Sparking Excitement for STEM: Implementing an Educational Lab in Venice with Modern Technologies

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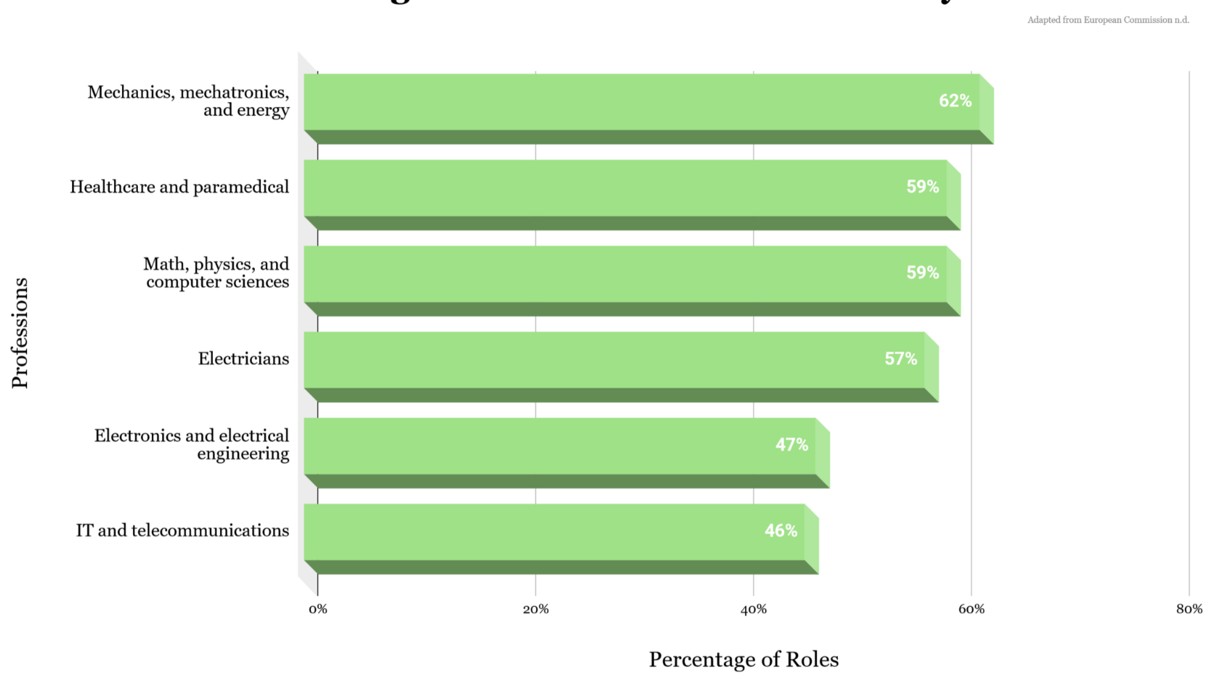
Abstract

Through stimulating students' interest in STEM fields at an early age, educators make it more likely those students will further their STEM education and pursue STEM careers for the betterment of a society. Italy specifically is in great need of technology experts, engineers, and scientists. In this project we studied the best practices for teaching science, technology, engineering, and mathematics, gathering advice from STEM programs and educators, and reviewing core learning objectives for STEM from curriculum guidelines in the US and in Italy. We used this information to develop a start-up STEM education lab for Venetian students. The lab incorporates fun, hands-on activities and lessons, using two modern technologies owned by the Venice Project Center, Farmbot and Simtable. Our ultimate purpose was to design a lab that might teach students about plant life, topography, programming, and other topics, while keeping them engaged and excited. We prepared the equipment for use and designed a set of beginner and intermediate learning activities for use with each technology. Getting feedback from experts and exposing several children to the lab, we summarized our findings and made recommendations for future teams implementing the lab. Our menu of lesson plans, activities, and relevant instructional handouts were published on an online website. Venetian teachers can use it as they bring their students to the lab in the future.

Executive Summary

Research and development in STEM fields can bolster a country's economy and provide its citizens with jobs. As such, bringing passionate and talented young people into the STEM workforce is paramount. In Italy, however, many STEM related jobs are going unfilled as seen in the following graph.

Percentage of Unfilled STEM Hires in Italy



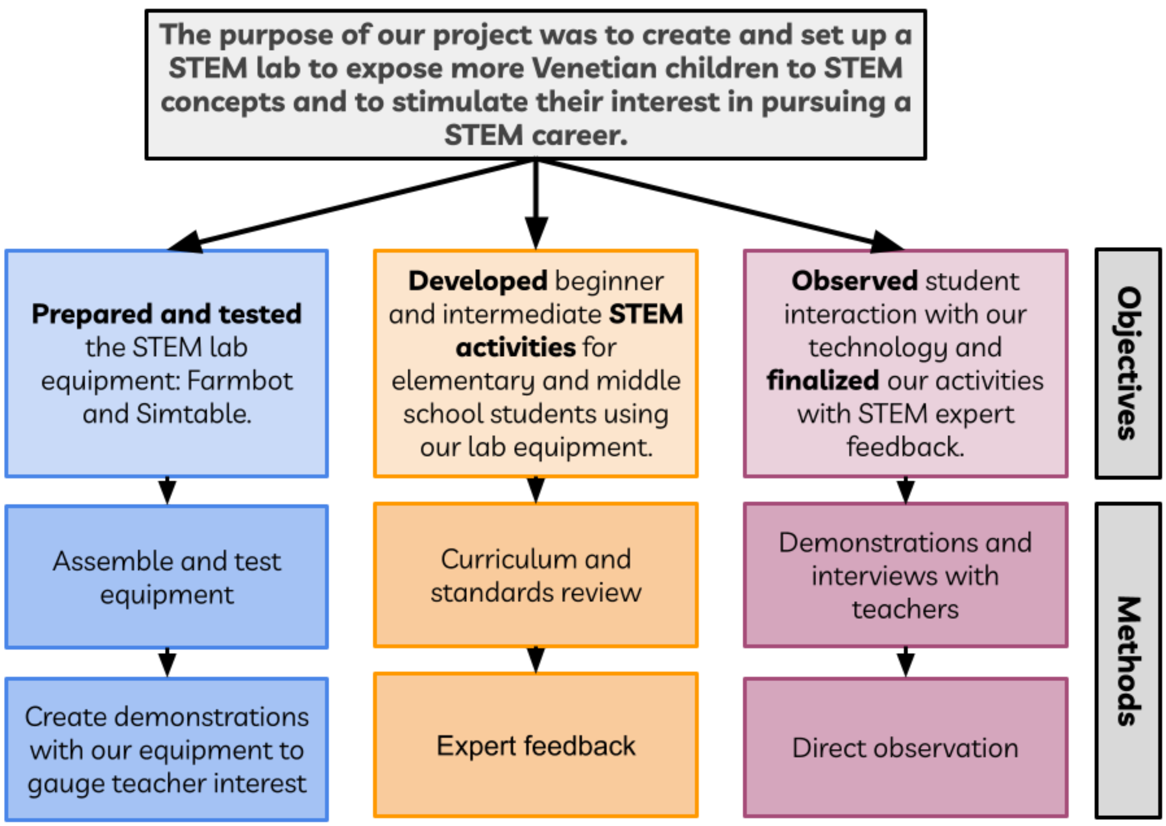
Our research has shown that engaging students in challenging STEM projects and activities early (rather than a lecture-based approach) can increase their interest in these fields and possibly even get them to consider careers in STEM.

Over the course of two months our team laid the foundation for an engaging and educational STEM lab for Venetian students, located in WPI's Venice Project Center (VPC). We produced a series of lesson plans and activities for lower secondary school students in Venice. These lesson plans and activities were added to a new repository website that teachers can use with their students in the VPC.

Venice has been a global center for trade, creativity, and culture for a millennium. However, in recent years it has been suffering from three major economic and environmental issues: depopulation, overtourism, and global warming, the latter of which has led to rising seas and increased flooding. In addition, there has been a shift in job opportunities to low paying tourism-related jobs. Venice itself has been making efforts to bring in more STEM related start-ups, through groups such as SerenDPT and Venice Calls. Encouraging Venetian students to pursue STEM degrees and careers may be one way to prepare them for climate change response in the future, to revitalize the local Venetian population, and prepare young people for STEM job opportunities, whether in Venice or on the mainland.

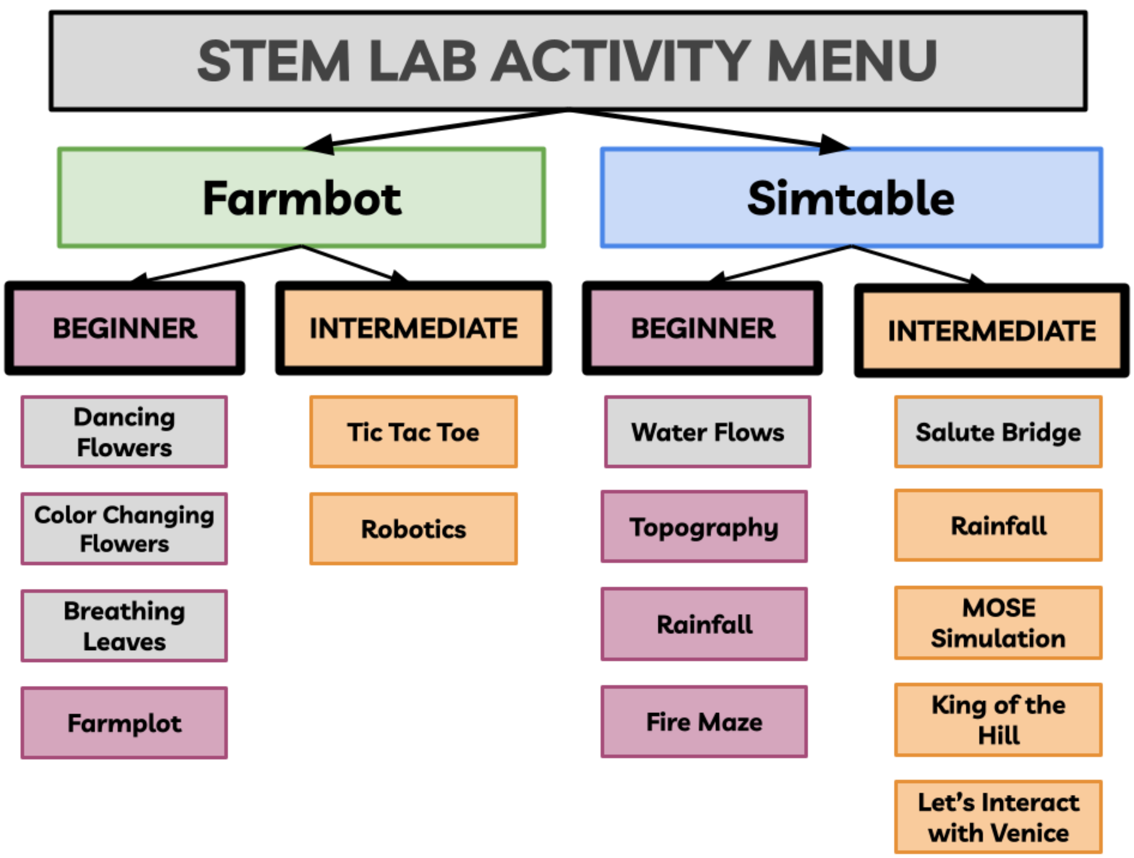
The STEM Lab, as such, is an attempt to spark Venetian children's interest in STEM concepts and careers through designing an educational lab with modern technologies: Farmbot and Simtable. Farmbot is an automated farming tool which can plant, care for, and harvest a small plot of plants on a raised bed, and Simtable allows for an interactive and user modifiable way to simulate natural world disasters in real locations on Earth.

For this project, our team identified and met three objectives. First, we prepared and tested the STEM Lab equipment: Farmbot and Simtable. Then, we developed beginner and intermediate STEM activities for grades 5-8 using our lab equipment. We designed these activities based on research from the American and Italian standards for STEM education and on interviews with expert educators. Lastly, we incorporated feedback on our materials and equipment from teachers, and from our observations of several Venetian children who were asked to explore and try out the equipment. A summary of our objectives and the methods we used to complete them can be seen in the following figure.



Before creating the activities we worked on assembling the equipment so it was usable and presented no hazards in our lab room. We replaced the current Simtable sand (which was ground walnut shells) with more hygenic and less allergenic calcium carbonate salt (similar to table salt). Farmbot required a new circuit board; we replaced the electronics, flashed new software, and prepared the planting bed with soil, a tarp, and pots. However, by the end of the term, we were able to get both technologies fully functioning and ready for classroom use.

