their own. If a group does not get along, however, an instructor can encourage problem-solving and conflict resolution that resonates more later in life than lessons taught in a competitive or individual environment. Cooperative learning teaches the subject matter, as well as important social skills, and a sense of respect, which is impactful.

This method has a few shortcomings that can be addressed if an instructor is diligent (Gillies, 2016). The main problem is some groups do not work well together. All it takes for a group to derail is one lazy member, or one dissenting opinion. The success of a cooperative learning environment is the instructor's responsibility. It is up to the teacher to ensure problems in the group are resolved in a timely and positive manner. As long as instructors teach the necessary social skills, promote individual accountability, and have students reflect on what has been done, cooperative learning will thrive.

2.3: Self-Esteem in regards to STEAM

Self-esteem is a construct that should be considered when teaching STEAM to students, both in a formal and informal setting. Self-efficacy, which is the belief in one's ability to reach a desired outcome, should also be considered (Litzler, 2014). There are groups of people, such as women and minorities, who generally have lower self-efficacy than white males in regards to STEM subjects. This is due to a variety of factors, although primarily include environmental factors. However, there are strategies to build self-esteem and in turn will improve one's self-efficacy. These strategies can be used in a classroom or in an after-school setting.

Self-esteem affects everyone and the activities they choose to do. How people feel about themselves can determine the challenges they decide to tackle. For instance, women and minorities are underrepresented in STEM fields, and low self-esteem is thought to contribute to this situation (Litzler, 2014). Another contributing factor is self-efficacy. Women generally have lower self-efficacy than men in STEM fields because they are more critical of themselves in regards to STEM subjects. Minorities often feel that others believe they are less intelligent than their white peers. Both women and minorities succumb to social pressure from their peers and teachers; they are given social cues that STEM careers are not for them, and that they should find another career path. Women especially feel social pressure if they want to study engineering. In addition to social cues, minorities do not have many role models they can connect with in STEM fields. These factors cause a disparity in the number of women and minorities represented in STEM as opposed to white males.

A study was conducted in which 7,833 undergraduate students studying STEM at 21 different schools were given an online questionnaire asking about their confidence in STEM (Litzler, 2014). Two models were used to analyze the data. The first model looked at race and gender of different groups and compared them to white men. The second model looked at race and gender in a similar way as the first model, but also took other factors that could influence confidence in STEM into consideration, such as professors and student relationships. The first model determined that women, expect Hawaiian/Pacific Islanders and Native Americans women, had lower confidence in STEM compared to white males. Asian and Hawaiian/Pacific Islander men also had lower confidence in STEM compared to white males. However, when other variables were considered in the second model, African-American and Hispanic males had higher confidence in STEM than in the first model. This means that these two groups are significantly impacted by the factors in their environment that were controlled for in the second model. The second model shows that positive relationships among teachers and students can overcome students' low self-esteem in regards to STEM. The results of this study show how factors can influence how people perceive their self-esteem in STEM fields. They also support that women generally have lower self-esteem than men in STEM fields.

There are several ways to build self-esteem. Kymberlee O'Brien (personal communication, January 23, 2018), a psychology professor at Worcester Polytechnic Institute, provided insight on how to advance self-esteem through a discussion with participants. This discussion could happen in a classroom or after-school structured environment. She suggests that a teacher start by creating a safe space where people can acknowledge their feelings. This is often achieved by the leaders of the discussion sharing their feelings first so participants are willing to share their own. During the discussion, the leaders should emphasize that the participants are central to the conversation. This is especially true if the participants have a lower socioeconomic status. People with a lower SES often feel marginalized, and the leaders should make them feel included during the discussion. As part of the conversation, leaders should talk about how practicing an activity, regardless of the domain, builds skill and self-esteem. Another way to increase self-esteem is by working in small groups. There is less risk involved with small groups as opposed to large groups. Therefore, small groups are an excellent environment for building self-esteem.

2.3.1: Student-Teacher Relationship (Volunteer-Member Relationship)

Students' relationships with their teachers are a crucial part of their education. By the time students reach high school they tend to have a preconceived notion of what is expected from them in regards to classes (Kelly & Zhang, 2016). Students who previously excelled continue to lead their class in academics, while students who struggled continue to follow a downward trend. Directly related to a student's self-esteem, the confidence students possess in regards to academics correlates with their performance in the classroom. A positive relationship between a student and teacher would ideally include a continuous line of communication, an emotionally-safe learning space, mutual respect, trust and feedback, and true equity (Lee, 2016). If students are successful in class, they would receive praise and congratulations by their peers and educators, which further builds their self-esteem. When teachers and students have a positive relationship, they form supportive environments where students can improve academically and socially (Kelly & Zhang, 2016).

Students' relationships with their teachers typically have a direct correlation to on how they do in that teacher's class (Kelly & Zhang, 2016). If students enjoy being in class with their teacher, they give more effort and usually perform better in class. On the other hand, if students do not enjoy being in class with a particular teacher, their interest and productivity tends to decline, followed by their grades. Students in high-poverty urban schools benefit more than students in high-income urban schools from a positive relationship with their teachers (Murray & Malmgren, 2005). Students in high-poverty urban schools have a higher rate of high school dropouts, low self-efficacy, and low self-confidence. This is where positive relationships with their teachers become important. In addition to a more positive social and emotional adjustment to their fellow classmates, a strong relationship with their teacher can help low income students achieve higher academic achievements.

2.4: Overview of Worcester

Worcester is a large city in Massachusetts (Data USA, 2015). Some residents of Worcester live in poverty, which makes their children considered "High Needs" (Worcester Regional Research Bureau, 2014). Many students who attend Worcester public schools are characterized as "High Needs." Even though students need extra support in the city, the public school system has made strides to improve education for its residents. One successful addition is the Worcester Technical High School. However, even though improvements have been made, there is more work to do; specially to help low income students. This section will discuss the poverty rate in Worcester, the public school system in Worcester, Worcester Technical High School, and roadblocks for low income students.

Worcester has a higher poverty rate, lower homeownership, and lower median income compared to the national averages, as shown in Figures 3 and 4 (Data USA, 2015).

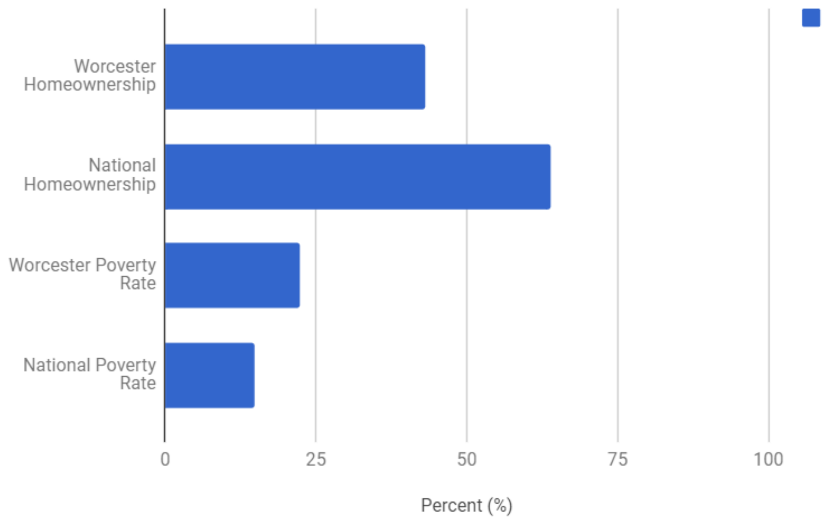

Figure 3: Homeownership and Poverty Rate Comparisons

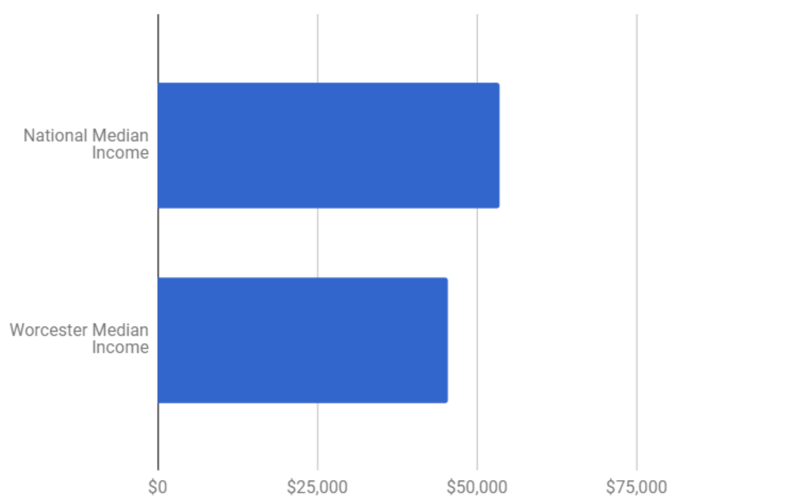

Figure 4: Median Household Income Comparison

Though the median household income in Worcester is lower than the national average, the median property value is $205,200, which is $15,000 above the national average. Since the cost of living is high in Worcester and the median income is low, many residents are in poverty, and it is difficult for them to get out of poverty. Therefore, the children in these families are considered “High Needs”, which is discussed in the next section.

Worcester Public School System

The United States Department of Education defines “High Needs” students as at risk of educational failure or otherwise in need of special assistance or support: including students living in poverty, attend high minority schools, are far below grade level, are homeless, are in foster care, have disabilities, or are English learners (Worcester Regional Research Bureau, 2014). In 2014, the public school system of Worcester characterized 82% of its students as “High Needs.” Students in Worcester Public Schools (WPS) are 38.1% Hispanic, 35.8% Caucasian, and 14.2% African-American. However, WPS has a voluntary desegregation plan that requires schools balance ethnicities. While most students attend the school in their neighborhood, others attend school outside their zone to achieve this balance. Seventy-three percent of WPS students qualify as low-income and 44% of all students speak a first language that is not English, which are two significant contributors to the 82% high needs rating.

The city’s students consistently score lower on the Massachusetts Comprehensive Assessment System (MCAS) than those in the rest of the state, and the schools have a higher unexcused absence rate (Worcester Regional Research Bureau, 2014). Though Worcester is the second largest city in the state, it ranked third for number of students enrolled in public schools. Once students in Worcester high schools turn sixteen years of age, the dropout rate becomes 12.9% versus the state rate of 6.9%. There is a trend of declining attendance as students move from middle school to high school.

Worcester Technical High School

Worcester Technical High School (WTHS) currently ranks 83rd among all high schools in Massachusetts (USNews, 2017). As one of seven high schools in Worcester, MA, Worcester Technical High School is the place to be in Worcester for students looking for a high quality education. WTHS demonstrates that the public school system in Worcester is improving and providing students who are considered “High Needs” with an excellent education. If more schools were like WTHS, students in Worcester would receive a better education.

One factor that led to the advancement of WTHS was the implementation of a student centered curriculum (Harrity, 2013). This new technical school gave students the opportunity to choose what subject they wanted to pursue. This allows students to become passionate about learning or guides them in discovering what they enjoy. By giving students a wide range of opportunities, students feel empowered to follow their passions, compared to previously being forced to follow a specific curriculum. With a new curriculum focused on improving their lives as a whole rather than just in the classroom, students gained confidence in their ability to apply knowledge in the “real world”. Several students from

WTHS attend the Boys & Girls Club of Worcester; the student centered approach used at their school should also be effective at the Club. The Boys & Girls Club of Worcester can use WTHS's model of providing students with various opportunities related to STEAM subjects so they can continue their learning and exploring in an after-school setting.

Even though WTHS is excelling today, its students were not always the finest in the past. The school opened in 1910, however by 1997, the school was unanimously voted to be placed on probation for failure to meet the Commission's Standard 10 on School Facilities by the New England Association of Schools and Colleges' Commission (Harrity, 2013). Ninety-seven percent of students were in the needs improvement category, as well as 76% of all students failing the MCAS test. In addition to being the lowest performing high school in the city, and one of the lowest in the state, WTHS also had a deteriorating school building and facilities.

In 2006, the school began to turn around by moving to a new $90 million, 400,000 square foot facility (Harrity, 2013). For five of the next six years, "Worcester Technical High School met the Annual Yearly Progress (AYP) for - "No Child Left Behind," - exceeding benchmarks in English, mathematics, and every subgroup, including special education" (p. 12). In addition to this, the school also met the Progress Performance Index (PPI) in both the Annual and Cumulative PPI, made significant gains in MCAS scores, increased their graduation rate, and decreased their dropout rate.

There are 1,404 students currently attending WTHS, with 46% being male and 54% being female, and there is an overall student to teacher ratio of eleven to one. Fifty-nine percent of the school's population identifies as a minority and 66% are from economically disadvantaged households. Despite this, the school continues to excel. On Massachusetts standardized tests, the student body is 96% proficient in English and 80% in mathematics compared to the state's 90% and 80%, respectively. This data shows that even though some of WTHS's students face challenges, they are able to succeed in STEAM subjects. Since students at WTHS were able to overcome their challenges and do well in STEAM subjects, members of the Boys & Girls Club of Worcester can do the same.

Roadblocks to Low Income Students

Studies have been conducted about the effect of low income on students in Massachusetts. Among students who come from the low income group, they have a 49.6% college enrollment rate, while students from the high income group have a 79% college enrollment rate (Goodman, 2010). Researchers looked for a correlation between this lower rate and financial restrictions, lack of skill, or some combination of factors. They found students living in low income areas almost certainly demonstrated a clear lack of basic skills, compared to their high income counterparts. The study concluded that more research was needed as this lower skill level could be attributed to various factors, such as financial reasons, lower quality of education, lack of interest, or lack of motivation. But it is these low income area students who are trying to be served and supported by the Boys & Girls Club of Worcester.

2.5: The Boys & Girls Club of America

The Boys & Girls Club of America (BGCA) (2017) is a national organization that strives to provide an inclusive and helpful atmosphere for its members. The mission of the BGCA is, "...to enable all young people, especially those who need us most, to reach their full potential as productive, caring, responsible citizens" (p. 6). The BGCA reaches out to all children, which shows its passion for helping them succeed. As of 2016, 433,000 members used the various Boys & Girls Clubs across the United States daily. Additionally, 4 million children and teens interacted with the BGCA in 2016 through outreach programs and membership. The BGCA holds events for the community throughout the year. These events expose more people to the Club and reach those who may benefit from the services the BGCA offers.

2.5.1: STEAM Program at the Boys & Girls Club of Framingham

Although there is a national organization of which all Boys & Girls Clubs are members, every club has its own distinctive characteristics. The Framingham Clubhouse has multiple features unique to their Club (S. Barthold, personal communication, February 12, 2018). Located on 25 Clinton Street in Framingham, MA, the Club focuses on serving children in grades two through twelve. The Framingham Clubhouse categorizes its members into four groups based on age. Grades two through five are the cadets. Students in this group are allowed in the clubhouse from school dismissal until 6:00 pm on weekdays during the school year. The second group, juniors, is strictly sixth graders, while the third group, intermediates, contains grades seven and eight. Finally, grades nine through twelve are referred to as seniors. Juniors, intermediates, and seniors are allowed in the Club from school dismissal until 9:00 pm during the school year. The club is also open 8:00 am until 5:30 pm throughout the summer and all groups are allowed in the facility for the entirety of the day. The forming of groups provides a level of organization to the Club. The Boys & Girls Club of Worcester could incorporate similar groups into its club, which would allow for more targeted activities, both in regards to STEAM and other topics.

At the Framingham Clubhouse all members of appropriate age have access to the Power Hour, Computer Room, Games Room, Arts and Crafts Room, Sports and Fitness Activities, Teen Center, Leadership Clubs, and Prevention Education (Boys & Girls Clubs of Metrowest, 2018). The Framingham Clubhouse also includes the Computer Clubhouse, which focuses on technology.

2.6: The Boys & Girls Club of Worcester

The Boys & Girls Club of Worcester (BGCW or Club) (2018) provides a safe after-school environment for children around Worcester to participate in various activities that interest them. Figure 5 shows the BGCW's building.

Figure 5: The Boys & Girls Club of Worcester on 65 Tainter Street Worcester, MA (Ryan Construction, 2013)

The Club is open to children ages 8-18 and offers programs in several different areas, such as athletics and the arts. The Club is also a place where children can do homework. It has a learning center and offers a Power Hour program. This program has children make a commitment to doing homework for a few hours each afternoon, and many children receive higher grades after participating in the program. The BGCW is not only interested in making sure children have a safe place to go after school but are also invested in their futures. For instance, it provides support when high school students are applying to colleges or helps them find full-time jobs after graduation. There is also a mentoring program where teenagers from around the area can be a Big Brother or Big Sister to one of the members. The BGCW provides children with role models and support they may not find elsewhere.

2.6.1: How The Club Operates

The BGCW (2018) strives to provide a welcoming after-school environment for children. The Club is open from 2:00 pm to 8:00 pm for its members. The members arrive after school ends, and therefore they arrive at various times. The members are free to roam around the Club; they can go to the game room, the teen room, the basketball court, the dance studios, the pool, or the learning center. Volunteers and staff members are located in all the rooms and hallways to make sure the members are safe.

About twenty-five of the BGCW members have made a commitment to the Power Hour program (B. Ojo, personal communication, February, 12, 2018). They go to the learning center every day after school and do their homework. After their work is done, they may leave or stay and do other activities in the learning center. The center has various resources for the activities, such as a Mac lab, a smart board, a rug area, and a television. The learning center provides an environment to connect with members and encourages them to try STEAM activities once they finish their homework.

The Boys & Girls Club is not the only after-school program in Worcester that is focused on integrating STEAM. There are a number of other youth-serving agencies that have some type of science-based education program. Sylvan Learning Worcester (2018) has a hands-on STEM program with classes for grades 1-8. There is a five-week Coding or Robotics program to choose from, but both are expensive, ranging from $250-$300. Girls Inc. (2018) of Worcester has a Summer STEM and Leadership Camp for grades seven and up, which is a hands-on research based program for girls. However, participants are required to make a 5-year commitment to the program. Friendly House (2018) has an after-school program that works in cooperation with WPI to offer a robotics program for kids ages 6-12. The YWCA of Central Massachusetts (2018) offers a math and science vocabulary program for grades 3-6. These are all less expensive programs, yet they all charge some fee to attend. The Boys & Girls Club of Worcester has the only program looking to integrate STEAM that is free of charge.

2.6.2: Working with Children at the Boys & Girls Club of Worcester

The BGCW (2018) has various activities that it offers every day to its members, such as homework help, dance classes, and games on the basketball court. These activities are engaging and enjoyable for the members. However, the Club would like to incorporate high yield learning activities (HYLA) as well in the Learning Center. Other Boys & Girls Clubs are integrating HYLAs, such as the Club in Framingham (Boys & Girls Clubs of Metrowest, 2018). The BGCW has recently acquired a 3D printer and several Lego Mindstorms kits (B. Ojo, personal communication, March 12, 2018). The Club hopes to use these resources to incorporate HYLAs into its daily operations.

2.6.3: High Yield Learning Activities

A main component of STEAM programs are the activities students participate in. The goal for HYLAs is to find a fun, exciting way for students to learn while doing activities they enjoy (Boys & Girls Clubs of America, 2006). These activities are designed to make learning and teaching enjoyable for everyone. A HYLA typically follows a theme so students and teachers stay on track throughout the activity. Each activity is tailored to different grade levels, such as K-5th, 6th-8th, and 9th-12th, so that the students get the most out of the activity. A successful HYLA has examples students use to avoid getting lost or confused. These activities can include anything and can vary in group size, location, and topic.

They can also be made so older students who have completed the activity can teach it to younger students. This way, the students have someone closer to their age they can look at as a mentor. A HYLA can be something as simple as shaking a slinky up and down so that it creates a wave like feature (S. Weaver, personal communication, February 19, 2018). As students enjoy playing with the slinky, the instructor can explain what they are seeing is called an amplitude wave. Following that, the lesson can be as thorough as the instructor wants.

2.6.4: Activities to Implement at the Boys & Girls Club of Worcester

The BGCW has various resources to contribute to STEAM based HYLAs: including a smart board, computers, a 3D printer, and Lego Mindstorms kits (B. Ojo, personal communication, February 12, 2018). The members have used the Lego Mindstorms kits to build several robots but have not programmed them to do anything. To fully utilize the resources, the Club has available, further research needs to be conducted on software options for the 3D printer and Lego Mindstorms. In the next chapter, we will explain how we will conduct research and collaborate with the staff and volunteers at the BGCW to use the Club's resources to implement HYLAs and improve STEAM education for its members.

Chapter 3: Methodology

The goal of this project was to develop a sustainable STEAM strategy and stimulate member interest in STEAM activities. In the spring of 2018, our team began working as volunteers at the Boys & Girls Club of Worcester (BGCW or Club). Throughout the team's time at the Club, we completed multiple assessments as well as conducted field work. The team first completed an assessment of the initial state of the Club's STEAM program to create a baseline understanding towards our starting point. From that point we implemented improvements to the Club and evaluated how the members reacted to each implementation. Near the conclusion of the project, we reassessed the state of the Club's STEAM program based off the immediate improvements made and created a few recommendations for the Club to implement in the future. All of these steps are displayed in Figure 6 below. In summary, to successfully implement a STEAM program, the following objectives were developed:

1. Determine current STEAM capabilities of the BGCW by using the *Everything STEM Planning Guide's* STEM Readiness Pre-Assessment.
2. Identify and implement immediate and long-term improvements at the BGCW using the *Everything STEM Planning Guide's* "STEM Improvement Plan".
3. Create and evaluate high yield learning activities using Lego Mindstorms, TinkerCAD, and a 3D printer.
4. Determine how the immediate improvements we introduced affected the readiness of the Club to continue its STEAM program by using the *Everything STEM Planning Guide's* STEM Readiness Post-Assessment and make long-term recommendations for the Club to implement.

The objectives and the methods we used to implement a STEAM program are explained in further detail below.

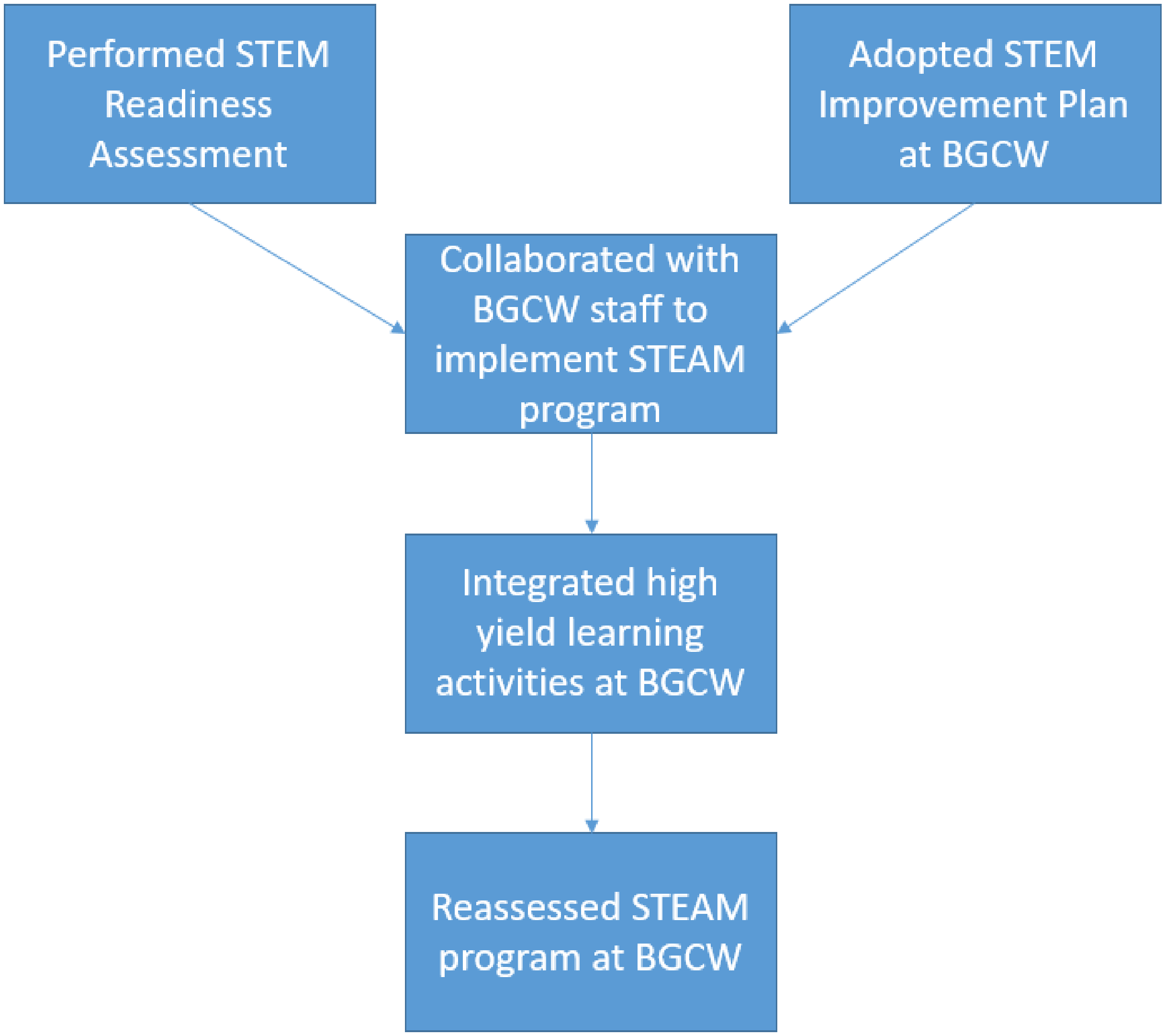

Figure 6: Project Objectives

3.1: Determine current STEAM capabilities of the BGCW by using the *Everything STEM Planning Guide's* STEM Readiness Pre-Assessment.

Stephan Barthold, a volunteer at the Boys & Girls Club of Metrowest, provided a copy of the *Everything STEM Planning Guide* by the Boys & Girls Club of America (Fowlkes et al., 2017). Within the guide there is a "STEM Readiness Assessment" that outlines the optimal technology and hardware, space, policies, programming, and staffing used to produce a successful STEM program. We added art elements into the guide and used it to develop a STEAM strategy for the BGCW. Each section of the guide has its own metrics to determine what state the Club is in for that category; the levels include foundational, intermediate, or advanced. To apply the metrics at the BGCW, we observed physical assets and spaces, reviewed policies, and discussed the daily operations of the BGCW with Bolaji Ojo (personal communication, March 19, 2018). Bolaji Ojo, Stephanie Rawady, Joanne Fowling, and Teju Richardson (personal communication, April 5, 2018) provided insight on the spacing, policies, and staffing at the BGCW, which was used to calculate the metrics. A portion of the assessment is provided in Table 3.

Table 3: Example from "STEM Readiness Assessment"

(Fowlkes et al., 2017)

SPACE			
	INDICATORS	SCORE	NOTES
Dedicated	1 Club dedicates a space for STEM at least two hours per week. 2 Club dedicates a space for STEM at least four hours per week. 3 Club dedicates a space for STEM at all times.		
Other	1 Club leverages other program spaces for STEM and integrates STEM into other programs.		

1 Foundational 2 Intermediate 3-4 Advanced

Total Score: 0

3.2: Identify and implement immediate and long-term improvements at the BGCW using the *Everything STEM Planning Guide's* "STEM Improvement Plan".

A plan was developed to improve the BGCW STEAM program and the STEM Readiness Pre-Assessment rating mentioned in Objective 1. The *Everything STEM Planning Guide* contains a chart that outlines objectives and steps to improve the level of the Club's STEAM program, titled the "STEM Improvement Plan" (Fowlkes et al., 2017). With our observations of the Club's operations, we filled out immediate improvements, most of which were written into the programming section. Through this chart, a course was mapped to utilize new resources to provide STEAM programming. A portion of the chart is provided in Table 4.

Table 4: Example of "STEM Improvement Plan"

(Fowlkes et al., 2017)

Category 3: SPACE ☐ Dedicated or Shared STEM Center Space					
Objective	Strategy	Lead Person	Approved?	Deadline	Completed?
			Y N		Y N
			Y N		Y N
			Y N		Y N
			Y N		Y N
			Y N		Y N

A meeting was held with BGCW staff to better understand the operations of the Club. The staff's insights were used to identify long-term improvements and mostly applied to the staffing and programming categories. Some of the questions asked throughout the meeting are listed below.

1. What is the best area to run STEAM activities?
2. Where do volunteers come from? (What school?)
3. Is it possible to add a training session for volunteers to learn about STEAM in the volunteer orientation?
4. Would the Club be interested in making a connection with WPI?
5. What is the potential for high school members to run the STEAM program?
6. What is the possibility of hiring a STEAM part-time coordinator?

3.3: Create and evaluate high yield learning activities using Lego Mindstorms, TinkerCAD, and a 3D printer.

High yield learning activities (HYLA) are a way for members to learn while doing an activity they enjoy (Boys & Girls Club of America, 2006). More information on HYLA is provided in background section 2.6.3. To implement HYLA at the BGCW we focused on creating activity plans for the Lego Mindstorms kits and 3D printing designs made using a web-based program called TinkerCAD. Lego Mindstorms kits can be used to build programmable robots using a free computer program and Lego pieces. TinkerCAD is a free to use program that simplifies Computer Aided Design (CAD) and makes it accessible to students with step-by-step tutorials. The BGCW wanted to focus its STEAM program around the Lego Mindstorms kits and 3D printer.

The first step was to educate ourselves on these resources. After building robots using the Lego Mindstorms kits, we followed tutorials to learn the Lego Mindstorms and TinkerCAD programs. The 3D printer was assembled and test prints run to determine the various ways TinkerCAD can be used: including printing original creations, downloading designs, and converting images. Once comfortable with these resources, we worked with Bolaji to implement HYLA using the Lego Mindstorms kits and 3D printer.

To pilot activities for these resources, the members built the robots using the Lego Mindstorms kits and learned how to use the provided controller to move them. The members also navigated through a maze using the controller and programmed the robots to accomplish different tasks. As the members were becoming familiar with the Lego Mindstorms robots, they were also introduced to the 3D printer and TinkerCAD. Members went through the tutorial and made their own designs on TinkerCAD. Once the members were familiar with TinkerCAD, they were asked to design a cup or castle by looking at a completed version. The activities for Lego Mindstorms and TinkerCAD incorporated the three key learning concepts discussed in background section 2.2.1.

Activity plans, both written documents and videos, were developed to explain the various activities the members participated in. These plans came from observing and conversing with the members to gain an understanding of what they enjoyed. Observations included how members interacted with the resources and with each other. Some of the activity plans were for the members to use, such as the videos describing how to create a cup and castle in TinkerCAD, and some were for Bolaji Ojo and the volunteers who work in the Learning Center, such as the written plan explaining how to program the Lego Mindstorms robots. The volunteers who work in the Learning Center include community members and students from the College of the Holy Cross and Clark University. To help the volunteers we created a guide to outline their responsibilities as a volunteer at the Club. The written activity plans and links to videos are also included in the *Volunteer Guide for the Learning Center*, in Appendix A.

3.4: Determine how the immediate improvements we introduced affected the readiness of the Club to continue its STEAM program by using the *Everything STEM Planning Guide's* STEM Readiness Post-Assessment and make long-term recommendations for the Club to implement.

At the conclusion of our time at the BGCW, the team reassessed the Club's STEAM program. The team used the *Everything STEM Planning Guide's* to complete a STEAM readiness post-assessment (Fowlkes et al., 2017). After completing objectives one and two, the team had come up with immediate improvements and long-term improvements. The immediate improvements were suggestions that could be completed by the team and staff in the duration of the team's time at the Club while the long-term improvements were suggestions that the Club would have to complete after the team left. The Club was reassessed using the outcome of the immediate improvements made by the team and staff. All the suggestions noted in this section can be found in results section 4.3.

Chapter 4: Results

The BGCW has been working hard to develop its STEAM program and through this project applied national Boys & Girls Club standards and assessment processes to better understand where the program is today and where it might go in the future. The *Everything STEM Planning Guide* created by the Boys & Girls Club of America includes guidance on how to develop a STEM program (Fowlkes et al., 2017). This chapter is separated into sections to describe the results obtained from the *Everything STEM Planning Guide*. It also contains insights and resources to assist in sustaining the BGCW's STEAM program. This chapter includes the following sections:

4.1 - STEM Readiness Pre-Assessment

4.2 – Immediate Improvements and Implementations

4.3 - STEM Readiness Post-Assessment and Key Insights

4.4 - Recommendations for Long-Term Improvements

4.1: STEM Readiness Pre-Assessment

The "STEM Readiness Assessment" was provided by the national Boys & Girls Club of America and consists of five categories: technology and hardware, space, policies, programming, and staffing (Fowlkes et al., 2017). Each category is separated into criteria and scored using a point system. BGCW's STEAM program was evaluated using this assessment tool, and the results from the pre-assessment, conducted at the outset of this project, are shown in Table 5. The pre-assessment gave the BGCW a total score of nine out of twenty-seven points, placing it at the foundational level. The other levels possible in the assessment are intermediate and advanced. With a little work, the BGCW's STEAM program could reach the maximum foundational level, if not the intermediate level.

Table 5: STEM Readiness Pre-Assessment

Criteria	Description	Score	Max
	Technology & Hardware	4	5
Wi-Fi	Sufficient broadband is available to provide for all programming, all administrative and some members' needs	2	2
Technology	A variety of computing devices are available, with a sufficient number to support programming and individual member needs	2	2
Management	Club has not completed the Technology Assessment in the Club Technology Planning Guide or created a plan for tech infrastructure improvements	0	1
	Space	1	4
Dedicated	Club dedicates a space for STEM at least two hours per week	1	3
Other	Club does not leverage other program spaces for STEM and integrates STEM into other programs	0	1
	Policies	1	3
BYOD	No Bring Your Own Device Policy	0	1
Mobile Technology	Internet safety education is part of programming	1	1
Wi-Fi	Members' personal devices are not incorporated into STEM programming	0	1
	Programming	1	4
Hours	Deliver STEM programming at least two hours per week	1	3
Variety	Does not run advanced STEM programs, characterized with longer dosage cycles (i.e. APP LAB, FIRST Robotics, etc.)	0	1
	Staffing	2	11
Programing Staff	No part-time STEM program staff coordinator	0	3
Technology Staff	No part-time technology staff	0	2
Volunteers	Use volunteers with backgrounds in STEM less than monthly	1	3
Training	Provide at least one annual opportunity for staff to participate in STEM-related training	1	3
	Total:	9	27

During the pre-assessment, the BGCW's STEAM program placed at the foundational level, according to the *Everything STEM Planning Guide*. However, the pre-assessment does not capture well the full value of the work Bolaji is doing in the Learning Center. On a daily basis, he runs the Power Hour program, checks in with members, manages the computer area and Mac Lab, and helps members with various tasks. In addition, he is sometimes asked to help run other areas of the Club, such as the gymnasium. Bolaji makes sure everything runs smoothly in the Learning Center, which is a significant step in developing a STEAM program at the BGCW. The categories of the pre-assessment are discussed in further detail below.