The main deliverable of our project for the STEM Lab was a menu of lesson plans, learning activities and instructional handouts. Farmbot was used for teaching plant biology, robotics, and coordinate systems. Simtable was used for teaching topography, precipitation, and combustion (fire). We put this menu into a VPC repository website for future users of the STEM Lab. Our activities were organized by the associated piece of equipment, Farmbot or Simtable, and by the level of difficulty, beginner or intermediate. We also included on the site a Farmbot Easy-Assembly Guide and a Simtable Easy-Setup Guide.



Our beginner activities are geared towards fifth and sixth graders. The cumulative activities require students to form their own hypotheses and then test them based on their observations, using evidence to write about and explain the results of their experiments. Using learning practices like claim-evidence-reasoning (CER), active learning, project based work, and cumulative learning will allow students to be engaged in the material and technology. Our intermediate activities are geared towards seventh and eighth graders. These activities require students to use critical thinking, active learning, claim-evidence-reasoning (CER), and modern technologies. Personal connection will allow students to draw parallels between what they are investigating in the activities to real-world problems they face in Venice.

Based on the feedback received from students and teachers, we modified some of our materials and made a number of recommendations for groups continuing the STEM Lab. Our main takeaways from this were student engagement levels, more information for teachers, and more worksheets for kids to use during activities. In the end, we recommended that the next team get in touch with multiple local Venetian teachers and host demonstration lessons for them and several small groups of students using the lesson plans we created. We also recommended some technical fixes that should be addressed later with the Farmbot.

Although we obtained additional feedback by inviting teachers to look at our materials and observed several young students engage with the equipment, more formal testing with the appropriate age groups and full activities, explained by a Venetian speaker, is necessary. We developed a methodology (involving direct observations and surveys) to test how effective the activities are in terms of:

- Basic functionality of the equipment
- Practicality of dividing groups into numbers conducive to the room size
- Ability of students to comprehend the concepts and procedures and successfully complete the lab within the allotted time
- Ability for students to work together as teams
- Enjoyability of the activities and level of interest in future STEM activities

We shared these methods in our report so they may be used by future teams once the lab is further tested in this way and relevant refinements are made and posted to the materials on the website. This will help determine how to divide the groups and coordinate the activities in and out of the lab.

Introduction

Research and development in the fields of science, technology, engineering, and mathematics (STEM) benefits many countries by bolstering their economies and providing jobs. In fact, according to Beatty (2011), "between 50 and 85 percent of growth in U.S. gross domestic product over the past 50 years was accounted for by advancements in science and engineering" (p. 3). As such, bringing passionate and talented young people into the STEM workforce is paramount for a country's success.

This project focused on fostering critical STEM education in Venice, Italy. This city has been a global center for trade, creativity, and culture for a millennium. However, in recent years it has been suffering from three major economic and environmental issues: underpopulation, overtourism, and global warming, which has led to rising seas and increased flooding. In the 1970s, the population of Venice was ~150,000, but by 2020 the population had shrunk to just over 50,000 and has been continuing to shrink (Williams, 2020). One of many reasons may be the shift in job opportunities to low wage, tourism-related jobs. The Italian labor market, however, indicated there are many job opportunities in the STEM field in Northern Italy: "38.3% of the jobs on offer remain unfilled and finding candidates remains particularly difficult for businesses in the north-east (42.0%)" (European Commision*, n.d.*). Venice itself has been making efforts to bring in more STEM related start-ups, through such groups as Venice Calls. Thus, encouraging Venetian students toward pursuing STEM degrees and careers may be one way to revitalize the local Venetian population and prepare young people for STEM job opportunities. Expansion of STEM jobs and interest in this part of Italy may in turn be crucial to helping Venice resolve its structural and environmental challenges that demand cutting edge scientific research and innovative technical solutions.

Therefore, the purpose of our project was to spark Venetian children's interest in STEM concepts and careers through designing an educational lab with modern technologies. To our advantage, at the start of this project, the Venice Project Center (VPC) possessed some cutting edge STEM technology, including a Simtable and Farmbot. Simtable allows for an interactive and user modifiable way to simulate natural world disasters in real locations, and Farmbot is an automated farming tool which can take care of a small plot of plants. With the input of local teachers, we designed a menu of lessons with these technologies.

Specifically, our team identified and met three objectives for the project:

1) Prepared and tested the STEM Lab equipment: Farmbot and Simtable.
2) Developed beginner and intermediate STEM activities for elementary and middle school students using our lab equipment.
3) Observed student interaction with our technology and finalized our activities with STEM expert feedback.

Background

This chapter will define STEM, its importance, and how it is being taught today. It will then explain how STEM fits into Italy's education system. Finally, it will identify how using technologies such as Farmbot and Simtable could be useful for teaching STEM topics to children.

Basics of STEM Education and its Importance

STEM is an abbreviation coined by the National Science Foundation in the 1990s for different, but related, subject areas: Science, Technology, Engineering, and Mathematics (Bybee, 2013, p. 1). Advances in STEM fields are continuously being made in support of social, economic, and technological challenges faced globally, which "means that STEM education not only has the ability to modify our society, but also has the ability to change it completely by presenting us with better knowledge when it comes to protecting it" (Davis, 2018).

Exposing students at a young age to STEM is beneficial as it has the potential to spark their interest in advanced education, STEM majors, scientific jobs, and much more. Robert Tai and Rena Subotnik (2011) studied graduates from high school STEM programs and found that if a student did their own original science research in high school, they were 70% more likely to pick a STEM major (Council, N. R., 2011). In addition, integrating STEM into curriculum at a younger age has a greater likelihood to pique students interest in the field and pursue STEM studies, and even STEM related jobs, as shown in Figure 1:

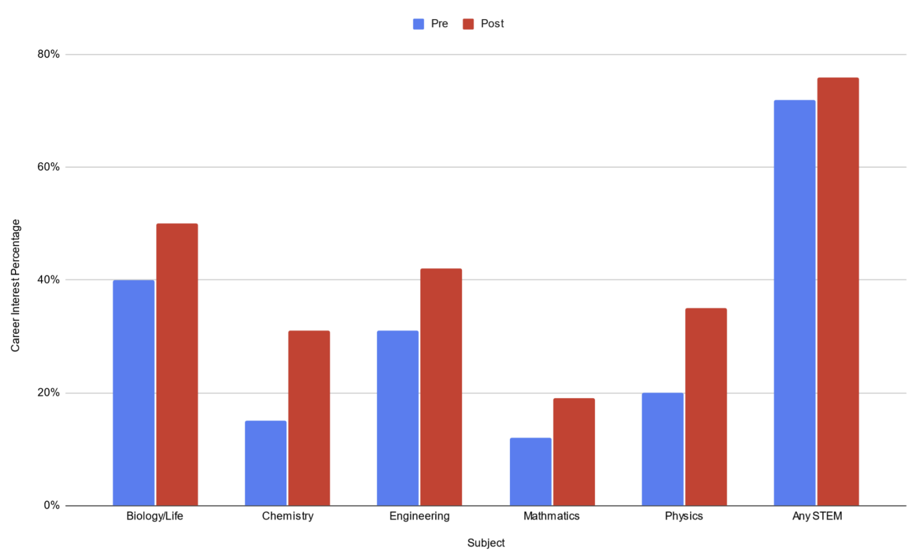


Figure 1. Survey results comparing student career interests before and after a STEM program (Adapted from Miller, D., Perron, J., & Ruvich, C., 2012).

Now more than ever, engineers, physicists, biologists, and technical experts are in high demand, as STEM can advance a society's social, economic, and political knowledge and power. In fact, in Italy, there is a high percentage of unfilled positions, which can be seen in Figure 2.

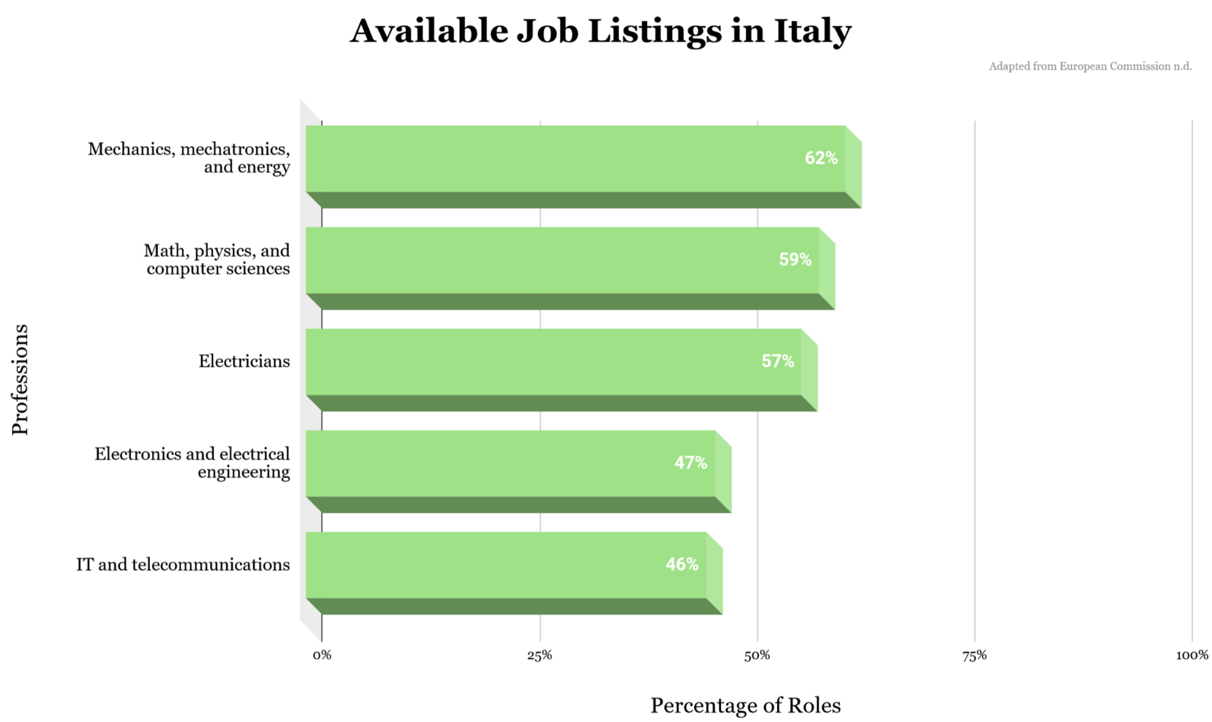


Figure 2. Available job listings in Italy (adapted from European Commission, n.d.)

(European Commision, *n.d.*)

In terms of technology, Italy also has fewer citizens with basic or advanced digital skills than many other European countries. For example, Italy is the 25th of 28 European countries for having the most capable IT workers (TensorGen, 2021). It can be seen in Figure 3 that Italy is the 21st of the 28 countries regarding its general IT capabilities (*Italy in the Digital Economy and Society*, 2021). Figure 3 highlights the relative capabilities of Italy's technology.

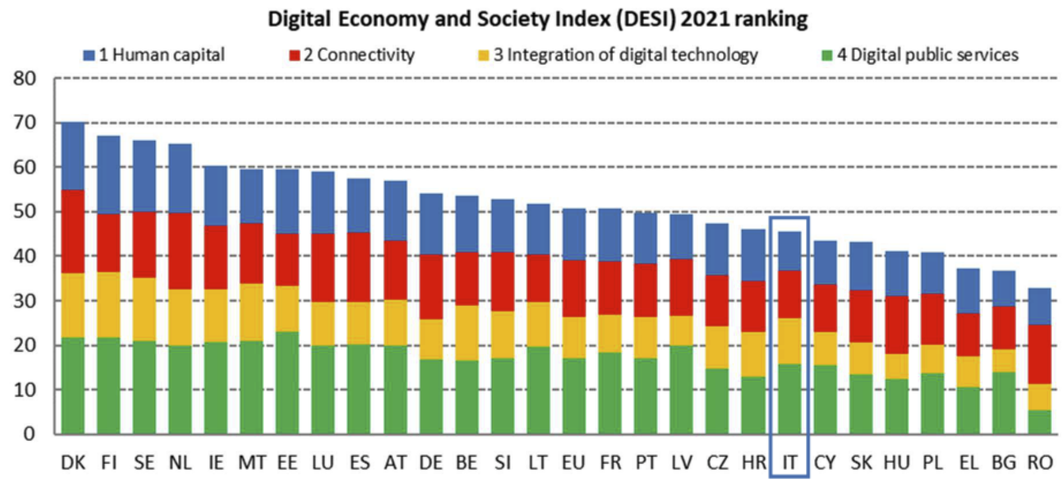


Figure 3. DESI 2021 comparison of 28 European countries for their technological capabilities (Italy in the Digital Economy and Society, 2021).

In addition to STEM's importance for the country as a whole, STEM education can help citizens understand how science can be used to shape the world. STEM education can promote an understanding of the fundamental properties of the universe and the technology made out of them, then how to use them in real-world situations (Bybee, 2013, p. 5). In sum, it allows for better civil and political decisions as well as more opportunities for work (Council, N. R., 2011).

Italy's Educational Performance

Is Italy preparing students to fill these jobs and develop these skills? In terms of school performance in science, some data suggest that Italy may be slightly behind other European countries. Globally, the performance of schools is measured by the Organization for Economic Co-operation and Development (OECD). The focus for their educational measurements are in three main categories: reading, science, and mathematics. Figures 4 and 5, taken from 2018 data, provide Italy's comparative test scores in these areas in 2018 and are taken from the Program of International Student Assessment (PISA), which is a subset of the OECD (OECD, 2018). In all three subjects, mean performance in Italy was lower than that in Belgium, France, Germany, the Netherlands, Poland, Slovenia, Sweden and the United Kingdom (amongst other countries) (*The Programme for International Student*, 2019). Figures 4 and 5 demonstrate more results gained by these examinations.

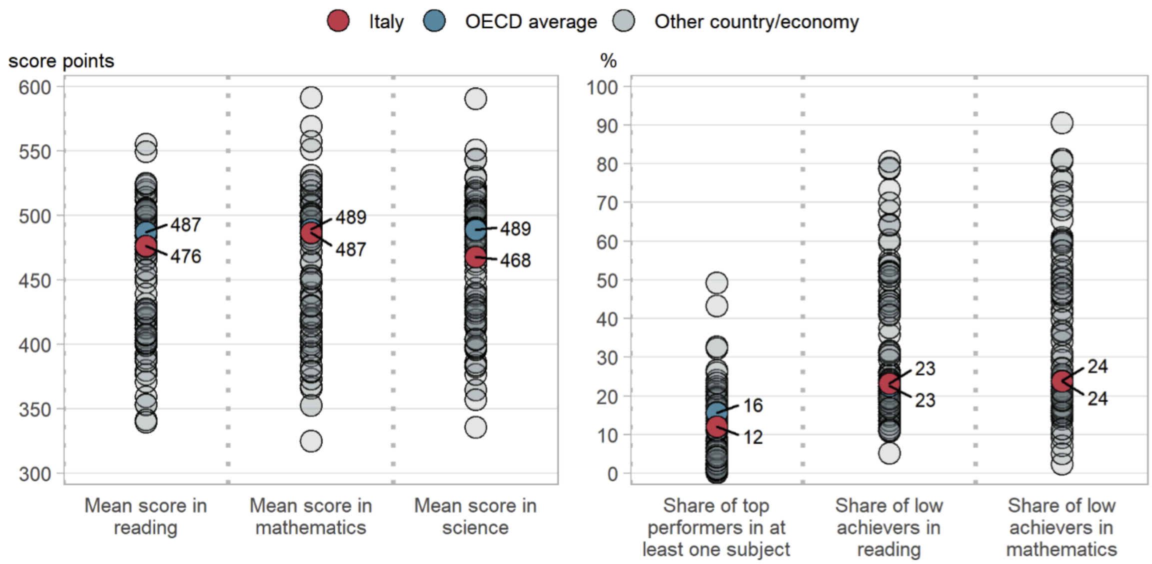


Figure 4. Comparison of Italy's mean scores to other countries from around the globe and comparison of relative student performance (The Programme for International Student, 2019).

The first graph of Figure 4 indicates that Italy consistently performs below average, with a score that is 2.3% below average in reading, 0.4% below average in mathematics, and 4.3% below average in science. The second graph shows, Italy has a 4% lower share of top performers in one subject, and shares the average in low performers in reading and mathematics (*The Programme for International Student*, 2019).

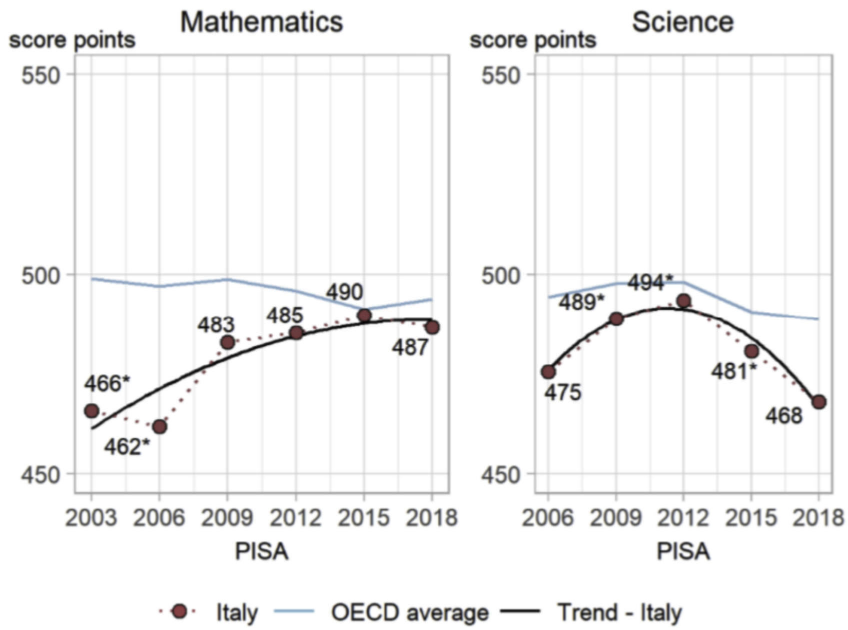


Figure 5. PISA average scores of Italian students over time compared to the OECD average scores over time (The Programme for International Student, 2019).

Figure 5 shows that Italy has made strides in improving its math scores and is close to achieving the OECD average. However, in science, Italy has been on a downward trend since 2012 (*The Programme for International Student*, 2019). Outside of scores and into general trends regarding education and technology, there are other systemic challenges that Italy is not alone in facing. For example, one quarter of Italian boys who are higher achieving in math say they will expect themselves to be engineers compared to one eighth of girls (*The Programme for International Student*, 2019).

Best Practices For Teaching STEM

Formal approaches to teaching STEM involve lecture-based work with homework to reinforce topics covered in class (Miller, D., Perron, J., & Ruvich, C., 2012), and some STEM topics are still taught this way. Nonetheless, *informal* approaches, which stress collaborative learning through problem solving, may be more effective at boosting a student's confidence and capturing a student's attention (Miller, D., Perron, J., & Ruvich, C., 2012).

A large challenge of integrating STEM into the curriculum is illustrating the importance of STEM to students. "STEM literacy" as defined by Bybee, is not merely a mastery of the four subjects, but the ability to apply concepts from all of these areas to solve problems (Bybee, 2013, p. 64). It is then critical to find ways to select real-world issues that need to be addressed and devise ways that students can draw on STEM concepts and technologies to address them (ibid., p. 3). For example, rather than formal approaches such as introducing static engineering problems or learning equations from a math textbook, teachers should pose open-ended research problems and have students apply their skills and knowledge to investigate the problems and create solutions.

There are many different ways to integrate STEM into the education curriculum. For example, embedding mathematical programs into technical programs improves test scores without impacting the technical scores (Council, N. R., 2011). Additionally, countries with the strongest STEM curriculum have a focused and logical structure, where topics progressively build on each other. Then, to create more engagement in the classroom, hands-on activities, such as labs, allow students to answer the questions posed by teachers themselves.

The National Science Teaching Association (NSTA) also has its own set of best practices. These are as follows (*STEM education teaching and learning*, 2020):

1. Learning should be active and not repetitive.
2. Students' personal motivations and beliefs as well as social interaction must be integrated into lessons.
3. There should be professional growth available for teachers so that they can continue to learn new STEM topics and practices to teach to their students.
4. Schools need to continuously provide new tools and technology to keep the STEM teaching modern in schools.

These tenets were similar to the advice given by two members of the WPI STEM Education Center whom we interviewed: Professor Chrys Demetry (C. Demetry, personal communication, September 16, 2022) and Donna Taylor (D. Taylor, personal communication, September 19, 2022). Demetry is the Director of the Morgan Teaching and Learning Center and Taylor is the Assistant Director of Professional Development on WPI's campus. Demetry specializes in running STEM summer camps for younger generations of female engineers while Taylor specializes in STEM professional development, especially at the middle school level.

When we asked Demetry about important topics to cover for grades 6-8, she mentioned that it is variable, but that it is important to look into the subjects being taught in their schools. To keep students engaged she highlighted that giving them a reason to care about the topics they are learning about keeps them motivated to stay focused.

Demetry referred us to Taylor due to her experience with the STEM curriculum. When we spoke with her, she discussed the core concepts covered in middle school STEM education and provided us with the Massachusetts STEM standards for public schools and the OpenSciEd website. In addition, she suggested practices for teaching STEM lessons. First, when it comes to STEM it is important not to lecture and to instead let the students figure out the problems themselves. This reinforces critical thinking and problem solving. This can be done by giving them a phenomenon and asking them to experiment on it, then asking them to make a claim and provide evidence for it. Second, it is important to reinforce good writing practices, even in STEM. She said to follow the claim evidence reasoning (CER) model such that they have to prove their claims with data and reasoning from their own experiments. Third, it is important to incorporate design projects, especially for teams. This allows for them to go through the engineering process and learn to work together with classmates.

Thus, there are strong agreements among different sources as to the best practices regarding how to carry out STEM education. Our team synthesized these into six practices, which were used by our team when designing lessons. They, along with their implications, are summarized in Figure 6:

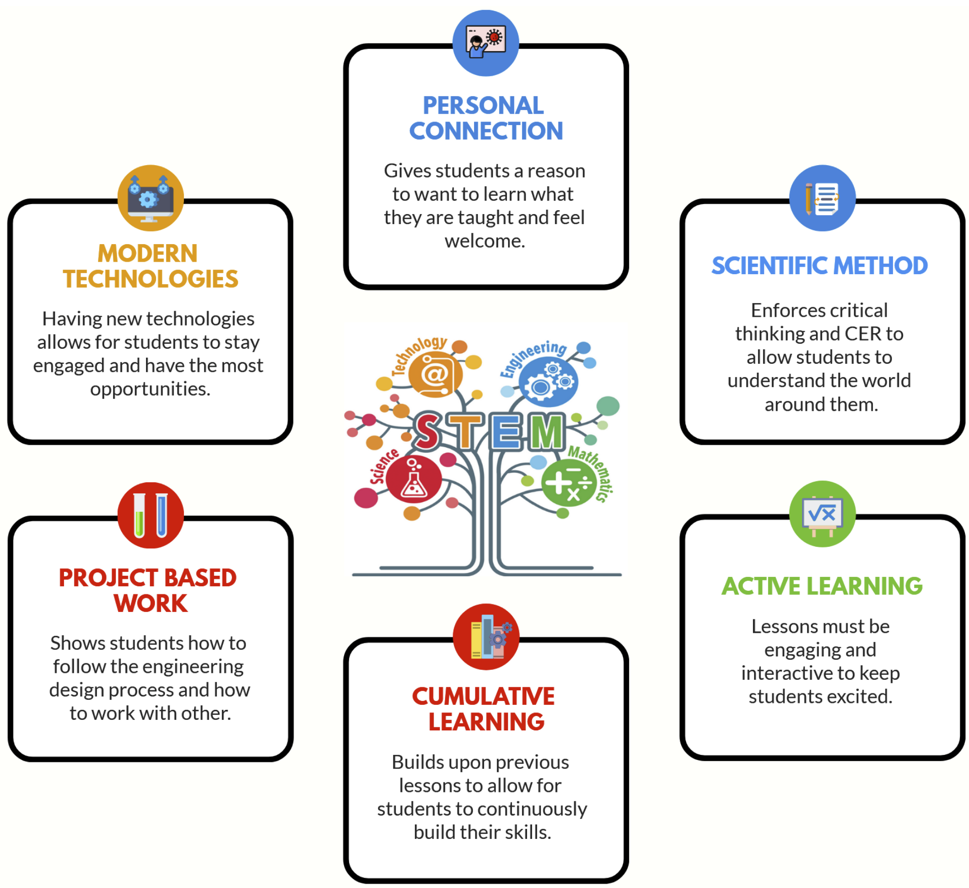


Figure 6. Summary of six best practices to integrate into STEM education.