BGCW has intermediate level Technology and Hardware.

The BGCW has a wide variety of resources available related to Technology and Hardware. The Club has been working hard to grow its technological resources, and the effort has paid off. There are many items that STEAM activities can be built around. For instance, the BGCW recently acquired a 3D printer, and many of the members are excited to use it. Members typically would not have access to a 3D printer at their respective schools, but the Club can now provide them this opportunity. The effort that the

BGCW's staff have put into increasing the available resources at the Club demonstrates how much they care for the members and want them to have positive experiences.

The BGCW resources related to Technology and Hardware, include:

- Wi-Fi with capability for staff and members
- A Mac Lab that contains eight Macintosh computers
- Fourteen desktop computers
- Leasing contract with Microsoft for laptops - about 30
- Six Lego Mindstorms kits
- One 3D printer
- One Smartboard
- Two televisions
- One gaming console

These are excellent resources to incorporate into a STEAM program. The criteria on Wi-Fi and Technology in Table 5 received the highest assessment scores, a two, available in the pre-assessment. However, the criterion on Management received a zero because the BGCW has not completed the Technology Assessment in the Club Technology Planning Guide. In total, the BGCW received four out of five points in the technology and hardware category of the pre-assessment, giving it an intermediate rating for this category.

BGCW has foundational level Space.

The BGCW received a one for having a Dedicated space because although the Learning Center is used for STEAM programs, it is never solely used just for STEAM. No matter the time of day, there are usually members on computers or doing homework in the Center. In regard to the Other criterion, the BGCW received a zero because the space in the Learning Center is quite small, which makes STEAM programming a challenge. Also, STEAM is concentrated in the Learning Center, and therefore it is not present in other program areas in the Club. For the Space category, the BGCW received a total of one point, giving it a foundational rating.

BGCW has foundational level Policies.

The Club received a zero for the Bring Your Own Device (BYOD) policy, which describes how and when members can use their personal devices in the Club, because they do not have this specific policy in place (Fowlkes et al., 2017). The Club does, however, have a policy describing how cell phones, mobile gaming devices, and iPods should be used, but it is loosely enforced. In regard to Mobile Technology, the BGCW received a one because there are various posters that emphasize the importance of using caution when online. In addition, the Wi-Fi provided by the BGCW censors websites that are inappropriate for use by children. For the Wi-Fi section, the BGCW received a zero because members do not use their personal devices for STEAM programming. In total the BGCW scored one out of three points for Policies, giving it a foundational rating for this category.

BGCW has foundational level Programming.

The BGCW received one point for Hours because there are limited staff available to run STEAM activities and therefore only two hours of programming on average are available per week. For the Variety criterion, the Club received a zero because there are currently no advanced STEAM programs available. In total, the Club received one point out of four in the Programming category, placing it at the foundational level.

BGCW has foundational level Staffing.

The Club received a zero for both Programming and Technology Staff because there is no designated STEAM program or technology support staff member. There are ten volunteers that regularly come to the Learning Center; two of the volunteers are retired community members and the other eight attend Clark University or the College of the Holy Cross. The volunteers usually help members with their homework during Power Hour or play games with them. However, some volunteers look overwhelmed in the Learning Center when a lot of members are in it. The volunteers would benefit from more guidance in the Learning Center so they feel more comfortable there. The BGCW received a one out of three in the criterion for Volunteers because several volunteers help the members with their mathematics or science homework, even though most do not have a background in STEAM fields. For Training, the BGCW received one point because Bolaji had been sent to a national conference where he learned multiple ways for how to implement STEM at the Club. In total, the BGCW scored a two out of eleven in the Staffing category, placing it at the foundational level.

"STEM Readiness Assessment" is easy to do, and valuable for understanding the current situation at the BGCW.

Overall, the "STEM Readiness Assessment" provided insight into the key components of a successful STEAM program. The assessment was fairly simple and a good starting point for thinking widely about the program. It provided a clear picture of the STEAM program at the BGCW. However, the assessment did not account for some important aspects of the program. For example, one aspect not considered is if the members are engaged in the STEAM activities and enjoying themselves. A second aspect is how the staff member leading the STEAM program interacts with the members. The leader of the program should care about the members' needs, be informed on the material, and adapt to situations so members get the most out of activities. Bolaji, for example, always goes about his daily routine with excitement and shows he cares about the members creating a safe environment. A third aspect is that the activities should be dynamic since if an element works for one activity it might not work for another. In our observations, the members were engaged and responded positively when we were enthusiastic about the activities. After summing the total points from the pre-assessment, the BGCW received nine out of twenty-seven points, which means the STEAM program is foundational overall. The total scores for each category are shown in Table 6.

Table 6 Total Scores from STEM Readiness Pre-Assessment

	SCORE:	LEVEL:
TECHNOLOGY	4 out of 5	Intermediate
SPACE	1 out of 4	Foundational
POLICIES	1 out of 3	Foundational
PROGRAMMING	1 out of 4	Foundational
STAFFING	2 out of 11	Foundational
TOTAL	9 out of 27	Foundational

4.2: Immediate Improvements and Implementations

For the next step in the objectives we utilized the "STEM Improvement Plan" from the *Everything STEM Planning Guide*. Through considering the results from the STEM Readiness Pre-Assessment, priorities were agreed upon and immediate improvements implemented. This section describes the immediate improvements separated by category in the "STEM Readiness Assessment". Most categories had areas that could be affected by the project, except the Policies category, which was beyond the scale and timeframe of the project. Through observations made while at the BGCW, it became clear these categories are closely intertwined. Improvements made in staffing, for example, could lead to a better space. Improvements made to any category, ultimately lead to the goal of a better STEAM program.

Technology and Hardware Improvements

The BGCW had acquired several resources that a STEAM program could be developed around, but they needed to be set up to utilize them. We assembled the 3D printer and performed test prints to make sure it worked properly. We also organized the Lego Mindstorms kits to facilitate building the robots for the members. The kits include Lego pieces to build five robots and a manual on how to build the robot called Tracker. The instructions on how to build other robots, attachments for Tracker, and program the robots can be found on the Lego Mindstorms website. In addition to the 3D printer and Lego

Mindstorms kits, the Smart Board was fixed as well. All of these Learning Center resources were thus readied for use in latter portions of the project and beyond.

Space Improvements

The Learning Center is the designated space for the STEAM program. Although to utilize the space effectively, it needed to be optimized. Tables were moved to provide a larger rug area for STEAM activities. The Mac Lab was also closed on days when there were several STEAM activities happening to minimize the number of members in the room. Members were asked to not play computer games when STEAM activities were running since they can be a distraction to members. These changes helped optimize the Learning Center for a STEAM program.

Programming Improvements

Our team developed multiple STEAM activities while at the Club, focused on the Club's Technology and Hardware investments, beginning with the Lego Mindstorms kits.

Lego Mindstorms

Each Lego Mindstorms kit had various components that can be put together to build different robots. After building a robot called Tracker, we divided the pieces for each component into zip-lock bags. Each bag was labeled with the component name and the number of the Lego Mindstorms kit they came from. Groups of members, either two or three, were given a bag with all the pieces necessary to build a component. They worked together to build the component. Once all the groups were done building each component, we helped the groups put the components together to finish assembling Tracker. Two robots were built this way. This method of building Tracker worked well because the small groups allowed more members to help build the robot. Separating the pieces into bags facilitated the building process because members did not have to look for the necessary pieces and it prevented pieces from being lost. Lost pieces had been a problem with the Lego Mindstorms kits the Club previously used.

With the robots assembled, the members were divided into small groups to conduct the Race Track Activity. The team placed masking tape on the ground to map out a race track in a U-shape. Participating members practiced operating the robot using the remote provided in the kits. Once they learned the basics of operating the robot, the team held races between members.

The team also held a Lego Mindstorms Programming Activity. One of the many capabilities of the Lego Mindstorms is that they can be remotely operated through a free downloadable program. Within the program there are tutorials that teach how to code the robot. The tutorial taught members how to make the robot move forwards towards a tire, hit the tire, and return to its starting position. After members successfully completed the tutorial we challenged them to make changes to the code so that the robot would perform other tasks. These tasks consisted of commanding the robot to move to different areas and hit a tire, and then move back to its origin. Throughout this activity, members were challenged to think divergently since there were multiple ways to complete each task. Members also asked each other whenever they were confused on a certain step.

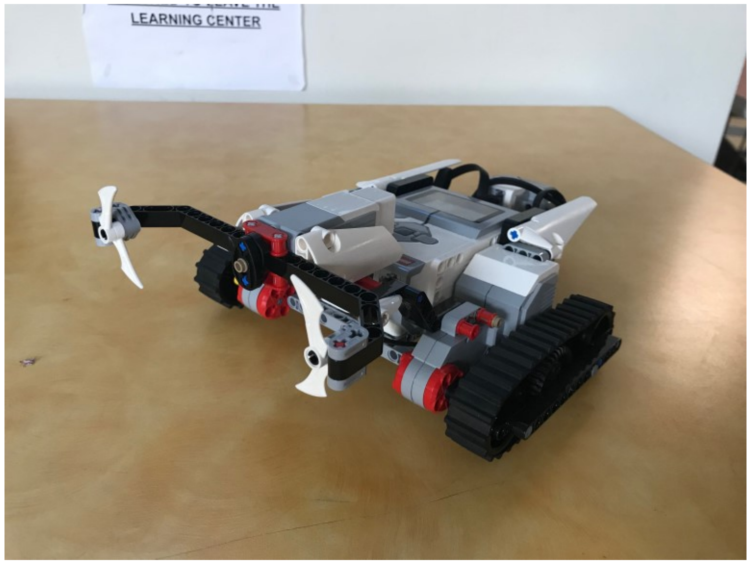

Figure 7 Lego Mindstorms Robot

Following the Lego Mindstorms activities, the team conducted ones focused around the 3D printer and TinkerCAD.

3D Printer and TinkerCAD

TinkerCAD is a free online software that allows users to design anything they can imagine using basic shapes such as spheres, prisms, and cylinders. Built in tutorials teach members how to operate the program. The 3D printer is a machine that the operator loads a file onto, it melts down material, and reshapes it to print what the file describes. The team was able to run an activity with members using both TinkerCAD and the 3D printer.

The team conducted the Drawing Activity, which allows members to draw an image that would later be 3D printed. This activity, however, required the team member running the activity to do most of the work. Since the 3D printer gets hot and is expensive, it is irresponsible to allow members to use it on their own. First, members were given a quarter sheet of paper and thirty minutes to draw an image of their choosing. At the conclusion of the thirty minutes, all of the drawings were collected and uploaded onto a computer. The image then had to be converted to a svg. file and uploaded onto TinkerCAD. Once the file was uploaded and sized correctly, it was exported and uploaded to the 3D printer, where the final product was printed. Beside the steps of this activity that involved the 3D printer, members can complete the other steps with sufficient TinkerCAD skills. Many of the members who took part in the activity enjoyed it because they were able to bring something home and show their parents.

Figure 8 3D Printer and Drawing Activity

Staffing Improvements

To help volunteers make the most of their Learning Center time, we created the Volunteer Guide for the Learning Center. It gives an overview for how the Learning Center operates daily and provides them with several activity plans that incorporate both the 3D printer and Lego Mindstorms. This guide should teach volunteers how to run Power Hour and run STEAM activities. 3D printer instructions are also included.

A significant contribution to the improvement in this category was the team serving as volunteers. With the addition of four dedicated volunteers with a background in STEAM, the Learning Center experienced a return to the true purpose of the space. The Power Hour timeframe and spirit were enforced once more than just Bolaji could run the area and contain the energy of the members; the area remained quiet during Power Hour, and members without homework were encouraged to spend their time in the Game Room. The computers were held for homework use instead of games. After a few weeks of affirming this structure, the members knew what was expected. At this point, with the groundwork laid, we could implement our activities on a schedule.

4.3: STEM Readiness Post-Assessment and Key Insights

After working at the BGCW for six weeks, we performed the STEM Readiness Post-Assessment to see how the immediate improvements made to the STEAM program were reflected. Using this assessment, we determined where there was still room for improvement. Next, we developed a list of long-term improvements in the form of recommendations. Key insights that will help when making these long-term improvements are also included in this section. The post-assessment scoring results are in Table 7.

Table 7 STEM Readiness Post-Assessment Total Scores

Criteria	Description	Score	Max
	Technology & Hardware	4	5
Wi-Fi	Sufficient broadband is available to provide for all programming, all administrative and some members' needs	2	2
Technology	A variety of computing devices are available, with a sufficient number to support programming and individual member needs	2	2
Management	Club has not completed the Technology Assessment in the Club Technology Planning Guide or created a plan for tech infrastructure improvements	0	1
	Space	2	4
Dedicated	Club dedicates a space for STEM at least four hours per week	2	3
Other	Club does not leverage other program spaces for STEM and integrates STEM into other programs	0	1
	Policies	1	3
BYOD	No Bring Your Own Device Policy	0	1
Mobile Technology	Internet safety education is part of programming	1	1
Wi-Fi	Members' personal devices are not incorporated into STEM programming	0	1
	Programming	2	4
Hours	Deliver STEM programming at least three hours per week	2	3
Variety	Does not run advanced STEM programs, characterized with longer dosage cycles (i.e. APP LAB, FIRST Robotics, etc.)	0	1
	Staffing	5	11
Programing Staff	No part-time STEM program staff coordinator	0	3
Technology Staff	No part-time technology staff	0	2
Volunteers	Use volunteers with backgrounds in STEM at least monthly	3	3
Training	Provide at least three annual oppurtunity for staff to participate in STEM-related training	2	3
	Total:	14	27

The categories of technology and hardware and policies remained the same for the pre-assessment and post-assessment, as the BGCW had already received an intermediate rating in this category and no immediate improvements were made. The policies category has a foundational rating, however, this category was out of the scope of the project so we did not make any improvements in this category either.

Overall, the immediate improvements played a major role towards implementing a successful STEAM program. While the team was able to make these immediate improvements during our stay at the Club, maintaining may be difficult. The improvements are divided into the sections of Space, Programming, and Staffing, the latter two being the most important. Long-term improvements in each are also included later in the chapter.

Insights Regarding Running the STEAM Program

Staffing and space are the top priorities for the STEAM program to become sustainable.

The STEAM program will need dedicated staff to run well and be most beneficial for members. In addition to dedicated staff, the volunteers in the Learning Center can be given more guidance onhow to support the STEAM program and, help the Learning Center run smoothly.

Staff wants to start with one hour dedicated to STEAM per week and build off of that.

After meeting with Joanne Fowling and Teju Richardson, a plan was thought of for continuing the STEAM program after we leave the BGCW. The goal is to designate one hour to the STEAM program per week, from 4:00pm-5:00pm in the Learning Center. The Center will be closed to all other activities besides STEAM during this time. In the future, the staff would like to continue growing the STEAM program, but for now the one time per week is manageable.

Fenway is not an option for dedicated space for the STEAM program.

After meeting with Joanne Fowling, Director of Operations, and Teju Richardson, Human Resources Manager, of the BGCW, we learned the room in the BGCW called “Fenway” cannot be the dedicated space for the STEAM program. This room needs to remain open to everyone in order to hold meetings and activities. Therefore, the dedicated space for the STEAM program will have to be the Learning Center.

Insights Regarding Lego Mindstorms

The STEAM activities using the Lego Mindstorms kits incorporated well the three key concepts.

The activities used Activity Before Content (ABC) because the members tried moving the robot themselves first, and then we explained how to use the two motors in order to move the robot where they wanted it to go. This taught them about the technology and engineering aspects of STEAM. The activities also used divergent thinking because members had to problem solve on how to control and program the robots to do certain tasks. The activities used cooperative learning because the members worked in groups to build the robots and helped one another move the robots.

Members like building and controlling the robots.

The members were engaged while building Tracker and worked well together. They took turns putting pieces together and helped each other if a peer was having trouble. The members also liked controlling the robots, the maze and race. ~~One activity involved navigating Tracker through a maze that was outlined in masking tape on the floor. Once members were comfortable with moving Tracker, they raced the robots through the maze. Many of the members enjoyed the race.~~ Also, once members became interested in the robots, more members wanted to try moving the robot. They also worked together well and taught one another ways of moving the robot more effectively.

Members get excited about controlling the robot and sometimes are rude to their peers while waiting for their turn.