Example Activities and Programs

This section discusses examples of some successful activities and programs in STEM, leading the way in innovation and creativity in response to the need for increased engagement and interest in STEM careers.

DIGITgame is a project utilizing technology to keep students interested in STEM, while helping to teach about real-world issues. Through the European Union, five organizations from Italy and Turkey began this project after studies found that high school students were uninterested in science and found it “irrelevant to their lives" (Kirsti, 2007 as cited in Bonora, 2019). In DIGITgame, students develop a video game while simultaneously learning important environmental and biological concepts. The game itself involves the creation of a Smart City as a result of the user’s decisions and accumulating consequences. The goal is that students come to understand the importance of their decisions pertaining to the health of the planet and themselves, but through a virtual world (*Digitgame*, 2019).

The project proved to be a useful way to increase student’s interest in STEM and increase their knowledge of STEM topics through its integration into fun, interactive games. Results were gathered using an adaptation of the STEM Career Interest Survey (STEM-CIS), a 5 point Likert scale administered both before and after the DIGITgame project, with a 5 representing strongly agree and a 1 representing strongly disagree (*Digitgame*, 2019). The survey was administered to the students and teachers to compare their opinions of STEM as well as to gauge the students’ interest in STEM before and after the project. The surveys revealed a general indication of increased interest in each of the four STEM subjects as well as an increase in knowledge of the topics taught in the DIGITgame project as shown in Figure 7 (*Digitgame*, 2019).

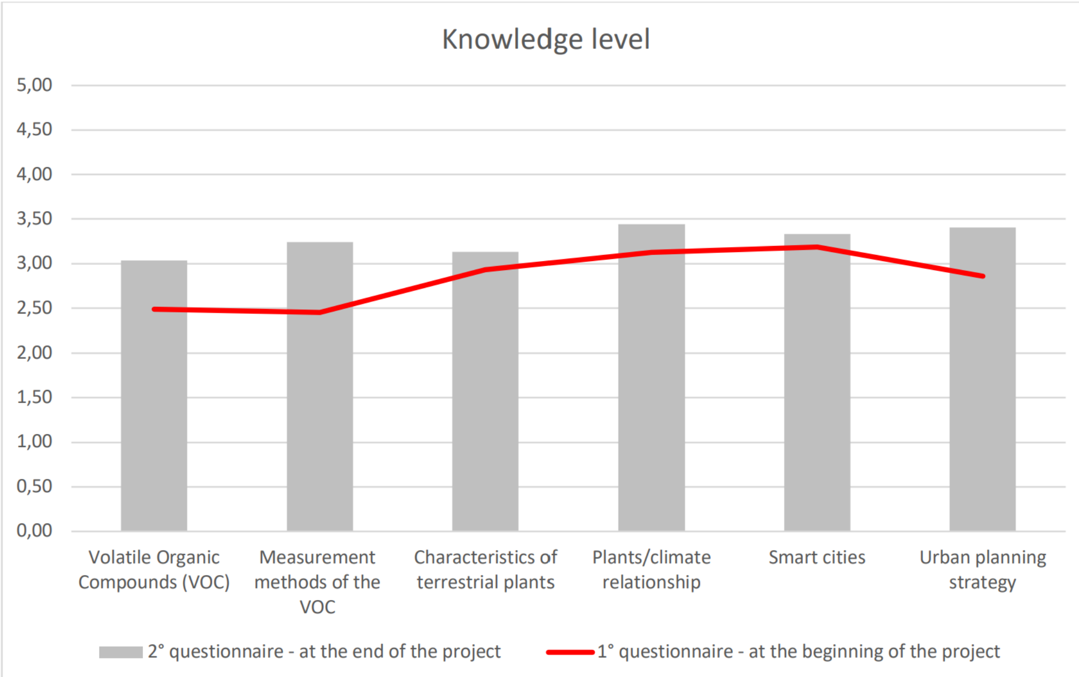


Figure 7. Survey results of students' knowledge in STEM topics before and after DIGITgame.

Another example of utilizing STEM to engage students in education comes from the Immersive Education Initiative (iED). The iED puts a major emphasis on the engagement aspect of incorporating STEM into education. To do this, they introduce students and adults alike to the world of virtual reality (*Immersive Education Camps*, n.d.). The iED claims to be the "world's foremost experts in immersive learning and immersive learning technology" because of their focus on simulating the real world through virtual reality technology (*Immersive Education Camps*, n.d.). This non-profit organization was founded in 2005 and works in collaboration with universities, researchers, museums and corporate companies. In fact, it has collaborated with the Italian Ministry of Education and the Italian National Research Council (*Immersive Education Camps*, n.d.). Their mission is to use the best teaching practices through digital reality platforms including AR, VR, video games, simulations, and training systems.

The iED hosts clubs and camps for all grade levels including college and the corporate workforce. Camps focus on one form of immersive learning technology or a combination of many that serve to engage students in a technology-based environment. An example of a summer camp includes three weeks of camp for pre-teens ages 9-12 and young adults ages 13-18. Each week teaches a different topic: week 1, Creating Immersive Virtual Worlds; week 2, Discovering Computer Graphics; and week 3, Web Page Development. In week 2 for example, "campers will develop hands-on skills and competencies using a variety of graphics tools and programs" (*Immersive Education*

Camps, n.d.). The iED serves as a benchmark for educational STEM programs and summer camps and can be modeled after when creating our STEM Lab in Venice.

One local after-school program is also utilizing interactive technologies to teach STEM topics to children. Our Bright Future, a non-profit educational organization in Worcester, MA joined with True Robotics, a company creating robotics kits and curriculum for six through eighth graders run their afterschool program to introduce underprivileged children in the Worcester area to STEM early on in their education. In this program, students are introduced to CAD, basic coding, robotics, and 3D-printing through hands-on experience with computer software and robots (K. Acheampong, personal communication, 28 September 2022). Our Bright Future has seen evidence of the success of the program by investigating the improvement of their students' grades in school. Data shows that the students in the Robotics program improved their grades in math and science from C's to B's to A's over the course of three trimesters (Galgano, 2016).

WPI also hosts a summer camp for educating young girls ages 6-8 on STEM topics, as discussed in the previous section. Professor Demetry shared a calendar for her schedule for the two weeks of the camp (see Appendix D). It can be summarized in this order (C. Demetry, personal communication, September 16, 2022):

1. Introduce students to each other and establish bonds between them and their teachers/advisors
2. Give them a background in the topics they will be working with.
3. Establish constraints and criteria for design with room for creativity and problem solving on their own.
4. Form teams for students.
5. Allow them to design and offer them suggestions.
6. Give them a break, then return back to step 2.

These steps will be essential to our team's development of the programs that will be offered in the lab.

Italian STEM Education

Like the k-12 education systems in the United States, Italy allows for different types of schools, which can be interest-specific for students, some state run and some private institutions. School is required of all children from the age of 6 to 16 years old (*Italy—Education*, n.d.). The government controls public schools in various different ways. The State executes legislative acts which affect the entire public system, while the Ministry of Education and the Ministry of University and Research handle execution of these policies. These two ministries then distribute responsibilities to decentralized offices which then must meet minimum requirements as defined by these ministries for the office's specific region (*Welcome to Eurydice*, n.d.). This can be thought of in similarity to federal education requirements vs. state education implementation in the

United States. Each region shares general practices such as calendars and the distribution of school resources (*Welcome to Eurydice*, n.d). Schools generally have a high amount of autonomy, but the central government acts as a check, and one of the ways they do so is that they make an educational plan for these regions (*Welcome to Eurydice*, n.d). The structure of this schooling system can be seen in Appendix F. The age range of focus for this project was Scuola Secondaria di Primo Grado (lower secondary school), which is the equivalent of 6-8th graders in the United States. We also placed some focus on fifth grade material.

The national Italian government established a set of standards in September 2012 which hold the primary skills and material that must be taught by schools. The individual curriculum and lesson plans are developed at a state and district/city level. Italy breaks these standards into two main subsets, skills and knowledge, then lists these for each main subject area. The subject areas of focus for us are science, technology, and math (*Ministero dell'Istruzione,* 2012). Outside of the Italian education system, we also took time to understand how the United States government handles schooling as well. Each state operates their schools differently, but Massachusetts standards are some of the strongest in the country, so they will be used as a model for the United States. The section of focus from these standards is the STE Framework, which addresses science, technology, and engineering practices for teachers to use with students k-12 and is extremely comprehensive. Outside of the Italian education system, we also took time to understand how the United States government handles schooling as well. Each state operates their schools differently, but Massachusetts standards are some of the strongest in the country, so they will be used as a model for the United States. The section of focus from these standards is the STE Framework, which addresses science, technology, and engineering practices for teachers to use with students k-12 and is extremely comprehensive. The key topics that we addressed with our technologies, Farmbot and Simtable, are summarized in Table 1.

	Math	**Science**	**Technology & Engineering**
Simtable	**1.** Solve problems with different contexts by understanding existing knowledge/common techniques. **2.** Apply critical thinking to problem solving.	**1.** Conduct experiments and model phenomena based on the knowledge that they have gained from previous experiments. **2.** Interpret maps including caridnal points, topography, and a compass. **3.** Understand fundamental concepts of nature, such as force, gravity, heat, electricity, etc. **4.** Ask questions and form hypotheses **5.** Obtain information and describe the difference in climate between different regions.	**1.** Undertand how to measure and graphically display school environments or home. **2.** Understand and use various computer programs. **3.** Define problems and design solutions.
Farmbot	**1.** Perform every basic math operation with various different types of numbers (rational, irrational, fractions, etc.): addition, subtraction, multiplication, and division. **2.** Understand math operators, such as exponents, square root, and parenthesis **3.** Understand how to simplify numbers, round them, express in powers of 10, and use significant figures	**1.** Understand the living systems of the world and the resources available to it. **2.** Understand the cellular model of an organism as well as other microorganisms. **3.** Understand respiration, metabolism, plant growth, and photosynthesis. **4.** Obtain, evaluate, and communicate information. **5.** Compare the life cycles of different organisms.	**1.** Understand basic programming concepts for a simple robot. **2.** Understand designs and schematics for a machine. **3.** Define problems and design solutions.

Figure 8. Relevant education standards addressed by the STEM Lab (adapted from Ministero dell'Istruzione, 2012 and 2016 Science and Technology Engineering Framework, 2016).

Thus, both sets of standards made it clear that it is important for students to overall have a decent understanding of the world around them and be able to qualitatively and quantitatively describe it. It's not only important to educate students on material, but to teach them how to think scientifically about life. They should understand how to communicate their ideas and prove their points using evidence. With an idea of how Italy and the U.S. handle their STEM education, we look in depth at the technology that we used in the lab.

Technology for the STEM Lab

We integrated two specific technologies into the STEM Lab: Farmbot and Simtable. This section describes what they are, how they operate, and how we used them.

Farmbot

The Farmbot is a robotic farming machine (Figure 9) controlled remotely through a free WebApp. This allows easy, labor-free farming from a mobile or desktop device using "Drag and Drop" controls. (*Farmbot*, n.d.). The robot comes disassembled and must be built over a raised planting bed. The Farmbot is composed of metal railings, an arm for seeding and weeding the soil, and hardware, using high quality materials such as corrosion-resistant aluminum, stainless steel, and UV-resistant plastics. The robot also features a raspberry pi as its core processing unit and custom designed microcontrollers which allows students to control the robotic arm on rails to seed, weed, and water from their phone. This technology lends itself to several core STEM learning objectives noted in section 2.4: an opportunity to educate students about plant science and robotics (*Farmbot*, n.d.).

Figure 9. Image of one of the standard Farmbot models, the Farmbot Genesis (Farmbot | Open-Source CNC Farming, n.d.).

The Farmbot has the potential to become a major, large-scale agricultural tool through what is considered "precision agriculture" in which resources like seeds, soil, and water can be optimized using precise quantities and placements by the robot (Murcia, P et al, 2021, p. 235), but for our purposes, it can be used as a tool to teach STEM concepts.

Farmbot can be used to teach core science skills mentioned above by allowing students to conduct plant science experiments and core technology skills through programming the farm's layout and understanding the functions of the machinery. Math could also be included through solving critical geometry problems centered on optimizing plantings. Other learning objectives may include environmental sustainability, plant science like photosynthesis, basic coding through the app's software, mechanical and robotic engineering via assembly, and data collection and interpretation through water usage and analysis of plant growth.

Simtable

The Simtable is a sand table, where various landscapes can be projected onto the surface, and results of various climatic challenges can be predicted, but its immense capabilities require more discussion (*Simtable*, n.d.). Figure 10 shows an image of the Simtable in use for research at Harvard University.

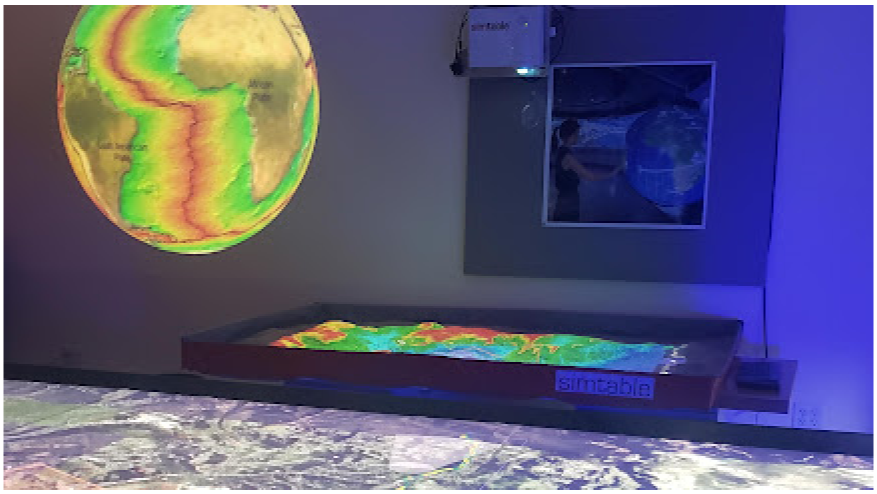


Figure 10. Image of Simtable in action at Harvard University (photo credit: Steven Guerin).

The Simtable utilizes agent-based modeling to display an augmented reality (AR) image over the sand of a sand table. A projector and camera which are hooked up to a computer are mounted over a table filled with sand as shown in the diagram (Figure 11).

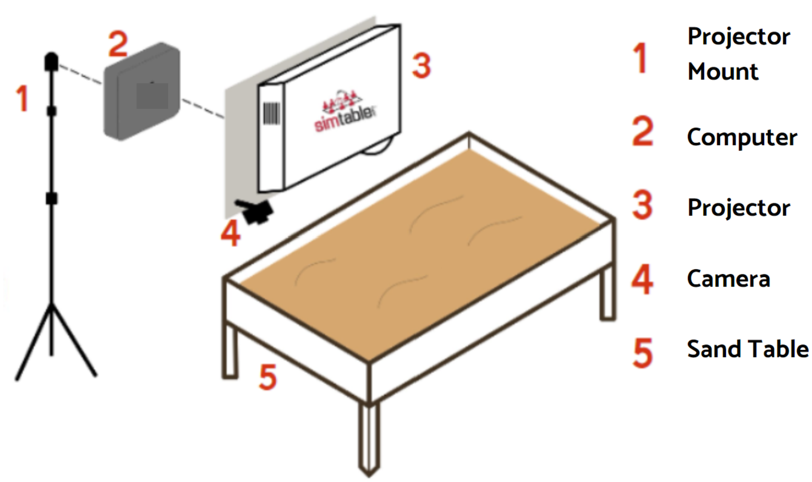


Figure 11. Diagram of Simtable parts (adapted from (Woodland et. al, 2021)).

Augmented reality is the use of a digital projection to "augment" the physical world. This allows the projection of effects such as rainfall and flooding, wildfires and storms, airborne gasses, and even human traffic over a digital composition of any global terrain possible.

There are two ways the computer's AR projection can function. One way is by first molding the sand to a desired topography, scanning the given three-dimensional layout using the projector's camera, and then displaying a representation of the topography of the sand using the computer and projector. This function of the Simtable can be used to teach students the functions of the different components of the equipment such as the camera, projector, sand, and computer. We can encourage critical thinking by asking the students what each component is responsible for after demonstrating the AR projection of the sand. Lessons can be designed to teach technology topics such as augmented reality, programming and modeling, and projection as well as science topics such as topography and geography.

The Simtable's projection can also function inversely. First the projector displays the topographical or geographical depiction of a specific location using the camera and computer, and then the sand can be molded based on the given projection of the geography. This function is more commonly used in the professional fields because it allows the user to display their desired location on the globe. The Simtable is most notably used by emergency management crews to model the effects of wildfires and prepare evacuations, and other responses in specific geographic locations (*Simtable*, n.d.). Schools and universities also use the Simtable to educate students on STEM subjects by modeling behavioral patterns for smart cities and to display the behaviors of weather like the physical effects of watersheds on erosion and flooding.

The Simtable's wide range of features gives ample opportunities to teach STEM concepts through the technology itself, but also through the applications of the technology. Augmented reality is one technological innovation that can be utilized to teach about flooding, traffic behaviors, and the spread of wildfires to name a few.

Methodology & Results

The purpose of our project was to create and set up a STEM Lab to expose more Venetian children to STEM concepts and stimulate their interest in pursuing a STEM career. This chapter explains the methodologies we used to address our project objectives (Fig. 9), and it reports our results.

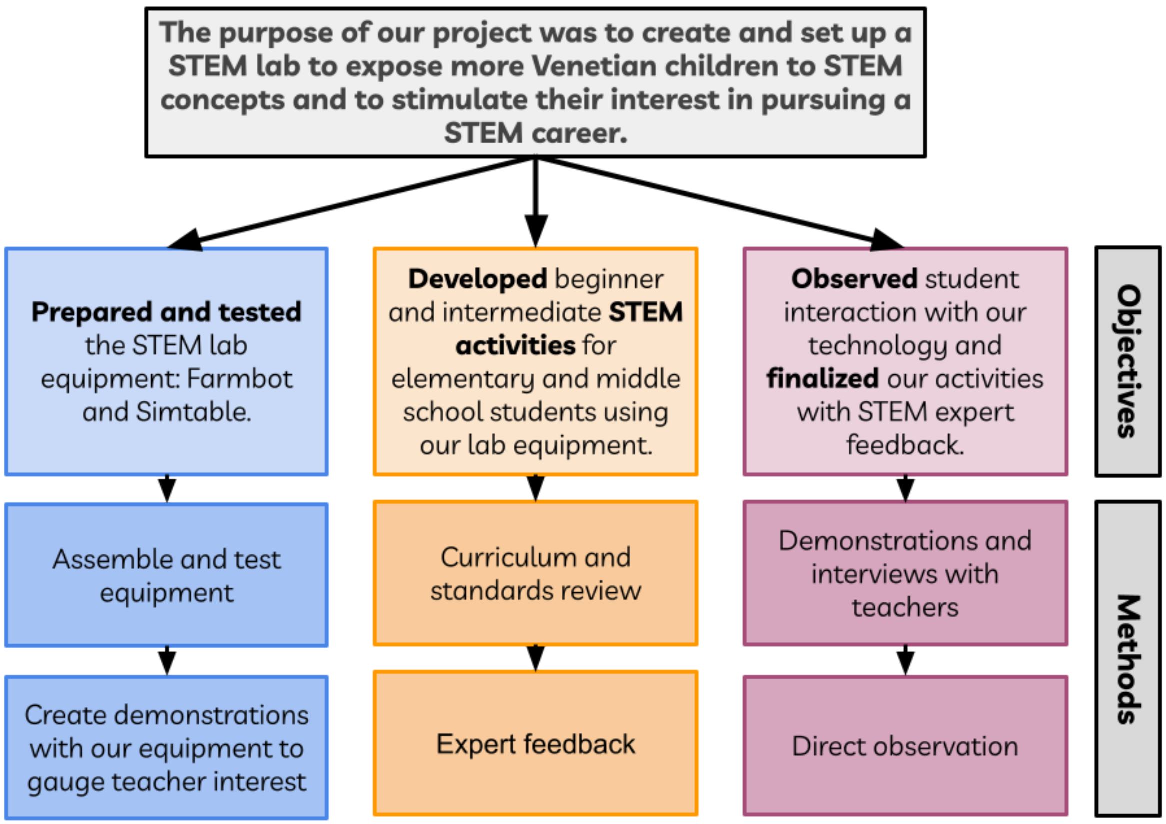


Figure 12. STEM Lab mission statement, objectives, and corresponding methods.

Preparing the Lab Equipment

The VPC supplied us with their Farmbot Genesis 1.4 2018 model. The Farmbot was left partially assembled: the plant bed and metal rail system were already built and the electronics were configured. We attached the metal rail system including the electronics box and connected all necessary wires for operation. Our team created an assembly guide outlining the process (see Appendix A) for future use and troubleshooting.

Once the Farmbot was assembled, we began the setup process by connecting the

WebApp (my.farm.bot) to the robot. Originally, the Farmbot WebApp could not recognize the Farmbot but once we rewired the electronics box (see Figure 13), the wifi configuration was successful.

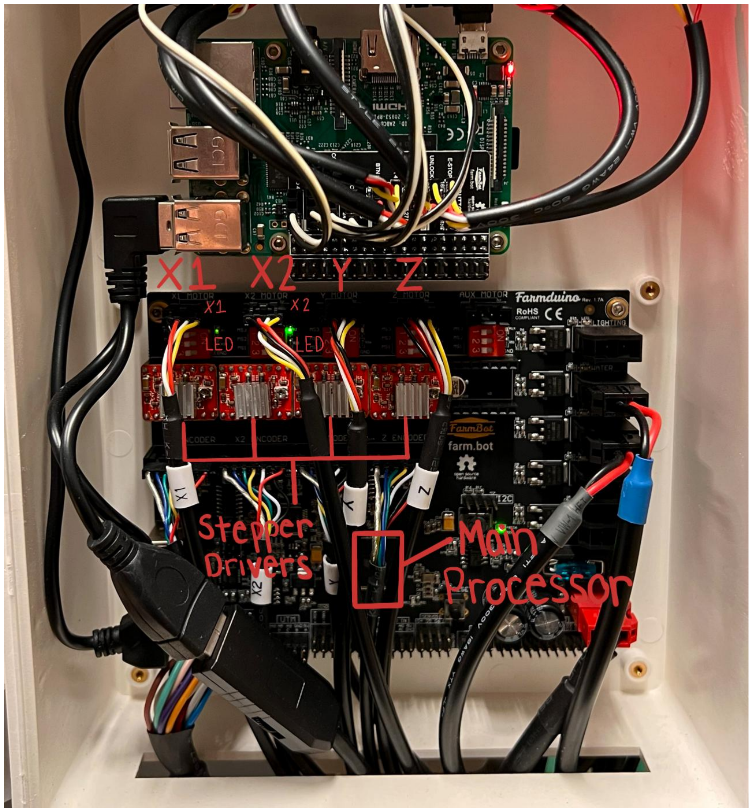


Figure 13. STEM Lab mission statement, objectives, and corresponding methods.

Once the Farmbot was connected to the WebApp, we were able to begin testing the robot's functionality. We noticed that the rails didn't move along the x-axis (left and right) smoothly. Hence, we ran tests with the motor controllers on the Farmduino (a custom Arduino circuit board for Farmbot). We learned that the X1 motor controller had been broken before our team's arrival and in troubleshooting, we also broke the X2 motor controller due to a broken part from the X1 controller. After speaking with the Farmbot support, we found that we needed to get a new Farmduino. This was ordered and replaced, bringing full function back to the Farmbot's X1 and X2 motors.

Then we had to find a water pump to get water into the Farmbot as using a hose from outside of the room proved to be much more difficult. This was connected to allow the Farmbot to water plants. In addition, the glass walls of the STEM Lab were blacked out using black construction paper to prevent light from entering the room and a large LED light was placed above the plants to ensure that they grow upwards, and to allow us to use the projector on the Simtable in a dark room. We also lined the Farmbot's plant bed with a plastic tarp for containing the soil. Lastly, we had to solder an extension cable to the existing light source used to feed the plants so that it could reach the wall outlet.

Figure 14. Assembling the planting bed of the farmbot with pots and a tarp.

The Simtable was already assembled and configured in the lab. The sandbox contained crushed walnut shells which were messy and a possible allergen; we replaced them with a finer and cleaner white sand: calcium carbonate. It leaves a smaller amount of edits Originally, Simtable's camera was struggling to detect the laser pointer given to us, leading us to order a new, brighter laser pointer for the lab.