As more members became interested in the Lego Mindstorms robots, they had to wait for longer periods of time in between turns. Some of the members became impatient and got angry with those controlling the robot. Members became especially frustrated when the robots were racing through the maze. The supportive atmosphere changed to a hostile one where members were treating each other unkindly. Some members made discouraging comments to the member controlling the robot if he/she was going slowly or outside the maze lines. The change in atmosphere was likely in part due to an increase in member participation while the number of robots stayed the same.

Members like programming the robot and enjoy completing challenges with the robots.

Once members were familiar with how the robot moved, they learned how to program Tracker through Lego Mindstorms' software. The software was downloaded onto three of the computers in the Mac Lab and one of the robots was connected to each computer through Bluetooth. After seeing the tutorial for moving a tire with Tracker and learning the basic features of the programming software, the members were given several programming challenges most of which involved moving a tire from a spot on the Lego Mindstorms cover. Once members could move the tire from several locations, they were challenged to program Tracker to move around the cover and end where it started. This was the hardest challenge for the members because they had to figure out when to have Tracker turn and how far to turn each time. Most members needed a few hints during the challenges but were able to accomplish them. They were also excited when they figured out how to do one of them and eager to try another. The challenges are described further in the *Volunteer Guide to the Learning Center* in the Appendix.

Insights Regarding the 3D printer and TinkerCAD

The STEAM activities using the 3D printer and TinkerCAD incorporated well the three key concepts.

The activities utilized the three key concepts. ABC was used because members made various designs before watching tutorial videos for TinkerCAD, and the video activity plan for designing a cup on

TinkerCAD. The activities used divergent thinking because there were multiple ways to create the cup. The video activity plan shows them only one way of designing the cup. Finally, the activities used cooperative learning because the members helped one another with their designs.

It does not work well if multiple members use one TinkerCAD account.

When members started using TinkerCAD, many of them used Bolaji's account. However, this did not work well because when one member did something on the account, the other members could see it. This created an issue when several members were going through the tutorials because one member would do the tutorials and the rest would watch and not learn how to do the tasks themselves. Also, some members deleted parts of the tutorials and then no other member could do that part. Instead of having the members use one account, they should make their own accounts. If they are twelve years old or younger, which includes most members using TinkerCAD, they need a parent's email to make an account. However, the email is only needed to sign up for an account because Bolaji can give the members a code to access their accounts. The code also allows him to monitor their accounts. Therefore, the question asking for a parent's email is a formality that could be filled in with an email the BGCW makes specifically for TinkerCAD accounts. Once the members put in the email, they will not need it anymore. Having a separate email will make it easier for the members to make accounts because some of their parents do not have an email or they do not know their emails.

Video tutorials for TinkerCAD will most likely work better than written tutorials.

The members were asked to do the tutorials on TinkerCAD. There were written step-by-step instructions provided by TinkerCAD that explained how to incorporate different features in the designs, such as resizing objects and making them hollow. However, this activity did not work well because members did not want to or could not read and understand the written instructions. This makes sense because the members were asked to do this activity after-school and after completing their homework. Most of them were probably tired and therefore did not want to read. It also appeared that some of them would not ask for help out of perceived embarrassment. To combat this issue, the team created video tutorials for TinkerCAD because they will be easier for members to follow. Also, many members enjoy watching videos in their free time, so they are more likely to watch a video tutorial than read instructions.

Members should not operate the 3D printer themselves.

Parts of the 3D printer are hot, almost 200° Celsius, when it is in use, and members should not use it themselves. A staff member or volunteer should operate the 3D printer instead. Many of the members are interested in the printer, and some have tried to touch it. This is a problem for two reasons; the printer could injure the members and the prints can be altered if the printer is shaken or touched while running. By putting the printer in the closet in the Learning Center, members usually leave it alone. Also, the closet automatically locks when the door is shut, so it is a safe place to keep the printer.

Insights Regarding Facilitating STEAM Activities

Members work better on activities that have a common goal rather than a competition.

A few STEAM activities were run as competitions, mostly to gather interest in the activity. These activities ended up with members becoming rude to each other and making disparaging remarks if someone fell behind. In contrast, when activities had a common goal, such as building the robot, the members were much kinder to one another. This finding is supported by our background research.

Members usually work better together in small groups rather than large groups.

Members often worked in groups during STEAM activities, so they incorporated cooperative learning. The groups were more successful when they were made up of two or three members as opposed to four or more. Once the group got too large, the members argued with one another instead of working together. The environment in the Learning Center quickly turned negative when the groups contained four or more members. After the environment changed, it was difficult to bring the members back to a positive place of working together well.

Insights Regarding BGCW Staff and Volunteers

The staff and volunteers work hard to make sure the members have a safe and supportive environment to come to after-school.

The BGCW strives to provide a positive environment for its members to come to after-school and it accomplishes this goal. The staff and volunteers greet the members and ask them about their days. They sit and talk with the members and help them when needed. It is clear that the staff and volunteers care about the members and want them to enjoy their time at the BGCW.

The BGCW would benefit from more staff members.

The staff at the BGCW works hard every day to make sure the members have what they need. However, there are not enough staff to have someone in every room all the time. Sometimes different areas of the Club are closed because no staff member can be in the room. The staff do the best they can to open as many areas of the Club as possible, sometimes even having one staff member run two areas of the Club, but this is difficult. Volunteers provide support since they can help run areas of the Club, but not all volunteers are comfortable running a room by themselves. It would be beneficial to have more staff members; however, it is difficult to hire more people because the staff want to keep the BGCW accessible to its members. The membership fee for the BGCW is low because the staff want to make sure every child who wants to come to the Club can. A way to increase staff would be to apply for more grants to provide salaries for the new staff members. Many staff members' salaries are currently funded through grants.

The BGCW staff have been trying to fund a full STEAM program for several years.

After talking with Malory Truman, who writes the grant requests for the BGCW, it came to our attention that several grants have been proposed since 2016 to fund a full STEAM program. These grants requested a full staff, equipment, and technology support. However, the Club wishes to remain service charge free, to better serve its members. This has been a stumbling block with finding funding, as many organizations do not wish to support a salary for a dedicated program director, and will only provide equipment. To combat this problem, the staff could look for new avenues of funding, such as different organizations to provide grants. An organization that works in the STEAM field may be willing to fund a grant to develop the STEAM program further.

4.4: Long-Term Recommendations and Project Summary

While the team was able to implement the immediate improvements that came from the "STEM Improvement Plan", there were multiple long-term improvements that the team was not able to implement. In terms of the *Everything STEM Planning Guide* that focuses on Technology and Hardware, Space, Policies, Programming, and Staffing, many of the long-term recommendations that we made revolve around Staffing (Fowlkes et al., 2017). If the Club can address the Staffing category of the guide and improve the category's score, the rest of the categories will follow the trend. These long-term improvements were separated into two main sections: Recommendations for the Learning Center and Recommendations for the BGCW staff. The recommendations are described in detail below.

Recommendations for Learning Center

Determine a specific time and structure for the STEAM program.

There needs to be a dedicated time and space for STEAM activities. The Learning Center should be the dedicated space from 4pm to 5pm once a week. Starting at one hour per week is most feasible, but this can be built on over time.

Clarify volunteer expectations while in the Learning Center.

Clarifying expectations with the volunteers that come to help the Learning Center will assist in ensuring they make the most out of their time at the Club. The Volunteer Guide should be able to assist them and help make them feel more comfortable when volunteering.

Reaffirm the Learning Center purpose and rules with members.

The Learning Center should be a place where members can come and get their work done without distraction. Reaffirm that the Learning Center is not a place to hang out with the members; it should be like a library especially during Power Hour or when STEAM activities are being run.

Recommendations for BGCW Staff

Hire a part-time dedicated STEAM staff member.

If the BGCW were to hire a part-time dedicated STEAM staff member, this person could be in charge of programming and technology support for the STEAM activities. This staff member would be crucial to the sustainability of the program. It will be difficult to get a grant approved for this position and it is understood that the BGCW has already made several attempts to do so. It is possible that WPI could be of assistance in finding a grant.

Regularly review volunteer program performance at staff meetings.

During the weekly staff meetings at the BGCW there could be a brief update on volunteers. This could help improve the accountability of the volunteers. It will also encourage open communication between the staff to make sure everyone is on the same page in regards to volunteers.

Form a stronger, ongoing connection with WPI.

WPI has an interest in assisting the Worcester community as a whole; it especially has an interest in helping the children of Worcester experience STEAM opportunities. For example, the office at WPI called the STEM Education Center does outreach programs and provides professional development to local schools. They may know of organizations that would be willing to provide a grant for hiring a dedicated STEAM staff member. There are also clubs on campus that provide opportunities for children to be introduced to STEAM. One of these clubs is Robokids, which organizes weekly sessions to teach Lego Mindstorms programming to children who go to Friendly House in Worcester. The possibility was explored that Robokids could come to the BGCW during the school year and continue to work with the members to use the Lego Mindstorms robots. The members of Robokids expressed interest in coming to the BGCW, however, Robokids does not currently have enough volunteers to dedicate a separate time for the BGCW. The BGCW could reach out to Robokids and other clubs like them in the future to begin a relationship. To assist the BGCW in finding volunteers with a background in STEAM, the Club could come to WPI's work study fair in the fall. Many WPI students attend the fair with the intentions of finding employment for the school year. Since the Club already has work study students from Clark University and the College of the Holy Cross, they could also have work study students from WPI. Another way WPI could help the Club would be to have IQP teams continue to develop the STEAM program. This will keep the program exciting and engaging for the members. An IQP team could also help to grow the relationship between the BGCW and WPI. If this connection is made, it would be helpful to WPI as well because members of the BGCW may want to attend school at WPI one day. These recommendations could help foster a mutually beneficial relationship between the BGCW and WPI.

Project Summary

After working at the Boys & Girls Club of Worcester (BGCW or Club) for seven weeks, our team with BGCW liaison, Bolaji Ojo, took the steps towards implementing a new STEAM strategy at the Boys & Girls Club of Worcester. The strategy helped stimulate member interest in STEAM and helped the BGCW understand the necessary steps needed to develop its STEAM program further. Over the course of the project, we researched peer-reviewed literature, discovered the *Everything STEM Planning Guide* from the Boys & Girls Club of America, collaborated with BGCW staff, assessed the STEAM program, made immediate improvements, reassessed the STEAM program, and made recommendations for long-term improvements. These tasks have laid a foundation for a successful STEAM program to be implemented at the BGCW.

The immediate improvements advanced the STEAM program and the long-term improvements are intended to as well. We created resources, such as the *Volunteer Guide for the Learning Center* and video tutorials for TinkerCAD, which will assist volunteers in running the Learning Center and help sustain the STEAM program. The insights gained from facilitating STEAM activities included in the methodology could also assist BGCW staff or volunteers who help with the STEAM program.

We hope that through the opportunities in STEAM the BGCW provides its members, they will feel empowered to pursue their passions, be they in STEAM or something else. The BGCW is helping members achieve their dreams and we are grateful to be a part of this mission.

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Appendix: *Volunteer Guide for the Learning Center*

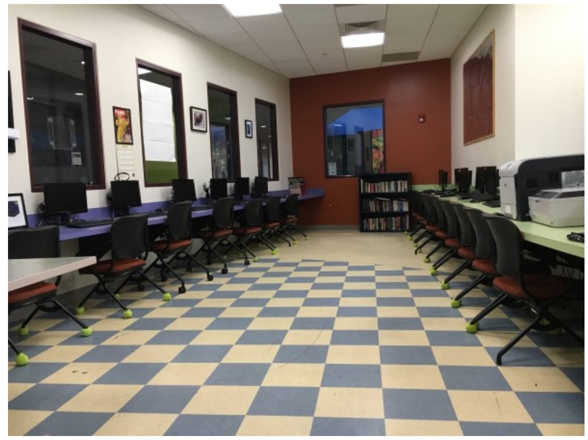
After working in the Learning Center at the BGCW, we thought it would help volunteers if there was a guide that outlines the various tasks in the Learning Center and how to facilitate STEAM activities. The *Volunteer Guide for the Learning Center* describes how to help during Power Hour and after it is over as well as run STEAM activities. The guide is attached below.

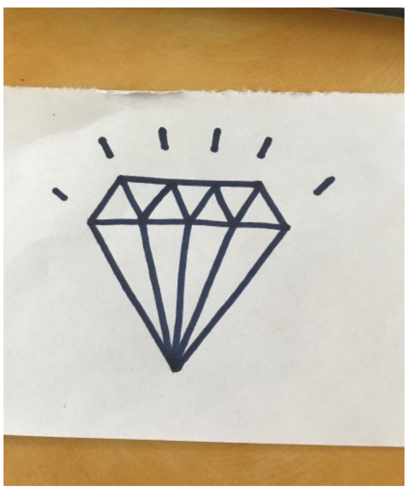
Volunteer Guide for the Learning Center

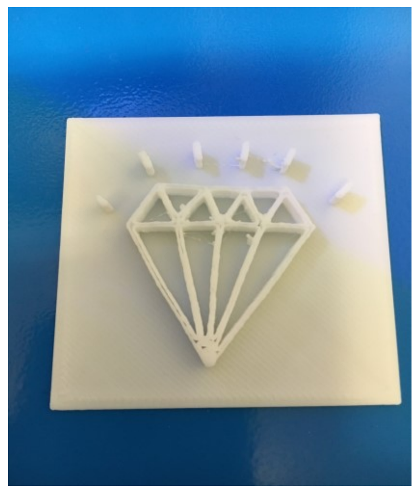
The Boys & Girls Club of Worcester

Created April 2018 by WPI Student Team

Includes STEAM Activity Plans







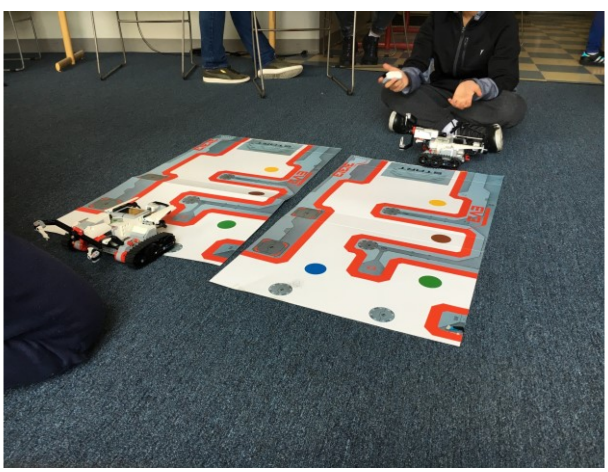


Table of Contents

Overview

The Boys & Girls Club of Worcester provides a safe after-school environment for children around Worcester to participate in various activities that interest them. The Club has several program areas including the Learning Center, gym, boxing room, dance room, game room, and teen room. The purpose of this guide is to assist volunteers in determining the various tasks they can do while in the Learning Center. It was developed in April 2018 by a group of WPI students working to integrate STEAM (Science, Technology, Engineering, Art, and Math) activities into the Boys and Girls Club. Power Hour runs from 2pm to 4pm, which is when members should be working on their homework. Members will often be reluctant to ask for help, so try to offer members help with their homework if they are struggling. After 4pm the Learning Center should become a dedicated space for STEAM activities. Provided is a daily guide for running the Learning Center, key concepts to consider when running activities, and several activity plans that can be used. Please ask Bolaji, the Education Coordinator, if you have any questions about the tasks.

Managing the Learning Center

During Power Hour (Monday-Thursday, 2pm-4pm):

- Power Hour is a time members can work on homework and get help with it if needed.
- Ask members if they have any homework and if they need help with it.
- If members do not have homework, ask if they would like to do a quiet activity (i.e. drawing) in the Learning Center. If members do not have homework, ask them to go to the gym, game room, or teen room until 4pm when Power Hour ends.
- Be sure to keep the room as quiet as possible, so that those doing homework have no trouble staying focused.
- Members should not be in the supply closet for any reason at this time.

After 4pm (Monday-Thursday):

- Power Hour ends at 4pm so often times members come into the Learning Center to sit and talk with one another after 4pm.
- Ask members if they would like to do an activity. i.e. playing a board game from the closet, drawing, practicing typing, using TinkerCAD, and using the Lego Mindstorms kits (there are directions for using TinkerCAD, the 3D printer, and the Lego Mindstorms kits if the members would like to do these activities)
- Members should not be playing games on the computers during this time unless Bolaji gives special permission.
- Members can enter the supply closet only to pick out board games, and only after asking a volunteer.

Fridays (No Power Hour):

- There is no Power Hour on Fridays since many of the members do not have weekend homework.
- Friday is a game day and many members come into the Learning Center to play games.
- A lot of members like to play computer games on Fridays and the computer area should be monitored to make sure they are playing appropriate games (i.e. no games with guns). If more members want to play games than there are computers available, facilitate them taking turns. They should switch about every 20 minutes so everyone gets a turn to play.
- Many members enjoy spending time watching Youtube videos. Similar rules apply, make sure that the content is appropriate for the Learning Center.
- Other members like to play board games or draw.
- Putting on a movie on Bolaji’s Xbox is also a great Friday activity.