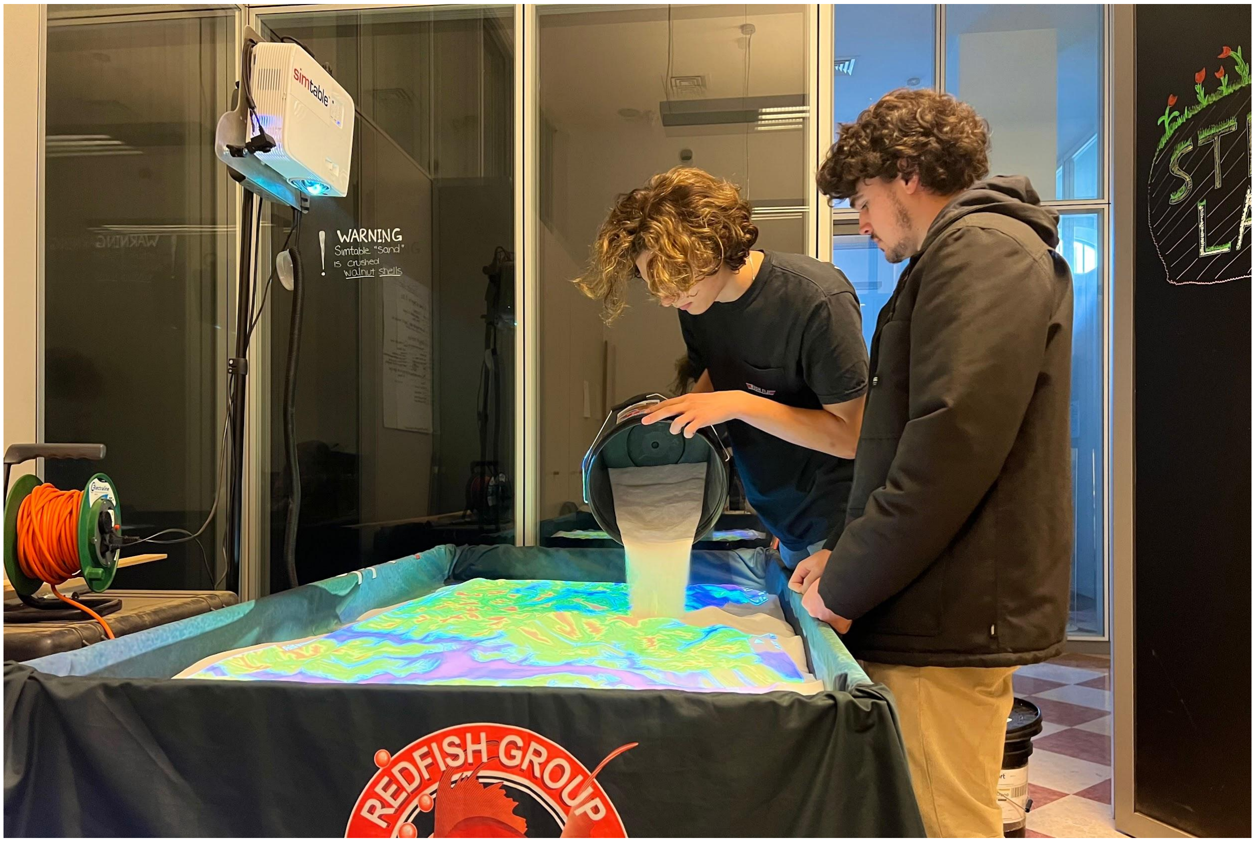


Figure 15. Replacing the crushed walnut shells with white calcium carbonate sand in the STEM Lab.

Once the lab equipment was fully functional, our team began speaking with teachers. With the help of employees from the VPC, we invited teachers from a local school to attend a quick demonstration session for the equipment in the lab. We introduced them to ourselves and our project. We presented a full demonstration of the Simtable, however, the Farmbot was not functioning at this point. We were able to share video demonstrations of the Farmbot to allow the teachers to understand how the machine works when functionable. They were excited about the technology, especially the Farmbot, and think students would love the opportunity to work with it.

Designing the Activities

In addition to speaking to local Venetian teachers, we also referred back to the STEM education standards published by Italy as well as the United States, which we discussed in the background chapter. We noted specific concepts and skills and paired these with the technologies' capabilities. As we said in the background, we had talked with experts Chris Demetry and Donna Taylor and volunteered for Our Bright Future after school program in Worcester. A summary of the STEM learning standards, best teaching practices, and recommended components of any STEM program were discussed previously in the Background and are summarized in Figure 6. These practices and learning goals informed our next step– developing some prototype activities.

Part of this design process involved further discussion with STEM professionals, Demetry (C. Demetry, personal communication, 18 November 2022) and Taylor (D. Taylor, personal communication, 16 November 2022). We shared some initial activity ideas with these experts. Initially, we thought we might provide students with worksheets to record hypotheses and reason through the results of small experiments they might do to learn about plant growth.Taylor suggested creating t-charts for the students where one side would be filled with their observations and the other side would contain questions from the students. She critiqued the difficulty level of the experiments we considered using to teach plant respiration, photosynthesis and other concepts, which led us to generate activities for beginners (students in 5th and 6th grade) and for more intermediate level students (7th and 8th grade). Her most important comment was that we get further feedback from the students rather than the teachers. She believes this would be more telling on the successfulness of the lab.

Demetry gave us further ideas for designing the activities. She placed a large importance on hands-on activities, and games as well as thinking about the logistics of the lab, such as how to break students up into groups or teams. She suggested prelab activities to be completed in the classrooms or during periods when groups might need to wait to enter and use the lab, given the occupancy limits. She also noted length and complexity of activities would be dependent on the limited "trip hours" of the students.

After these follow up discussions with Taylor and Demetry, we revised our initial ideas and more fully developed the activities. In what follows, we describe the goals, general activities and steps, and other materials we developed for both pieces of equipment.

First we defined our goals for the activities. Each activity contains critical cognitive , and procedural learning outcomes that we wanted the students to take away. More importantly, we wanted the activities to have an inspirational effect on the students in hopes that they find an interest in STEM (our affective goals). We hoped the students would leave with knowledge of some of the core concepts (eg., plant life, weather effects, elevation and water flow), skills in conducting and explaining experiments and be able to use new innovative technology. With these goals in mind, we created two menus of activities with different ability levels; one for the Farmbot and one for the Simtable. As shown in Figure 16, each menu contains beginner and intermediate activities so prospective administrators of the STEM Lab can choose them based on their students' grade levels. The beginner activities are geared towards 5th and 6th graders and the intermediate activities are geared towards 7th and 8th graders. The visual also depicts which activities are completed directly with the equipment and which activities are completed without the equipment, also referred to as prelab activities.

Prelab activities are colored gray in Figure 16. The rest of this section will discuss each of these four main groups of activities.

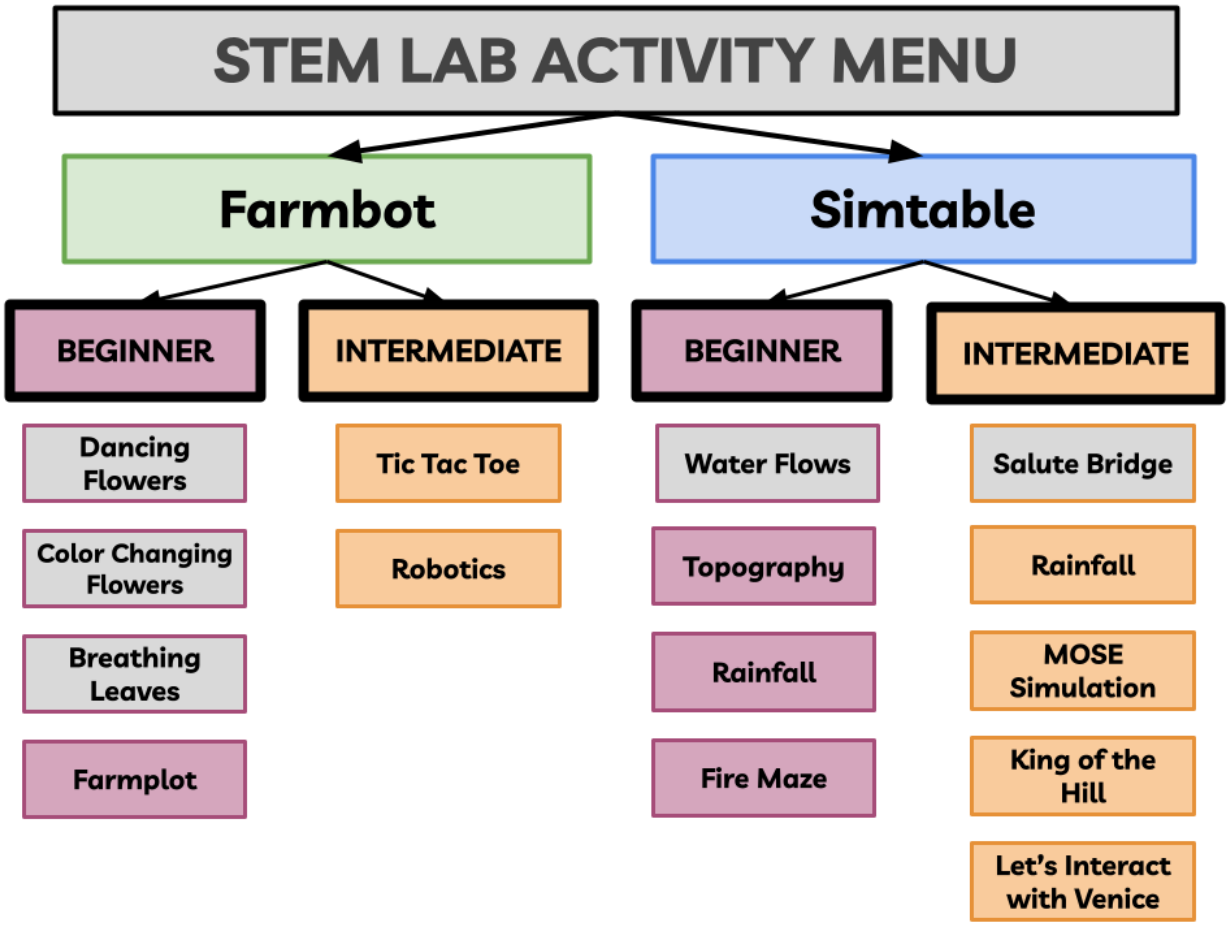


Figure 16. All 15 activities created for the STEM Lab are organized by technology and difficulty.

Farmbot – *Beginner*

The beginner prelab Farmbot activities are geared towards fifth and sixth graders and should be completed sequentially as they build upon each other in the order provided in Figure 17. Upon completion of the first three, in which students learn about the effects of light on plants, plant respiration, and how plants draw water through their roots and stems, students will understand the key elements of photosynthesis. The first three activities are completed without the Farmbot. Students will be able to illustrate how plants absorb sunlight, water and carbon dioxide and draw parallels between the essentials needed for all living organisms. Upon completion of the final plotting activity, Farmplot, students will understand Cartesian coordinates and the x and y axis by manually planting seeds using drag & drop coding on the Farmbot. Below we outline the general process for each activity, for more information see the team website for teacher guides.

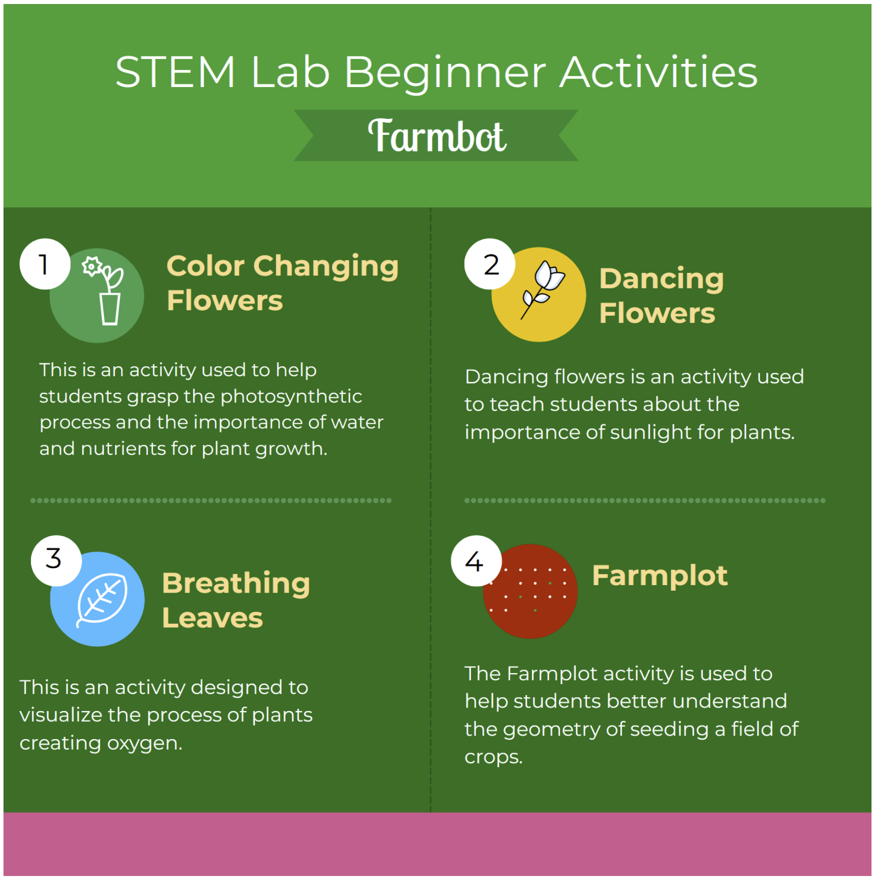


Figure 17. STEM Lab beginner activity summaries.