STEAM Program Overview

The Boys and Girls Club of Worcester wanted to focus its STEAM program around their Lego Mindstorms kits and 3D printer. The Club has six Lego Mindstorms kits located in the back closet of the Learning Center. The Lego Mindstorms computer program is downloaded on the computers in the Mac Lab; here you can find step by step directions for building and programming the robots. For the 3D printer activities, you will be using the free online program called TinkerCAD. The WPI student team has created some basic TinkerCAD tutorial videos that can be accessed on the

This guide provides a few High Yield Learning Activities that aim to improve STEAM education for members. All volunteers should be capable of running one of these activities. There will always be challenges when introducing STEAM concepts to members for the first time, including self-esteem issues and the overall stigma against STEAM subjects. These activity plans are designed to avoid these challenges by following three important key concepts.

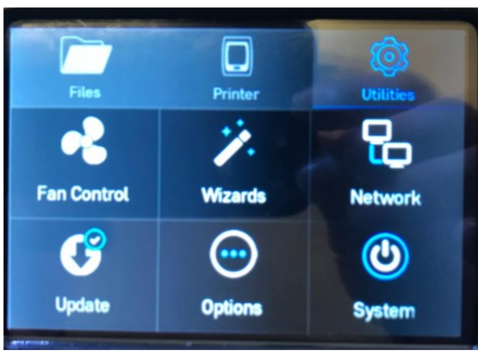
There are three key concepts that should be considered when STEAM topics are introduced to members. They include the Activity Before Content (ABC) approach, encouraging divergent thinking, and utilizing cooperative learning. ABC emphasizes the importance of running an activity before introducing the content; this will get the members more excited to learn. Divergent thinking is the concept of allowing members to look at a problem from multiple angles and think of novel solutions. Cooperative learning promotes education by placing students in groups to accomplish a task as a team. Be sure to keep these key concepts in mind when running activities; they should all be included in the following set of activities.

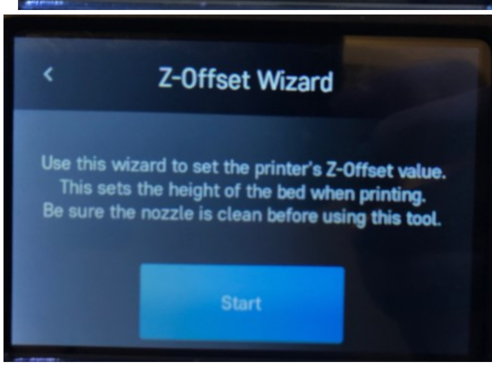
3D Printer Instructions

The 3D printer is located in the back closet of the Learning Center. It should only be operated by staff or volunteers. Members should not be near the printer when it is running; they could injur themselves or cause the print to be altered if the printer get moved. The following steps teach you how to set up the printer and load a file on it to be printed.

1. Turn On (allow the printer to set itself up for ~ 2 minutes)

2. Set Z-Offset
    a. Utilities => Wizards => Z-Offset => Start => -Z or +Z



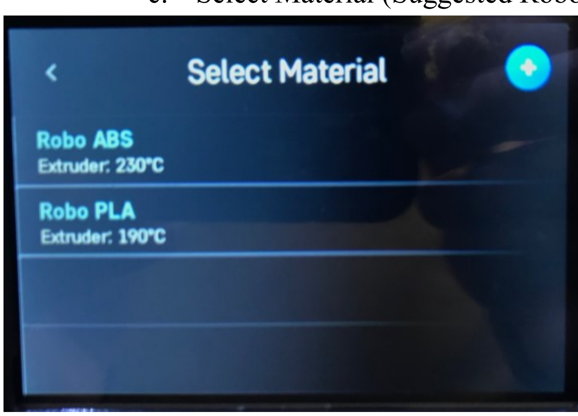


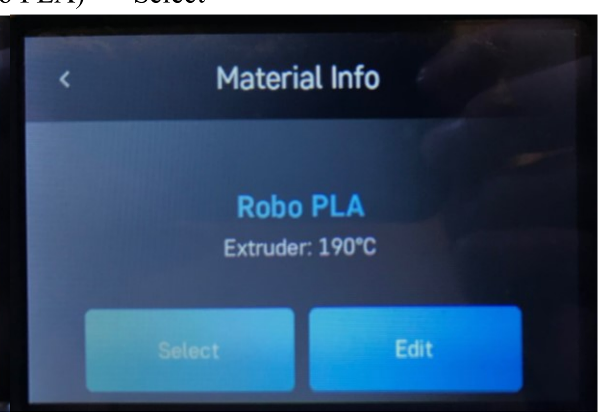
    b. Grab Z-offset paper or any regular piece of paper
    c. When moving along the Z axis, adjust so that the nozzle barely rubs against paper

   d. => Done

3. Load filament
   a. Load filament (if filament is already loaded)
   b. Utilities => Wizards => Filament Load => Start =>

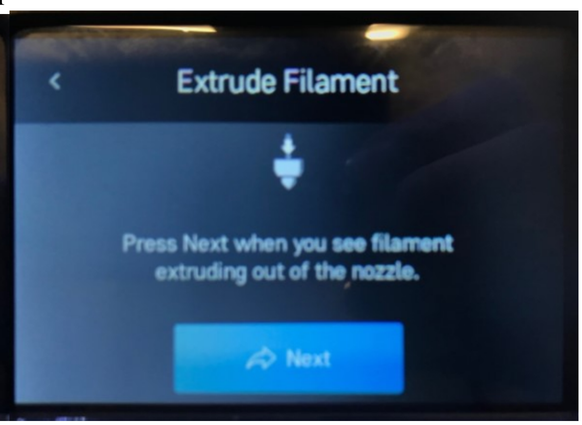
   c. Select Material (Suggested Robo PLA) => Select



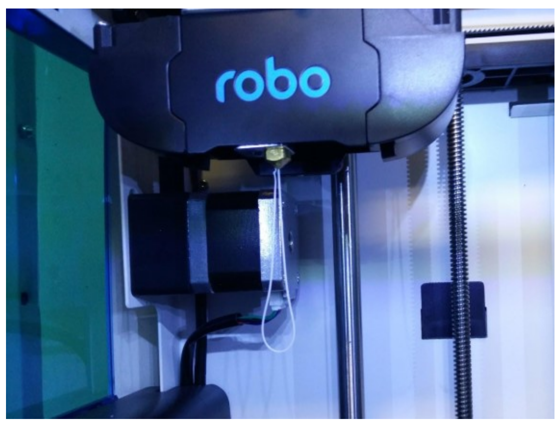


d. Allow printer to heat up

e. => Next => When filament appears press next



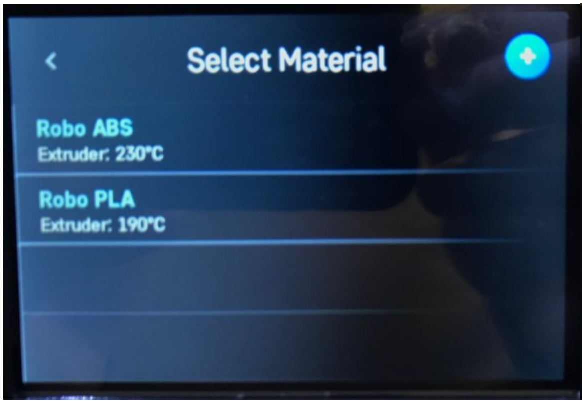
f. => Ok



g. Remove filament from nozzle

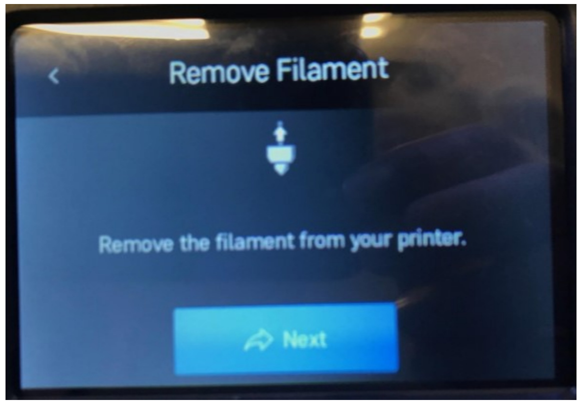
4. Change filament (if filament is not loaded or color needs to change)
    a. Utilities => Wizards => Filament Change => Start =>

    b. Select Material (Suggested Robo PLA) => Select



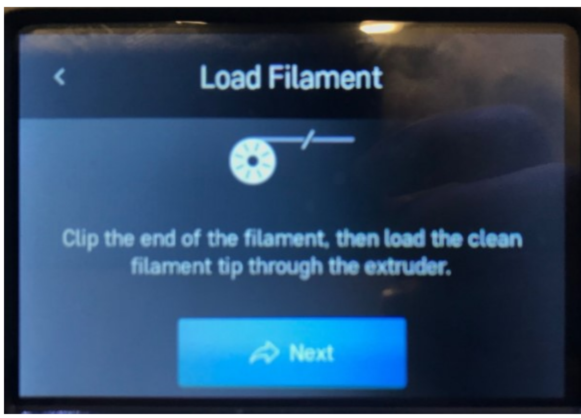
    c. Allow printer to heat up

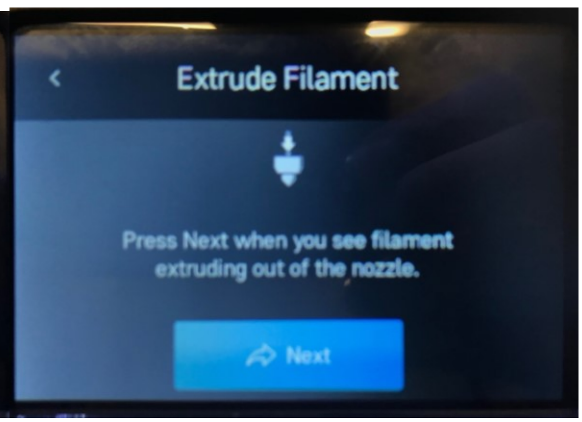
d. Remove filament => Next



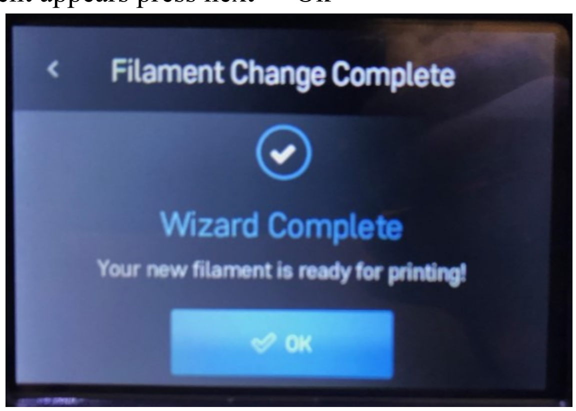
e. Choose new filament => Cut off until tip of filament is clean =>

f. Load filament into extruder=> Next=>





g. When filament appears press next=> Ok

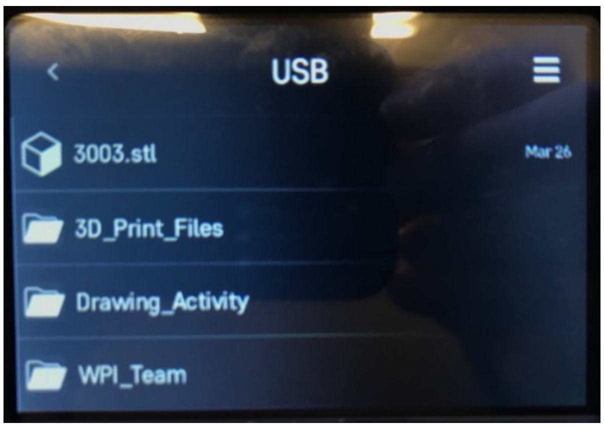


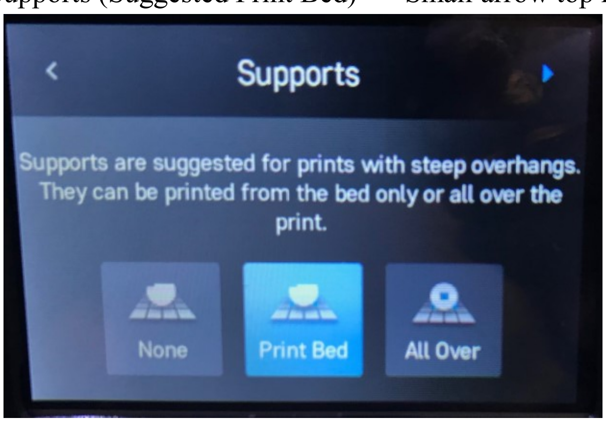
h. Remove filament from nozzle

5. Load file onto flash drive from computer as a .stl file

6. Load file onto 3D printer (plug in flash drive)

7. Convert file into a .gcode file
   a. Files => USB Storage
      i. 

   b. Select the file => Start
      i. 

   c. Select Supports (Suggested Print Bed) => Small arrow top right
      i. 

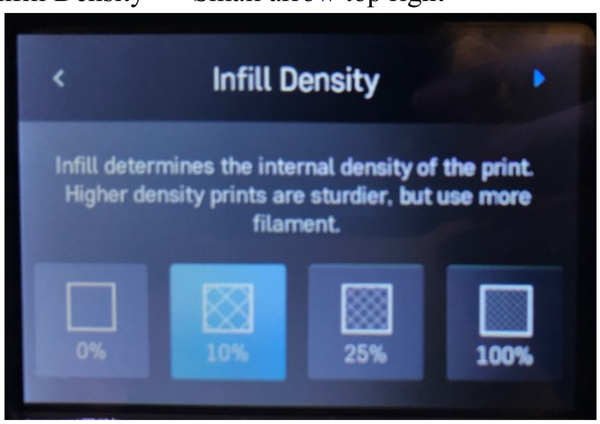
   d. Select Bed Adhesion => Small arrow top right

i. 

e. Select Print Quality => Small arrow top right

i. 

f. Select Infill Density => Small arrow top right

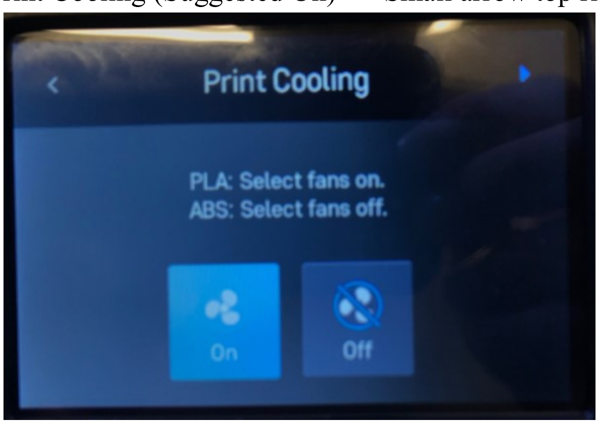
i. 

g. Select Material (Suggested Robo PLA) => Select

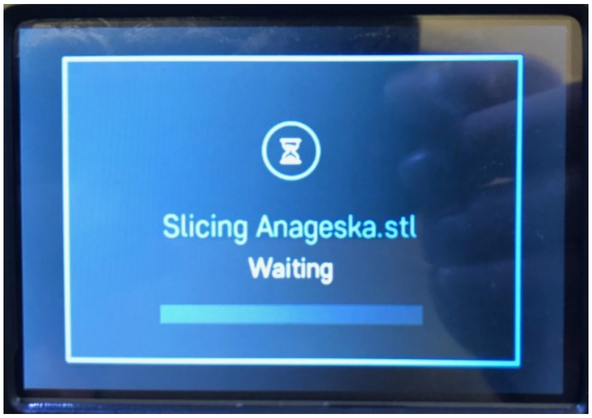
i. 

ii. 

h. Select Print Cooling (Suggested On) => Small arrow top right

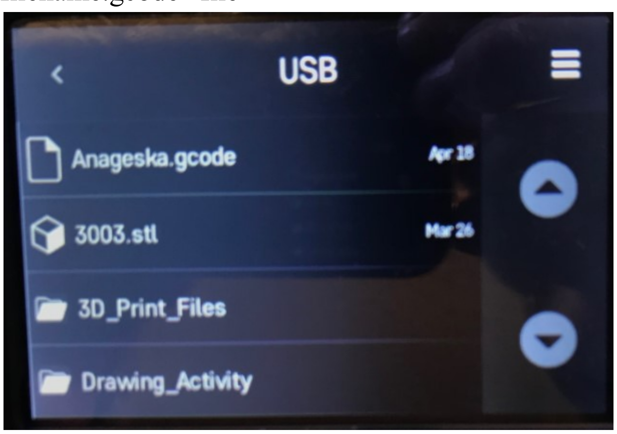
i. 

i. Allow to Load => Check mark top right

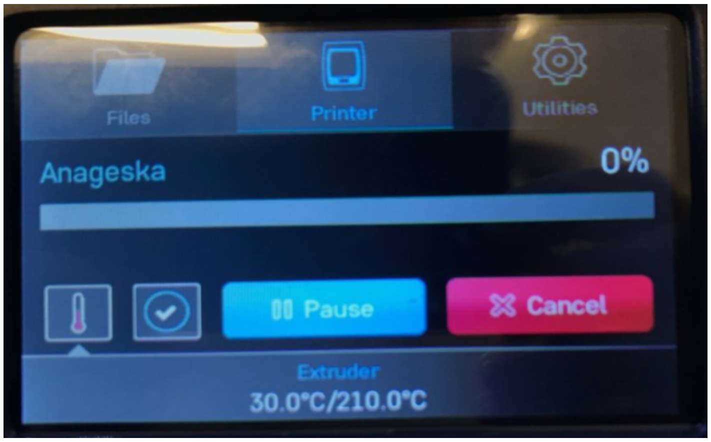
i. 

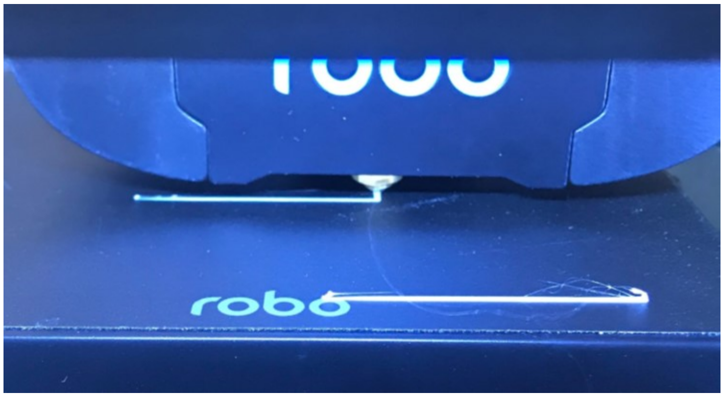
ii. 

j. Select “filename.gcode” file

i. 

8. Run program (Check every now and then to make sure the program does not crash)


Files
Printer
Utilities
Anageska
0%
Pause
Cancel
Extruder
30.0°C/210.0°C


robo


robo

3D Printer Drawing Activity

Introduction

This activity is meant to spark the creative part of the participants' thinking. With almost almost full range on the topic of their drawings, participants are allowed to use their imagination to bring their 2D drawing into 3D space. In this activity, the instructor is conducting a majority of the work. If participants want to be challenged, the instructor may allow the participant to conduct the instructor portion of this activity.

Activity Objectives

- Have Fun
- Explore creativity/imagination
- (Advanced Portion) Challenge TinkerCAD ability
- (Advanced Portion) Challenge knowledge of computer operations

Materials

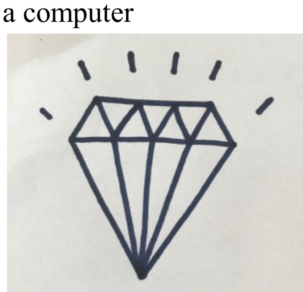
- Pencil and Dark Marker
- Paper (4 in x 5.5 in)
- TinkerCAD account
- Computer
- Image file converter
    - This link works well (https://image.online-convert.com/convert-to-svg)
- 3D Printer
- USB Drive

Instructions

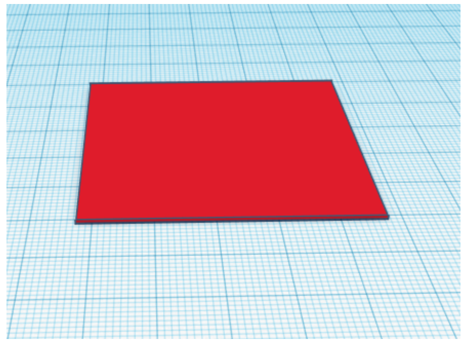
1. Decide on a criteria for all drawings to be based on (large, less detailed images work best) (anime character, logo, diamond, etc.)
2. Have all participants sit at a table with a piece of paper and pencil
3. Give participants 30 minutes to draw a picture that relates to the criteria
    a. On the back of the drawings have students write their names
    b. Most participants will not use the entire time allotted so have another quiet activity planned

Instructor's Job

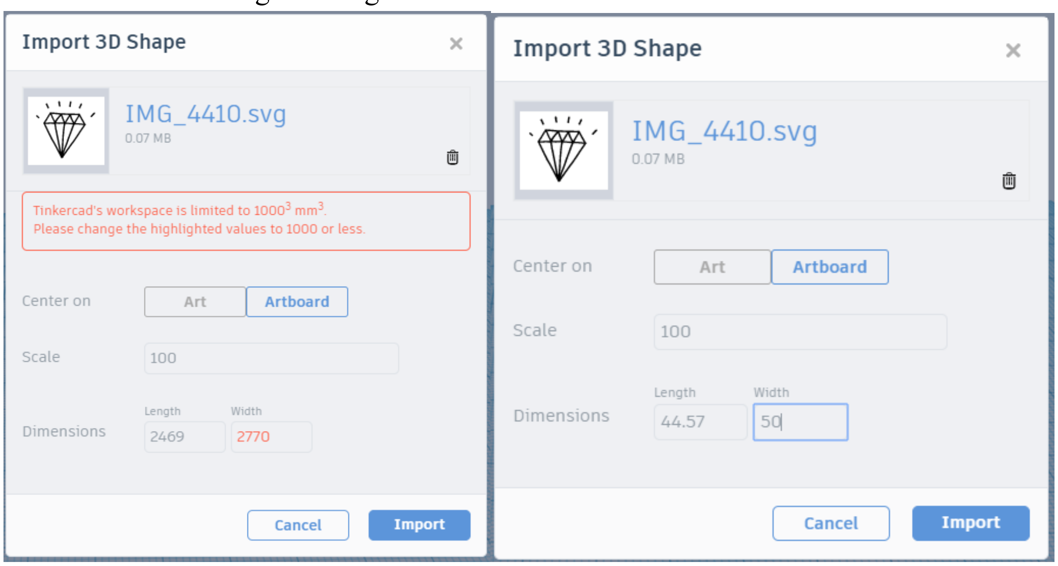
1. Outline the drawing in dark marker
2. Capture a picture of drawing
    a. Upload the image onto a computer



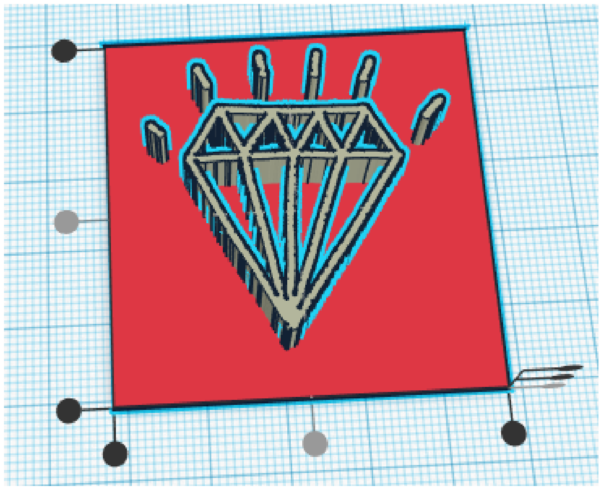
3. Convert the image to a .svg file using the link in the materials section
4. Open TinkerCAD
5. Create a box shape with dimensions 50 x 50 x .5



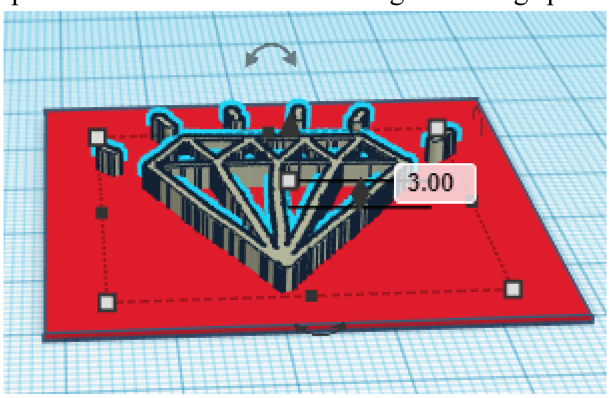
6. Import the file to TinkerCAD
    a. Transfer image to correct dimensions
        i. Change the larger dimension to 50



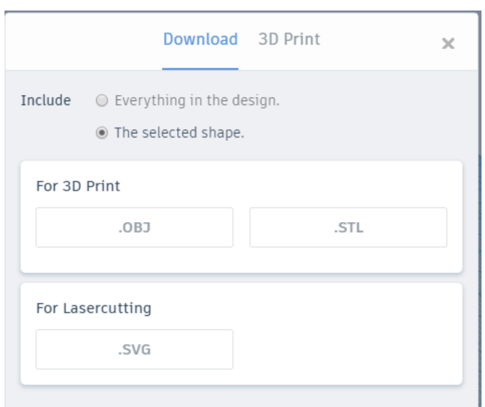
7. Align the two parts at the center on the length and width parameter



8. Change the height of the image part to about 3
    a. Depending on the amount of participants, printing drawings may take a long time so making the print smaller will save time and get drawings printed faster



9. Export the file and download as .stl file on a USB drive



10. Transfer to 3D Printer
    a. Refer to the 3D Instruction Guide to complete activity

TinkerCAD Cup Activity

Introduction

This activity is used to challenge participants' abilities in regards to TinkerCAD. The activity is not meant for someone has never used TinkerCAD before. TinkerCAD is a simple online CAD software meant for people of all ages. The software is user friendly and has tutorials within the software itself.

Activity Objectives

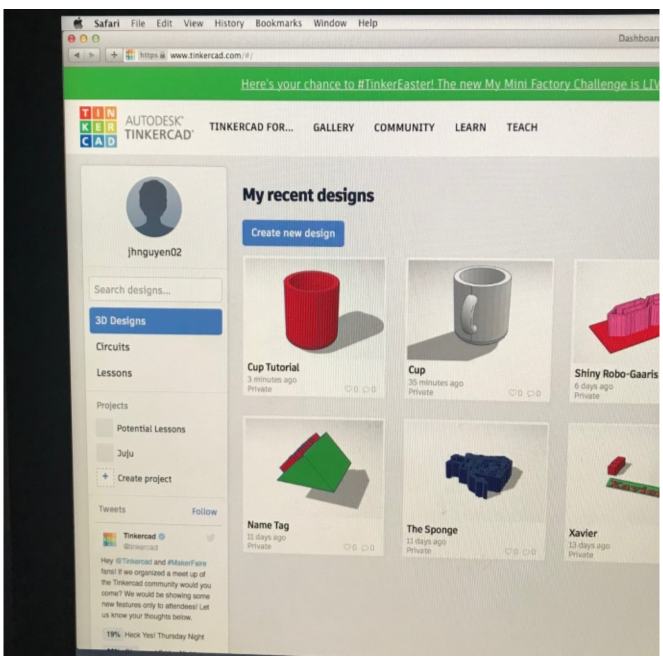
- Challenge user's TinkerCAD Ability
- Create a fun and intricate part that is 3D printable

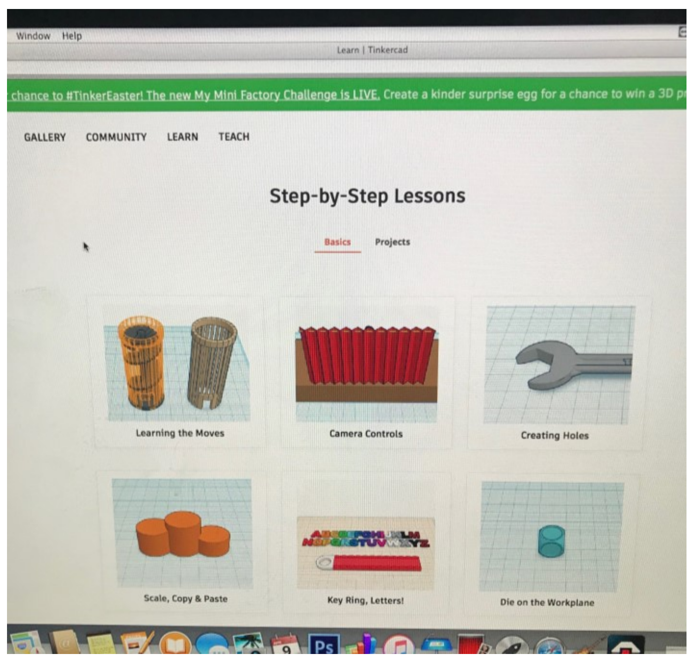
Materials

- Computer with Keyboard and Mouse
- TinkerCAD Account

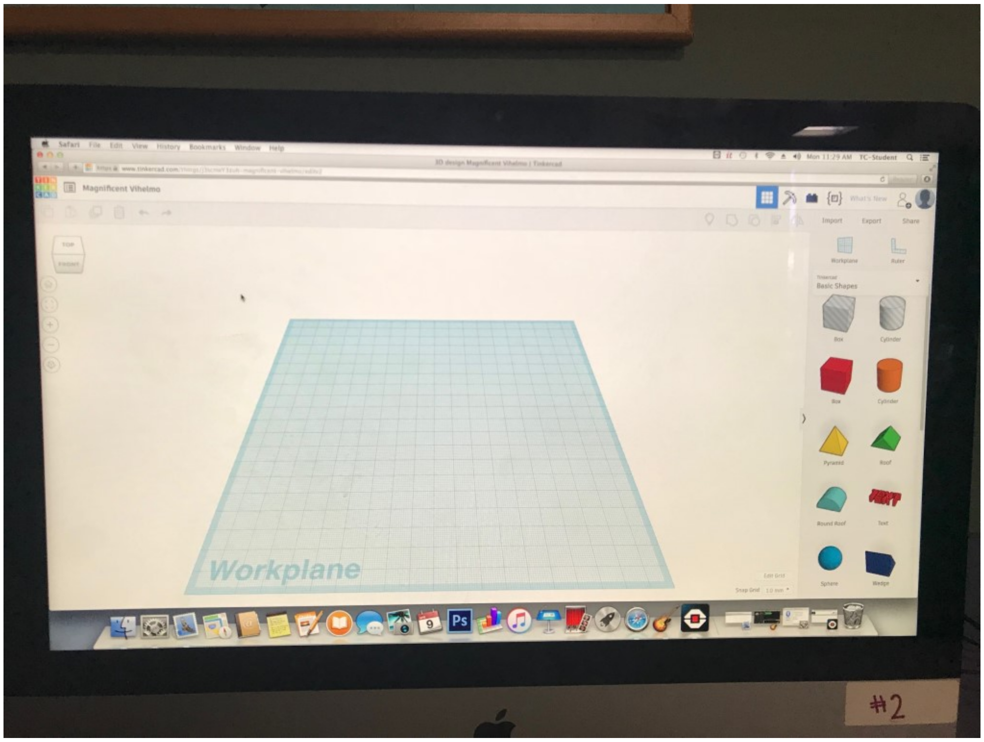
Instructions

1. Open TinkerCAD (Log in or Create an account)
2. Go through tutorial if you have not already
    a. On the home page click on the learn tab on the top of the screen
    b. Be sure go through the "Learning the Moves", "Camera Controls", "Creating Hole", and "Scale, Copy & Paste" sections





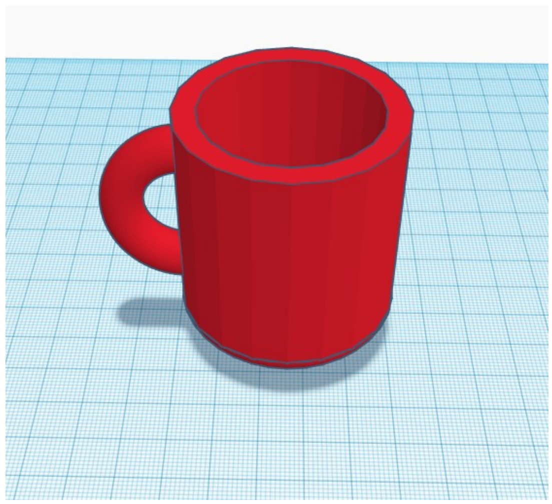
3. Create a New Design (Screen should look similar to the image below)



Activity

1. Rename your design
    a. Click on the “My Designs” button on the top left hand side of the screen
    b. Click on the gear
    c. Enter in the name of your design and save changes
2. Create a half sphere shape
    a. Rotate the shape so that the flat side is facing upwards
    b. Resize the shape to make it larger (50x50x10)
3. Move the work plane to the flat surface of the half sphere
4. Create a cylinder shape
    a. Adjust the size so it is the same length and width as the half sphere
        i. The height is up to the creators discretion (50x50x50)
5. Align the shapes at the midpoints
    a. Select both shapes and click on the align button on the top right hand side of the screen
    b. Click on the midpoint of the length and width side of the shapes
6. Group the shapes so it is one whole shape
7. Create a cylinder shape on the same work plane
    a. Make the length and width dimensions slightly smaller the previous cylinder but the height the same (40x40x50)
    b. Make the second cylinder a hole (not solid)
8. Align the shapes at the midpoints
9. Group the shapes (the center of the first cylinder should be hollowed out)
10. Change the work plane back to the original

11. Create a donut slice shape
    a. Rotate the shape so it is upright
    b. Make the dimensions about (10x20x40)
12. Align the two shapes so that the donut slice is at the midpoint of the cylinder
13. Move the donut shape into the cylinder so the flat surfaces of the donut shape are just inside the cylinder surface but do not extrude into the inner surface
14. Group the shapes
15. The final shape should look similar to the image below



<u>TinkerCAD Castle Activity</u>

Introduction

This activity is used to challenge participants' abilities in regards to TinkerCAD. The activity is not meant for someone has never used TinkerCAD before. TinkerCAD is a simple online CAD software meant for people of all ages. The software is user friendly and has tutorials within the software itself.