Color Changing Flowers is an activity used to show how plants absorb water needed for photosynthesis using white carnations and food coloring. The activity should go as follows:

- Prompt students to discuss their current understanding on how plants absorb water and why they need water.
- Discuss why humans need water and what might happen without it
- Provide the students with the corresponding worksheet and materials and allow students to conduct the experiment.
- Prompt the students to create a hypothesis about the colors they expect the flowers to turn too and why plants need water. Then record their observations.
- Encourage students to fill out the corresponding worksheet and materials in which they state their hypothesis, record observations after 20 and 30 minutes, and reason about what they observed.

- NOTE: The flowers should begin to change from white to the color of the food coloring.
- Following the experiment, have a discussion about the students observations and conclusions.

Dancing Flowers is an activity used to teach students about the importance of sunlight for photosynthesis in plants. The solar panel plants dance more with the higher exposure of light, and don't move at all when they're deprived from light. The activity should go as follows:

- Prompt students to discuss their current understanding of how plants absorb light and encourage students to draw parallels between plants humans and animals need for light.
- Provide the students with the corresponding worksheet and materials and allow students to conduct the experiment.
- Prompt the students to create a hypothesis on how much sunlight plants require and to record their observations.
- Encourage students to fill out the corresponding worksheet and materials in which they state their hypothesis, record observations, and reason about what they observed.
- NOTE: with more exposure to the light source the flowers should move more and faster.
- Following the experiment, have a discussion about the students observations and conclusions.

Breathing leaves is an activity used to show the oxygen that plants provide for the environment as a product of photosynthesis. The activity should go as follows:

- Prompt the students to create a list of five things people/animals need to survive. Then a list of five things plants need to survive.
- Prompt students to discuss their current knowledge about respiration in humans.
- Encourage students to draw parallels between breathing in humans and plants.
- Prompt the students to create a hypothesis about whether plants "exhale"and if so, what might happen if a plant is submerged in water.
- Provide the students with the corresponding worksheet and materials in which they state their hypothesis, record observations after 20 minutes, and reason about what they observed.
- NOTE: after submerging the leaves, small air bubbles should be visual, showing where the plant is "exhaling " oxygen.
- Following the experiment, have a discussion about the students observations and conclusions.

Farmplot is an activity used to help students better understand more about the geometry being used when planting the plants on the Farmbot. The true-to-size cutouts represent areas or plots that will be planted with a seed, allowing students to visualize the amount of space needed for each plant to grow. Students will arrange and count the total number of plots that can fit in the Farmbot bed Following this activity, students will use the Farmbot WebApp to physically lay out the plot, and the automated robot will plant their seeds. The activity should go as follows:

- Prompt students to discuss everything that plants need to live, thinking about the activities they have done.
- Ask students why seeds and plants need space and what would happen if seeds are crowded or too close together in one spot.
- Tell students they are responsible for plotting out their own section of the Farmbot bed, but they must consider how much space they need.
- Distribute the necessary materials and allow students in teams to design their own “farmplot” on their graph paper.
- Once students are finished they can move on to implementing their “farmplot” from the graph paper on to the Farmbot WebApp.
- Before students use the WebApp demonstrate how to program the robot to move to the designated plots and plant the seeds.
- Let students take turns programming the remainder of their plot
- When they are finished, allow each student to plant their own seed in a small pot.
- Ask them how they would care for the plant at home: what will be needed?

For more information and additional materials on the activities such as; teacher guides, step-by-step instructions, student worksheets and visual aids visit our team website.

Farmbot – *Intermediate*

The intermediate Farmbot activities are a set of activities geared towards seventh and eighth grade students. These activities should be completed sequentially as they build upon each other in the order provided in Figure 18. We have created two activities: Tic-Tac-Toe and Robotics that are both completed in the lab. Upon completion of these activities students will learn to use and explain basic drag & drop coding and how the Farmbot communicates with the online Webapp. Students will understand how to describe locations on a plot using x, y and z cartesian coordinates. Below we outline the general process for each activity. For more information, visit our team website.

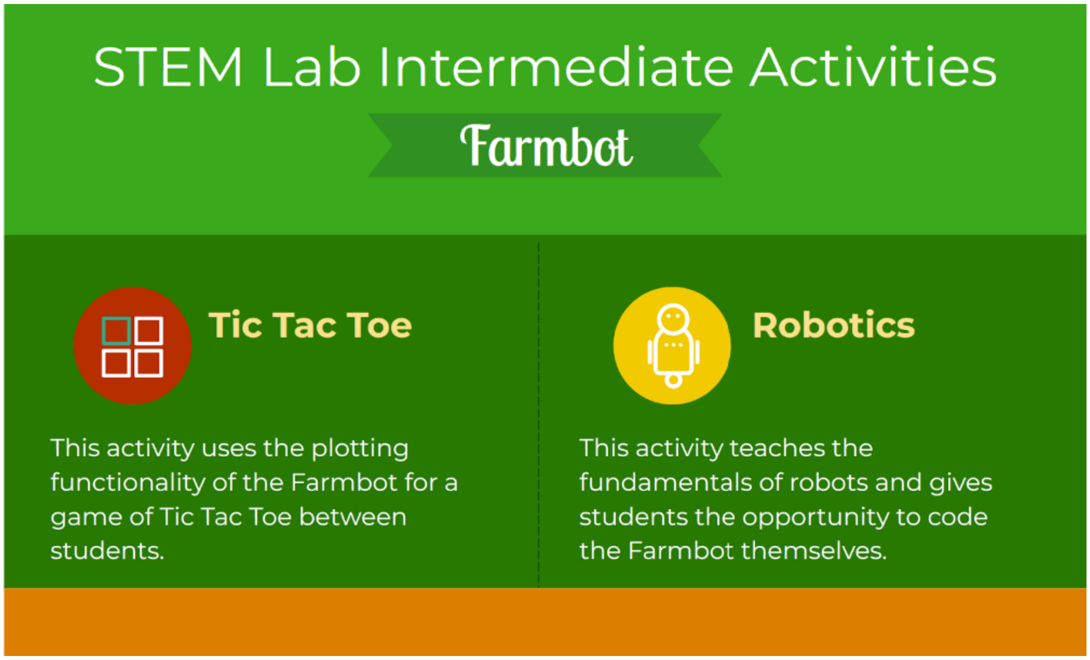


Figure 18. Summary of Farmbot intermediate activities.

Tic-Tac-Toe is an activity designed to teach students how to accurately measure cartesian coordinates and utilize drag & drop coding. The activity should go as follows:

- Prompt students to brainstorm their current knowledge of cartesian coordinates and have them explain what they are and how they are used to measure space.
- Set up the plant bed using the materials in the teacher guide.
- Explain to students the basic rules of tic-tac-toe and give them the necessary materials to complete the activity, which involves measuring the precise location of where they want to plant their seed on the plant bed using cartesian coordinates.
- Demonstrate how to program the Farmbot to plant seeds in a desired location.
- Allow each student to program the Farmbot to carry out the action.

Robotics is an activity designed to teach students how robotics communicate with computers to complete tasks. Students will create and execute a coding sequence to water the plants in the Farmbot bed. The activity should go as follows:

- Prompt the students to brainstorm their current knowledge of how robots move, and how robots communicate with computers.
- Set up the plant bed and materials as described in the teacher guide.
- Provide the students with the student activity guide.
- Allow students to work through the activity on their own, helping them use the materials if necessary.

- After the students complete their sequence, look it over and assist them in running it on the Farmbot.

For more information and additional materials on the activities such as; teacher guides, step-by-step instructions, student worksheets and visual aids visit our website.

Simtable – *Beginner*

The beginner Simtable activities are geared toward fifth and sixth grade students. The activities should be completed sequentially as they build upon each other in the order provided in Figure 19. The first activity, water flows, is a prelab activity and should be completed before the rest of the activities. Upon completion of the beginner activities students will better understand the way climate changes and weather impacts the landscape of the planet through its simulation of rainfall, and fire on different elevated lands. They will be able to illustrate the sources, causes and effects of precipitation on the landscape including flooding and pooling of water at lower elevations. Students will learn why fire burns with fuel, oxygen and heat, and that in order to stop a fire one of those elements must be removed. For more information, see our website.

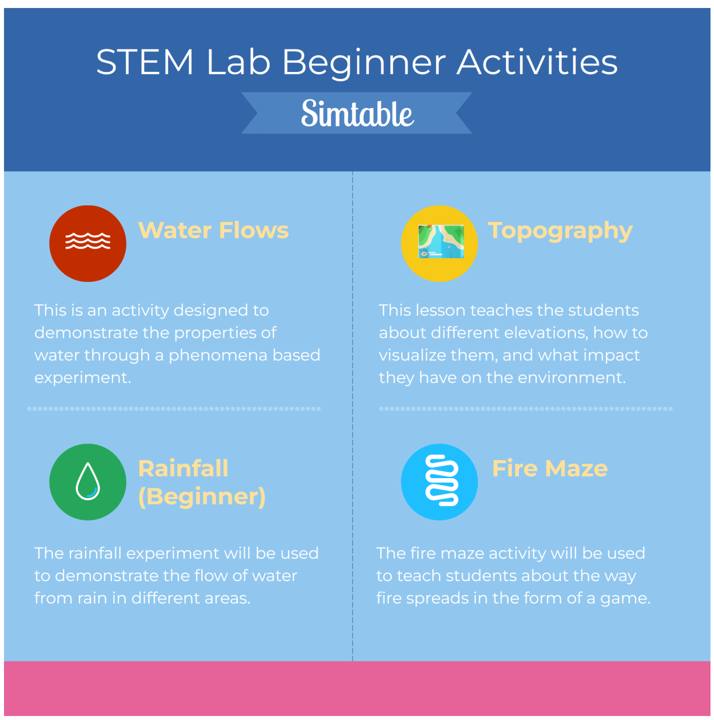


Figure 19. Summary of Simtable beginner activities.

Water Flows is a prelab activity used to demonstrate how water is a hydrophilic molecule and how it flows in a downward direction. This activity should go as follows:

- Prompt the students to discuss their current knowledge of water's properties and how water flows.

- Encourage students to form a hypothesis about what they believe the water will do as it is poured from the pitcher down the rope to the rock
- Students will observe the water being poured from the pitcher down the rope and to the rock
- Encourage students to note observations regarding what they see as the water travels along the rope
- Following the experiment, ask students to share their reasoning about what happened and why
- NOTE: teachers should notice the water traveling along the rope and sticking to the other water molecules (demonstrating water is hydrophilic)

Topography is an activity designed to teach the students about the various elevations in the environment.

- Prompt the students to discuss their current knowledge of land features such as mountains, valleys and rivers
- Explain the concept of elevation
- Encourage the students to engage in building various landscapes in the sand table with their hands
- Have them turn on the sim function to display rainfall and fire over the landscapes they created
- As the projection onto the landscape emerged, ask them
    - What do the colors mean?
    - Why are they different?
    - What is the highest point?
    - What is the lowest point?
- Following the activity, have a discussion about the students observations and conclusions.

Rainfall is an activity used to demonstrate the flow of water from rainfall in different areas. Students will be able to understand the ways rainfall collects based on the elevation they had previously learned about in the topography lesson. They will be asked to rebuild the Dolomiti and predict where water will accumulate, and test their hypotheses. This activity involves modern technologies, active learning, the scientific method, cumulative learning, and a personal connection.

- Prompt students to discuss their current understanding of precipitation
    - What is precipitation?
    - Why does it rain?
- Encourage the students to actively participate by assigning them to different rolls during the activity
- Allow the students to simulate rainfall on the Simtable

- Encourage the students to switch rolls

Fire Maze is an activity used to teach students about the way fire spreads depending on the various methods fires use to burn (fuel, oxygen, and heat). Students are able to experiment with fire, plumes and gas, and see the way these spread over the projected topography. It stresses to the students the danger and relevance of fire protection.