Activity Objectives

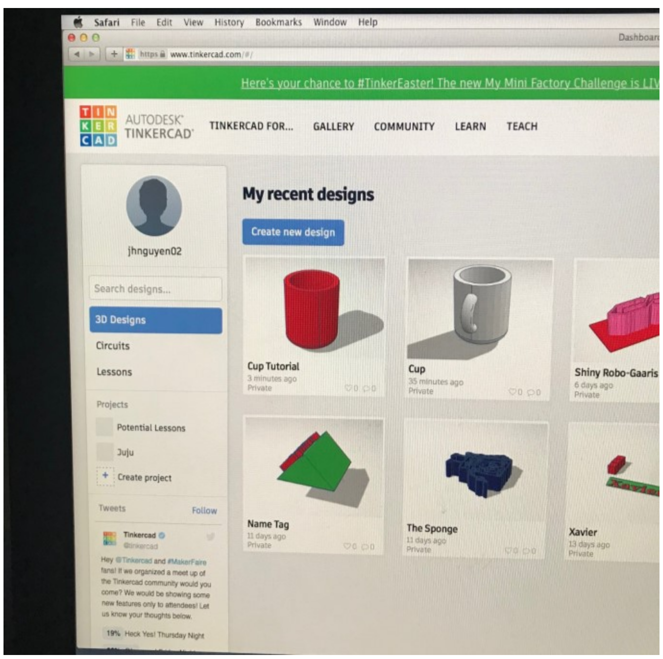
- Challenge user's TinkerCAD Ability
- Create a fun and intricate part that is 3D printable

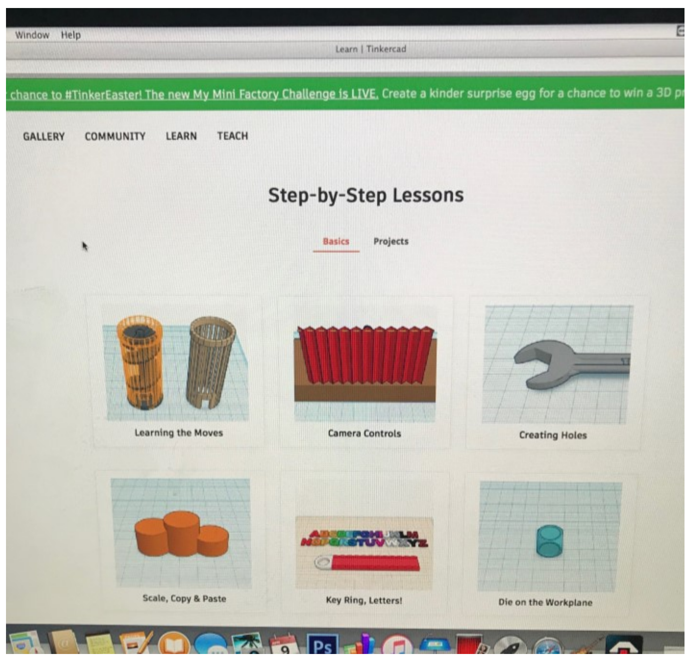
Materials

- Computer with Keyboard and Mouse
- TinkerCAD Account

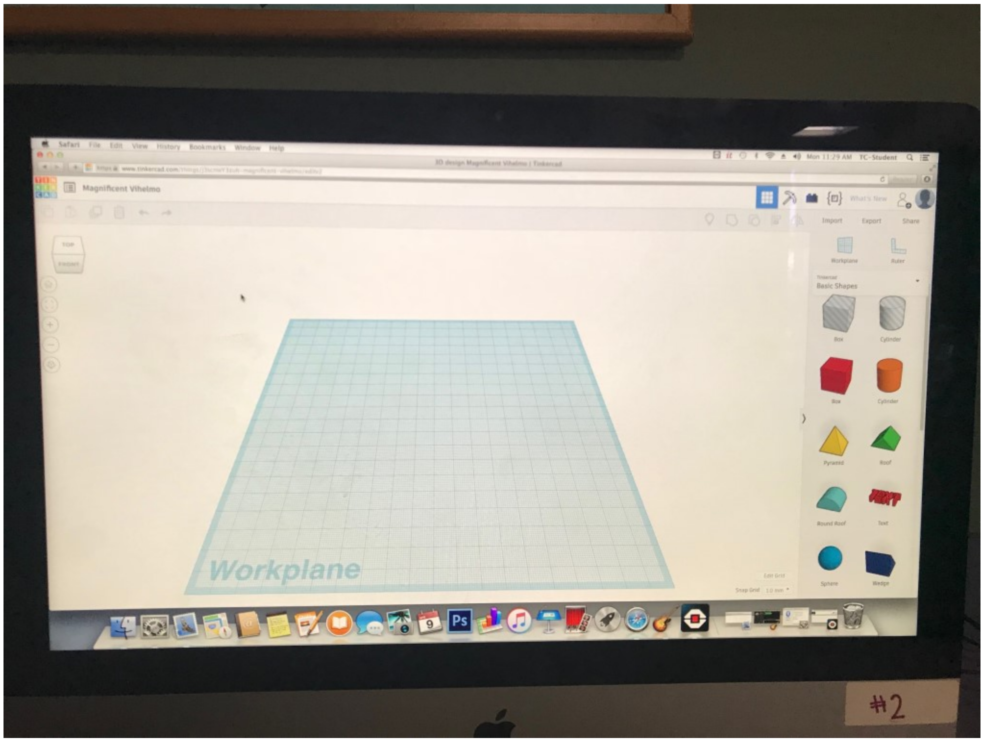
Instructions

1. Open TinkerCAD (Log in or Create an account)
2. Go through tutorial if you have not already
    a. On the home page click on the learn tab on the top of the screen
    b. Be sure go through the "Learning the Moves", "Camera Controls", "Creating Hole", and "Scale, Copy & Paste" sections





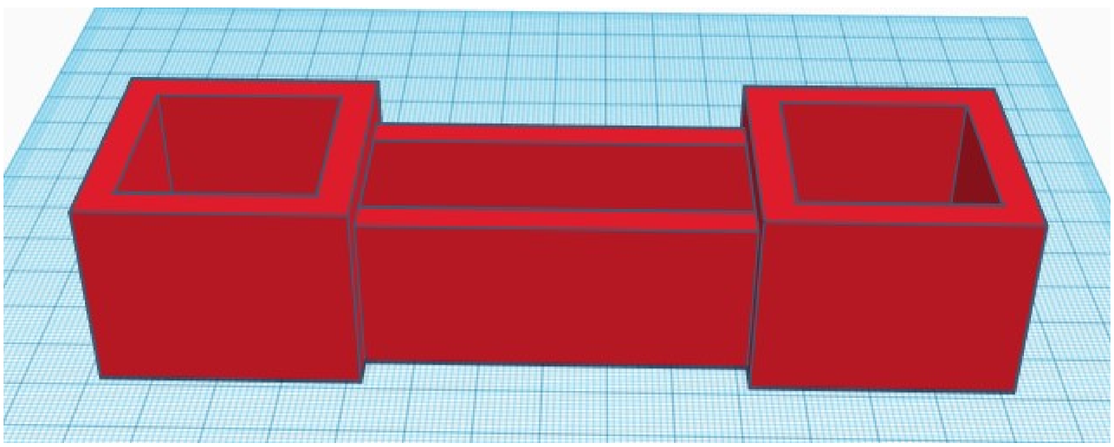
3. Create a New Design (Screen should look similar to the image below)



Activity

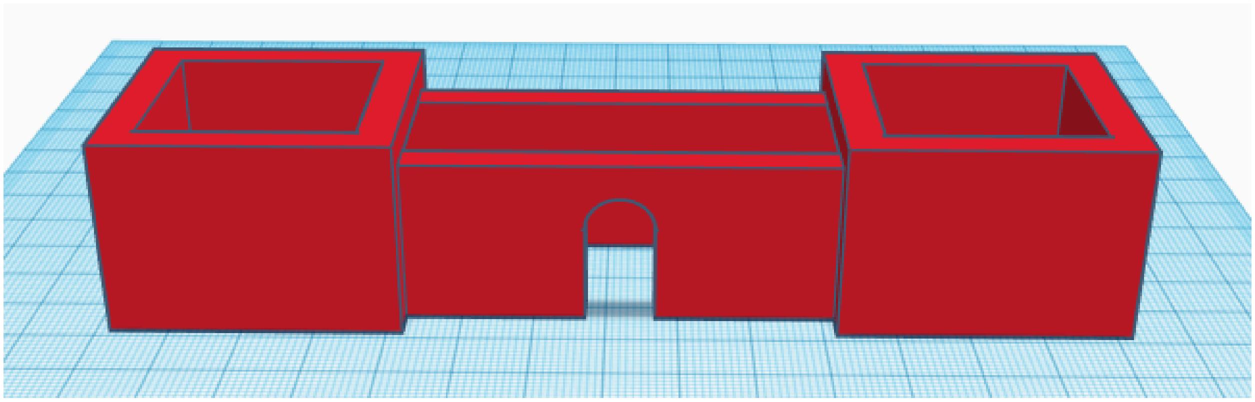
1. Rename your design
    a. Click on the “My Designs” button on the top left hand side of the screen
    b. Click on the gear
    c. Enter in the name of your design and save changes
2. Create a box shape
    a. Place it on the left hand (or right hand) side of the work plane
    b. Make dimensions about (40x40)
3. Create a box shape
    a. Place it in the middle of the the previous box
    b. Make the box a hole (30x30)
    c. Align the boxes so they are centered at the same point
    d. Group the boxes
4. Duplicate the shape
    a. Copy and paste the grouped boxes from step 3
    b. Move the second figure to the opposite side of the work plane
        i. Align the figures so the front is on one line
    c. The figures should be about 60 units apart
    d. Group the figures

5. Create a box shape
    a. Make the dimensions large enough that it connects the two figures in the previous step (61x30x25)
    b. Align the box so it is at the center of the previous figures
    c. Group the figures
6. Create a box shape
    a. Make the box shape a hole
    b. Make the dimensions larger in length but smaller in width than the previous box in step 5 (70x20x25)
    c. Align the box so it is at the center of the previous figures
    d. Group the figures
    e. The figure should look similar to the image below

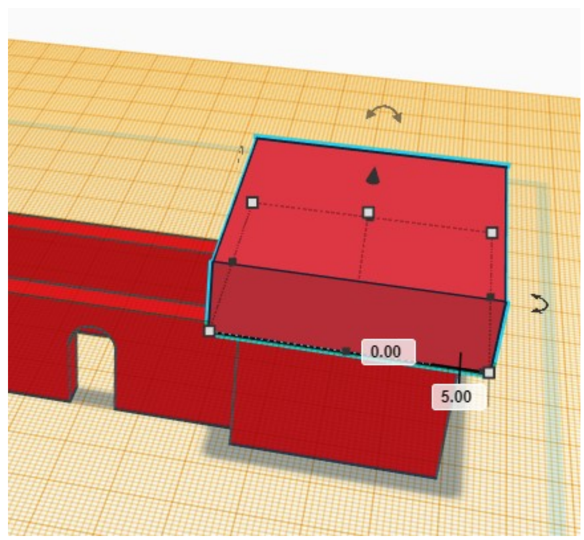


7. Raise the height of the figure to a desired height (30)
8. Create a box shape
    a. Place it in front of the figure
    b. Make dimensions about door sized (10x20x15)
9. Change work plane to the top of the box shape in step 8
10. Create a round roof shape
    a. Make dimensions (10x20x5)
    b. Align the base of the round roof and top surface of the box in step 8
    c. Group with box shape in step 8
    d. Make the figure a hole

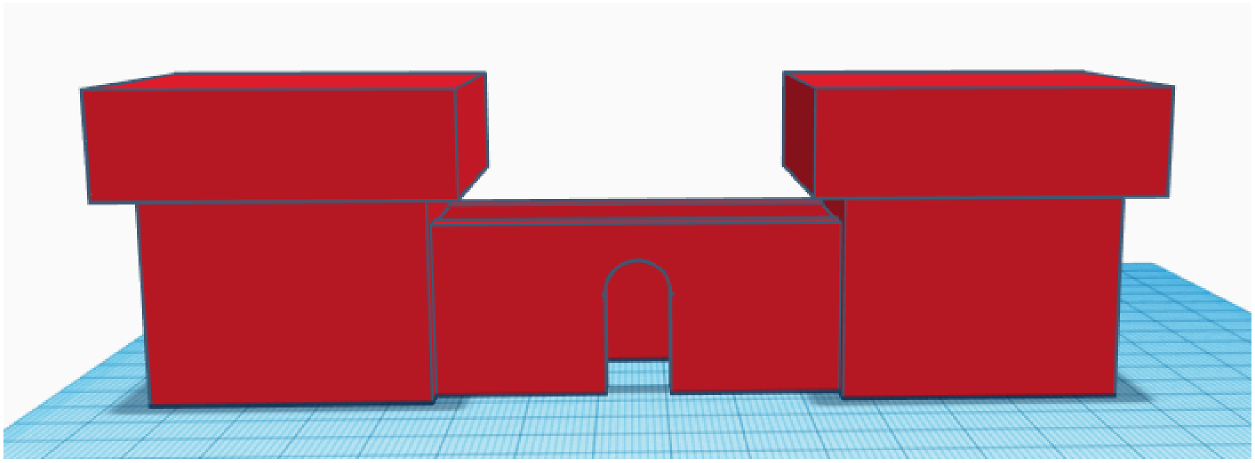
11. Align the two figure so it is center horizontally and at the front
    a. Group the figures
    b. May look similar to the image below



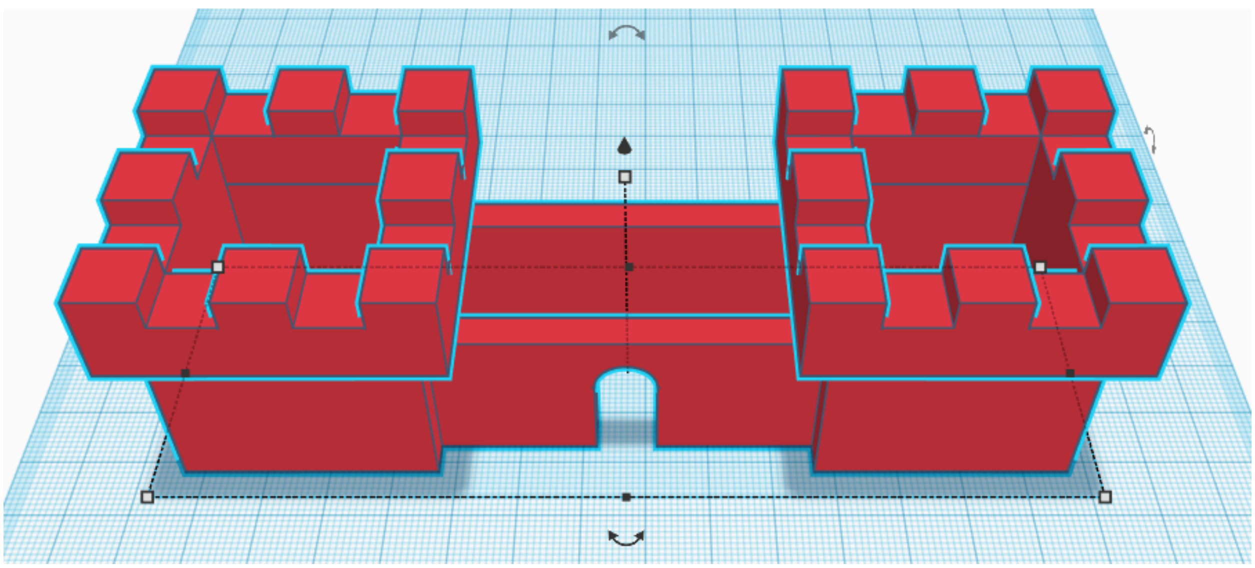
12. Change the workplane to be at the highest point on the figure (left or right side pillars)
13. Create a box shape
    a. Make the dimensions 50x50x15
    b. Align the middle (width side) of the two shapes and right (or left) most side of both shapes
    c. Move the box shape so that the box has an offset of 5 from the outer edge of the base figure (like the image on the right)
    d. Copy and paste the box shape
    e. Select the original box shape and the base figure and group them



14. Move the pasted box shape to the opposite side of the figure and complete the same actions as in step 13 part b, c and e. (Should look similar to the image below)



15. More advanced steps can include adding ridges to the tops of the pillars, adding a roof to the connecting box, adding windows to the towers, and adding more towers (making the castle have four pillars)
    a. May look similar to the image below



Lego Mindstorms Race

Introduction

This activity focuses on captivating participants through competition. As they make their way through the track, they must work together to beat the opposing team. In addition, they must also solve any issue/obstacles that may come up during the race.

Activity Objectives

- Encourage collaboration between participants
- Encourage communication
- Teach divergent thinking
- Teach persistence
- Assist in problem solving

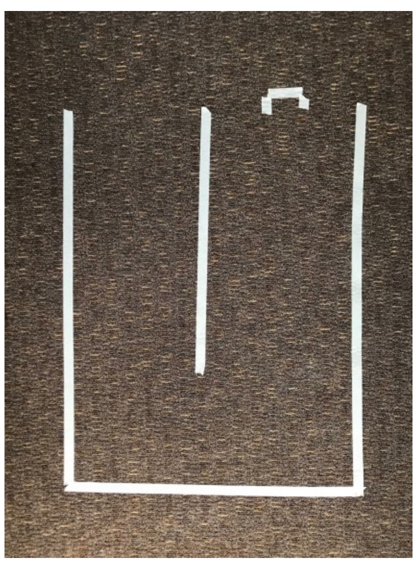
Materials

- Masking tape
- Lego Mindstorms Robot (preferably already built)(tracker)
- IR Controller (Disclaimer: Only works with two robots at one time)
- Space on the ground

Instructions

Making a track

1. Use painters tape to mark a basic tracks on the floor.
2. The track should be a U-shape roughly 3-4 ft long and about 2 ft wide
3. Mark a line as a start point
4. Mark off a small area at the end to place an object that must be moved by the robot's secondary function



5. Repeat steps 1-4 for as many tracks as necessary

Racing

1. Line the robots up at the starting line
2. Make sure the members understand that the race only starts on your word
3. After starting, the robots cannot cross the tape line.
    a. If a robot crosses a line badly, grab the robot and set it back straight but further back
4. After traveling the U-shaped track, they must move an object with the secondary function, usually a spinner or a claw.
    a. Set up a tire from the Lego set and have them move it with the spinner or the grab it with the claw
5. Once they have moved the object, they must return to the start line, again avoiding the lines

Controllers

1. Bluetooth
2. IR Controller
    a. Should be able to control robot with no setup as long as you are on the right channel
    b. To set channel, press the right arrow button on the robot, to get to the third tab
    c. Find IR Control, and press the center button to click on it
    d. Pick Channel 1-2 or 3-4
    e. On the controller, there is a slider near the bottom center of the controls
    f. This slider has 4 positions, one position for each channel.
    g. Click it into 1 if you chose channel 1-2 earlier or 3 if you chose 3-4, and press the buttons to move the robot.

Lego Mindstorms Programming

Introduction

Throughout this activity, participants will explore the capabilities of the programming side of the Lego Mindstorms. Lego Mindstorms are robots that can be assembled and operated using a remote, a cell phone, or computer. The goal is to have the participants work through problems that arise when trying to navigate their robot through a premade course. After going through the tutorial, participants will be challenged with adapting their program so that their robot can complete the challenge.

Activity Objectives

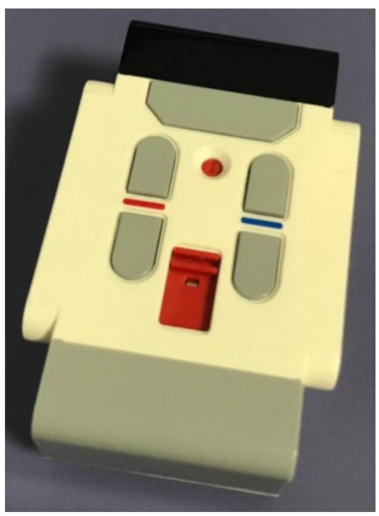
- Teach Basic Programming Skills
- Teach Problem Solving Skills
- Have Fun

Materials

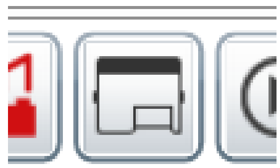
- Lego Mindstorms EV3
  - Preferable if robot is built
    - This activity was done with the Tracker robot
- Computer/Laptop with Lego Mindstorms Program downloaded
  - Program is downloaded on computers #1, #2, #5
- Track is the cover of Lego Mindstorms box

Instructions

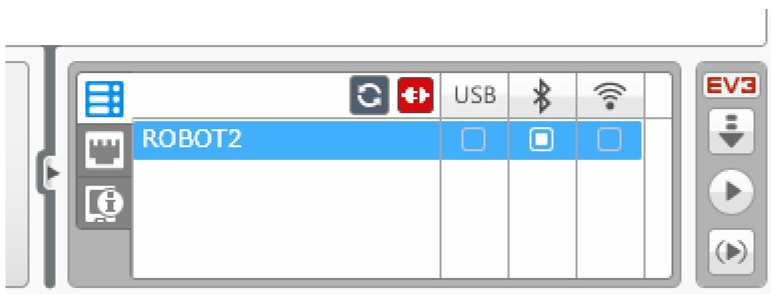
1. Wirelessly connect computer with the Lego Mindstorms brick using bluetooth
   a. Make sure bluetooth on the block is on and iPod/iPhone is off



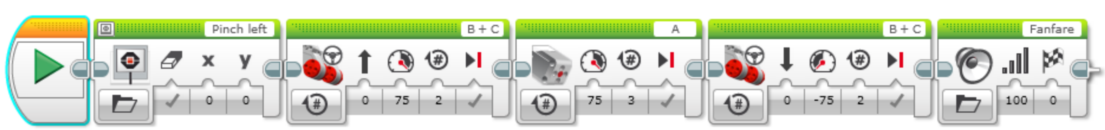
2. Open Lego Mindstorms Program on computer
    a. Select the robot you built
    b. Move to the top right hand side of the screen and click on the book button on the top right hand side of the screen and select the version you build
    c. Click the programming tab (image below)



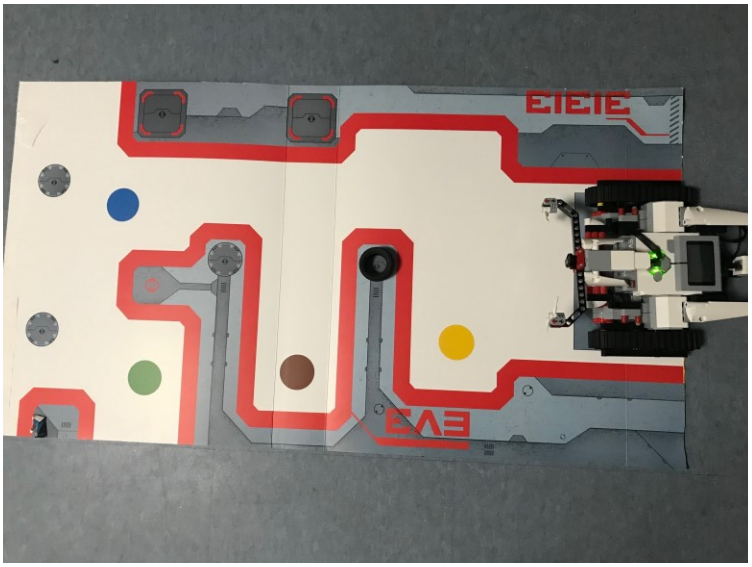
3. On the bottom right hand side of the screen refresh the device and connect the program with the block (image below)



4. Click on the "Follow step-by-step programming instructions"
    a. Complete the directions
    b. The final program should look like the image below



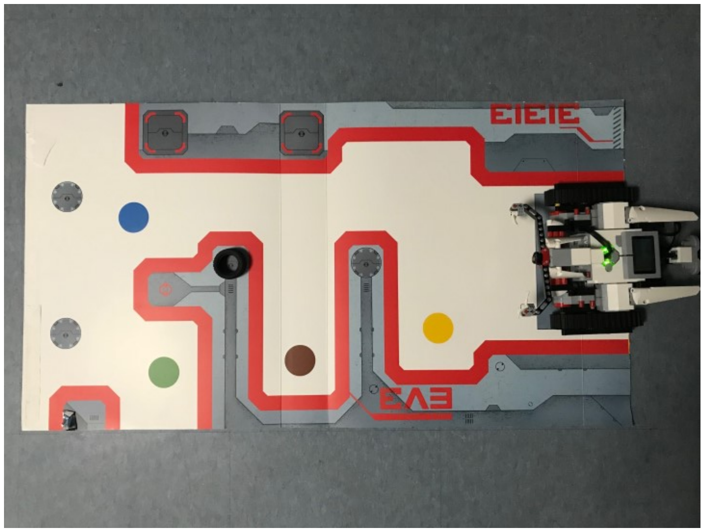
5. Set up the track so that it looks like the image below
    a. There is a small tire at the first circle in front of the robot



6. Run the program so that the robot hits the tire out of the spot and returns to the start area
7. If the program is run correctly move onto the following activities below

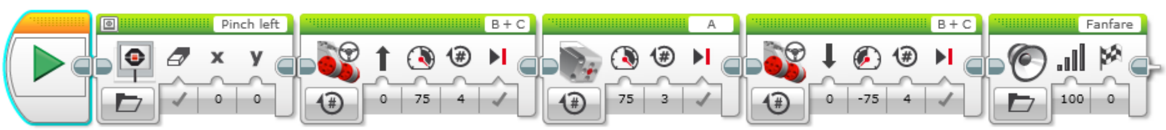
Tracker vs Tire Mission 1

1. Position the tire on the track so that it is in the second circle in front of the robot like below
2. Adapt the program so that the robot moves to the tire, hits the tire, and returns to its original



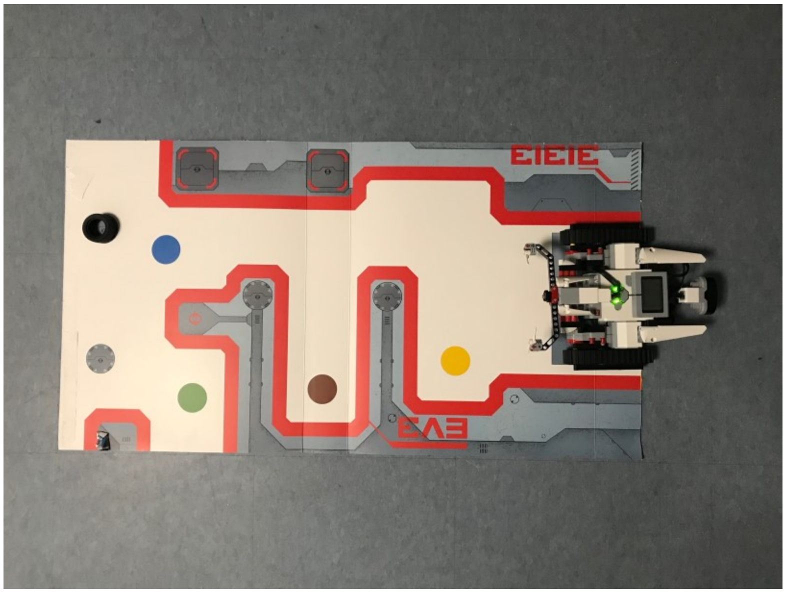
position

3. The program can look similar to the following
    a. In the second and fourth blocks, the number of rotations was changed from 2 to 4

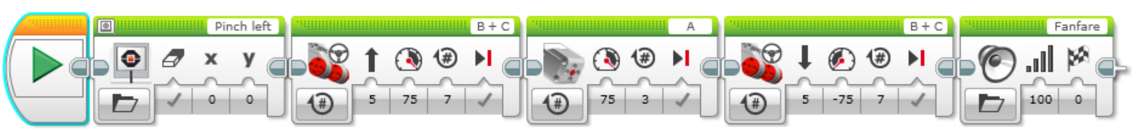


Tracker vs Tire Mission 2

1. Position the tire on the track so that it is in the farthest right side circle in front of the robot like below

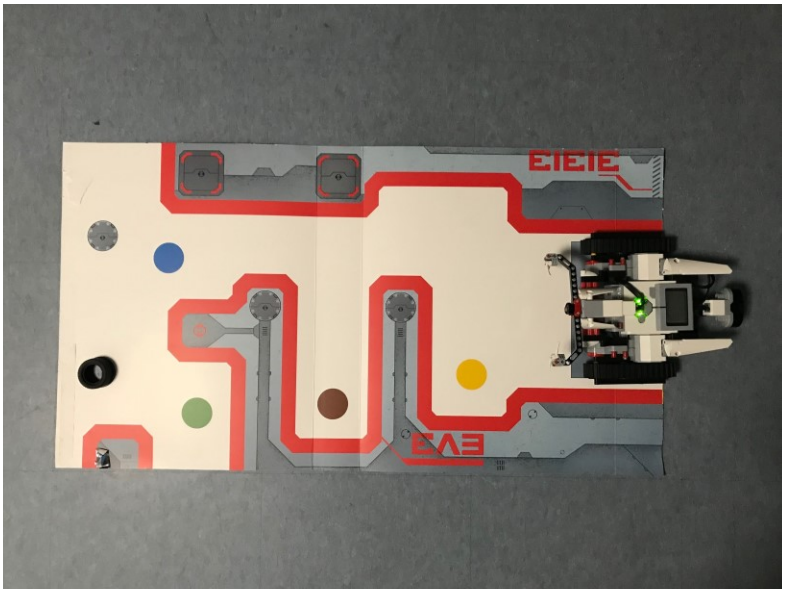


2. Adapt the program so that the robot moves to the tire, hits the tire, and returns to its original position
3. The program can look similar to the following
    a. In the second and fourth blocks, the number of rotations was changed from 4 to 7
    b. In the second and fourth blocks the directional number is changed from a 0 to 5

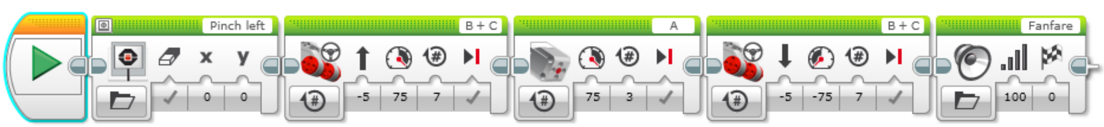


Tracker vs Tire Mission 3

1. Position the tire on the track so that it is in the farthest left side circle in front of the robot like below

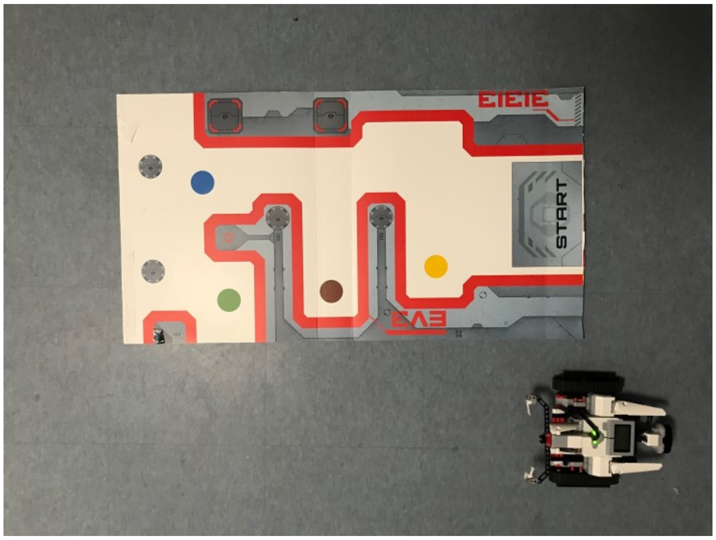


2. Adapt the program so that the robot moves to the tire, hits the tire, and returns to its original position
3. The program can look similar to the following
    a. In the second and fourth blocks the directional number is changed from a 5 to -5

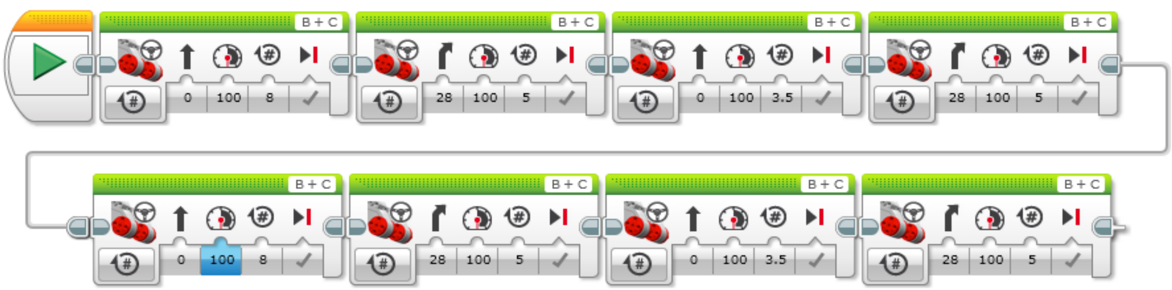


Victory Lap

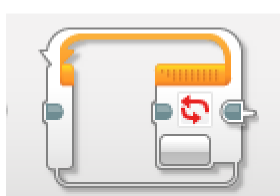
1. Position the robot on the left hand (or right hand) side of the track like below

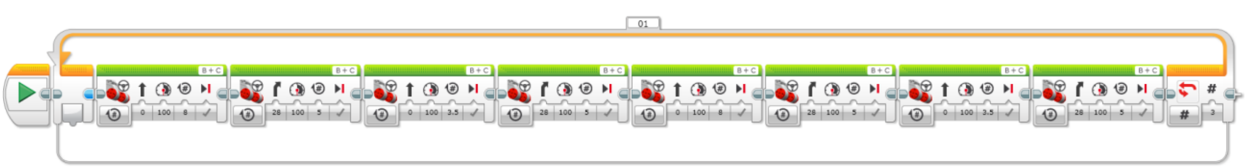


2. Create a program that allows the robot to complete one lap around the track
3. The program can look similar to the one below



4. Have the members edit the program to have the robot make unlimited laps around the track (the program will almost look the same with the added command as seen below)





Make Your Own Track

1. Have the members create their own track
2. Have the members then drive through the track using the remote
3. Have the members create a program to make the robot automatically go through the track