- Prompt students to discuss their current understanding of what a fire needs to burn and what a fire cannot burn.
- Demonstrate a forest fire on any landscape by placing fire on an area with fuel on the Simtable.
- Demonstrate a fire that dies out due to lack of fuel using the fuel painter.
- Prompt students to think about good and bad forms of fuel for fires. Ask them to think about fires they have sat around or seen in their experience.
- Allow students to create their own fires and fire mazes using the fuel painter. Give every student the opportunity to create their own maze. Challenge students to avoid mountains, water features, or even their own houses

For more information and additional materials on the activities such as; teacher guides, step-by-step instructions, student worksheets and visual aids visit our website.

Simtable – ***Intermediate***

The intermediate menu for the Simtable contains activities geared towards seventh and eighth graders used to understand different climatic effects on different projected topographies. The activities should be completed sequentially as they build upon each other in the order provided in Figure 20. The intermediate activities go behind the simple features of the Simtable and seek to use it for its intended purposes to get excited about the power of technology. Upon completion of the intermediate activities students will understand how different elevations can be shown on the Simtable. The impacts of sea level rise and heavy rainfall have on flooding. And lastly students will understand how wind, fuel and air density affect the behavior and movement of fire. For more information, see our website.

Figure 20. Summary of Simtable intermediate activities.

Rainfall is an activity used to demonstrate the flow of water from rainfall in different areas and the meaning of topography. It touches on gravity as well how water tables and vegetation play a factor in flooding. It will revolve around building a real location, creating rain and floods, then revealing that it is a real location that the students know.

- Prepare the students with a quick background on the Simtable
- Prompt the students to discuss their current knowledge of topography
    - What is it?
    - How does elevation and particular land features such as mountains, forests, waterways, valleys, etc impact things such as rainfall, fires, flooding?
- Discuss students knowledge on the background of rainfall

    - How does it form?
- Simulate rainfall on the table

King of the Hill is an activity designed to teach students about fire, fire spread, and fire protection. It is carried out as a competition to keep the top of a hill from burning.

- Form a large hill or mountain in the sand landscape? Also program in an area of trees and water?
- Prompt students to discuss their current understanding of what a fire needs to burn and what a fire cannot burn.
- Allow the students to experiment simulating fire, different firefighter (fire prevention) tools, plumes, and gas on the table.
- Give the students three firefighter tools and have them brainstorm how the tools can be used to prevent the fire from reaching the top of the hill
    - Simulate this following their brainstorming

Salute Bridge is an engineering competition between students to see which team can build the strongest bridge with limited materials and time. This activity allows for project work, engineering design process and active learning.

- Prompt students to discuss their background knowledge on bridges
    - What makes a bridge strong?
    - Pictures of potential bridge designs will be shown and students will be allowed to use the internet to research different bridge designs.
- Distribute a limited number of popsicle sticks and hot glue to each team and ask students to brainstorm their design plans
    - Describe the engineering design process to the students
- Give each team 45 minutes to build their bridge.
- Test which bridge is able to hold the most weight

MOSE Simulation is an activity for students to have a visual of the flooding in the city. Students will brainstorm ideas for ways to stop the common floods and hopefully become inspired by why engineering is important for their city. They will then try to stop the flooding using the sand on the table and see the importance of dams.

- Prompt the students to discuss their current knowledge on flooding in Venice
    - Have them think about how these floods impact them
- Project Venice on the table and have students build the topography
- Create a flood and have students observe where flooding occurs and where the sources of the water are.
- Ask students to build sand in the appropriate areas to stop the water from flowing.

- Rescan the sand and resimulate a damn release from the Adriatic sea to show that their walls stopped the water from entering Venice
    - Explain to them that this is how MOSE works

Let's Interact with Venice is an activity used to allow students to interact with their city from an aerial view to experiment with technology from their own devices. This activity gives students the opportunity to join the Simtable projection on their phones and interact with various features of the Simtable, such as wind, labeling locations, evacuation areas, and more.

- Project a map on the table and have students build the correct topography by moving the sand and creating different elevations.
- Using the QR code, allow students to access the Simtable tools on their phones.
- Simulate rainfall for the students and observe where it collects.
- Prompt students to brainstorm where the best places for farms would be.
- Simulate a fire on the table:
    - Prompt students to create an evacuation area on their phones in the regions they deem affected by fire and plumes.
    - Do various labeling of the maps
    - Ask students to label their house, their favorite store, their favorite bridge. See which places were the most common.

For more information and additional materials on the activities such as; teacher guides, step-by-step instructions, student worksheets and visual aids visit our website.

Observing student interaction with our lab equipment and finalizing our activities with STEM expert feedback

Following the full development of activities menu, we set up one last meeting with Donna Taylor, as she specializes in STEM curriculum and teacher development. Prior to the meeting we shared our website and activities menu with Taylor. Taylor noted that our menu was informative and easy to navigate. She advised that we include an expected results section in the teacher guides for each activity. This would be used to better inform the teacher of what exactly should be happening as the students are completing the activities. In addition, she mentioned that images could be added to the activity worksheets as younger students can greatly benefit from visuals, so we later added video how to clips such as the one in Figure x (include a screenshot of one of these and explain what activity it goes with0 Finally, she stressed the importance of adding warnings to the teacher guides such as laser pointer warnings (do not shine towards eyes), hot glue gun warnings (do not touch the glue or the nozzle of the glue gun), and emotional trigger warnings for the flooding and fire activities as students and their families could have been negatively impacted by these in the past (tell students what will be discussed in the activity and let them know if anyone is uncomfortable/ upset by it they do not need to participate and can even leave the lab for the duration of the activity).

We gathered a group of three student volunteers: a five year old, an eight and ten year old. Consent forms were filled out by the parents or guardians of the students (see Appendix B). The student volunteers helped us gauge interest, excitement, and ability to use the materials and equipment in the lab, despite being a bit younger than that target age group of 10-14 years old. Throughout experimenting with students we used direct observation to grasp a better understanding of their engagement and excitement regarding the technology along with their level of understanding of the activities being presented to them. To judge their excitement about the technology, we looked for specifics such as smiling, laughter, and engagement.

Observing their reactions, ability to follow directions given, and use the lab equipment, we learned the following:

- Students were excited about the technology
- Students were more interested in the Simtable than Farmbot
- Students were able to use the laser pointer to simulate rainfall and fire on the table
- Students understood the different colors that were simulated on the table and what each color indicated
    - Red being high mountains
    - Dark blue being low valleys
- Students will lose interest if one activity was carried on for too long
- Students quickly understood the Farmbot WebApp
- Students of a wide age range did not work well together

Figure 21. Photo of three venetian students experimenting with fire on the Simtable.

Due to the language barrier and the students being younger than our target age group, we focused mainly on demonstrating the table's functionality and observed how engaged they were and how able to operate the equipment to complete certain tasks through direct observation for each student. We were able to complete our topography activity, which is one of our beginner Simtable activities. We also completed interactive demonstrations of rainfall and fire on the table. Throughout the entire experiment, students were expressing interest and excitement about the lab. The students were able to understand the topographic map projected on the Simtable, corresponding with our Simtable Beginner Topography lesson.

Keeping the students' attention was difficult at times. If the same location and function were on the table for a long period of time, the students would get distracted. Although the students appeared distracted at times, they never lost interest in the table. They struggled to follow directions due to the language barrier. The students were very interested in interacting on the table with the laser pointer, so we needed to ensure each student got the chance to do this. This suggests the students would need to be closely monitored by teachers to help them take turns taking control of the simulation.

After completing the experiments and activities with the Simtable, we had the students experiment with the Farmbot. We asked them to attempt to move the robot to a desired location, which required knowledge of coordinate systems. Farmbot operation is part of our intermediate set of activities for this piece of technology, so we thought it was a bit advanced for the younger students. However, after using the robot for a few minutes, they were able to better understand how to read the coordinates and use them to operate it correctly. At the conclusion of the students' time in the lab, one of the students told his guardian that he did not want to leave the lab.

Figure 22. Photo of explaining the Farmbot software to two Venetian children.

After hosting the students in the lab, we concluded that we would not be able to host an entire class of students around one piece of technology at one given time. As our activity menu contained activities that were meant to be completed aside from the technology, however, this led us to believe a larger number of these prelab activities would need to be created.

More details regarding what future teams can do when testing the activities menu with students and teachers is discussed in the Conclusions and Recommendations section of our report.

Conclusions & Recommendations

In this project we studied the best practices for teaching science, technology, engineering, and math, gathering advice from STEM programs and educators, and reviewing core learning objectives for STEM from curriculum guidelines in the US and in Italy. We used this information to develop a start-up STEM education lab for Venetian students. Our lab incorporates fun, hands-on activities and lessons, using two modern technologies owned by the Venice project Center, Farmbot and Simtable. Our ultimate purpose was to design a lab that might teach students about plant life, topography, programming, and other topics, while keeping them engaged and excited. We prepared the equipment for use and designed a set of beginner and intermediate learning activities for use with each technology. We spoke to experts in creating STEM lessons and tested our activities with a small group of children to improve our teacher guides and implement feedback with the execution of the lab.

However, there is still more work to be done to continue to improve the capabilities of the lab that we were not able to accomplish in the time allowed. We listed these recommendations below:

- Run the lessons with a full sized class of students to see the response with a larger number of children . In doing so, make sure that you do it with a large group, running Farmbot and Simtable simultaneously. Then, use this feedback from the students to improve the activities further.
- We recommend utilizing some form of interactive survey for the students to give their feedback on the activities without feeling like they are doing work. We created the following “sticker-board survey” to understand the success rates of the lessons as shown in Figure 23.

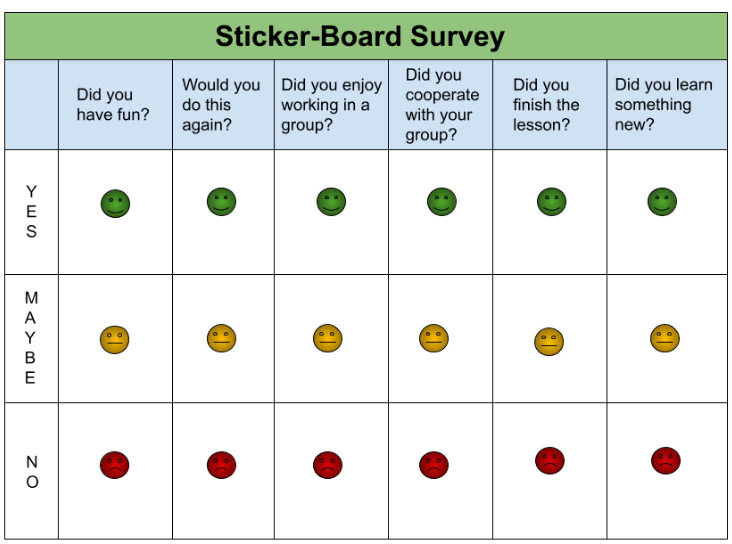


Figure 23. Sticker-board survey questions for the students after completing the activity. This will be used to understand the students' take on the lesson and will help with revisions for further lesson planning.

- To further determine the success of the activities completed in the lab, teams should create and provide a pre and post test for the students. This can help teams understand if the learning objectives and goals for each activity were met.
- The current Farmbot and Simtable are stationary and cannot be moved. Making a way to move the equipment into larger rooms would be beneficial allowing for larger groups. A set of larger spaces may also be needed for several teams completing the prelab activities before going into the lab then placing them back into the lab for smaller groups of kids and for storage.
- The lesson plans, worksheets, and setup guides need to be converted to Italian.
- Find a better light source for the Farmbot. The light post given to us was very unstable and requires soldering to a proper connector in order to connect the power source to an outlet safely. We advise finding a new use for mounting this light or finding a new, safer option.
- Create an advanced set of activities for high school students or middle school students who are not struggling with the intermediate activities.

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Appendices

Appendix A: Relevant Links

VPC: STEM Lab Website - link to Venice Project Center Repository for STEM Lab

STEM Lab Team Website - link to STEM Lab's team website

FarmBot - link to Farmbot website

Simtable - link to Simtable website

SerenDPT - link to SerenDPT website

Appendix B: Informed Consent Agreement for Participation in a Research Study for Parent/Guardian of Minor

Investigator: Kaleigh Caserta, Joshua Hollyer, Michael Bonito, Haley Gilbert

Contact Information: ve22.STEM@gmail.com

Title of Research Study: Venice STEM Lab

Sponsor: Venice Calls

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

Purpose of the study:
We are university students from the U.S. studying science and engineering and working with the Venice Project Center and a local organization called Venice Calls. Our team is creating an afterschool activity session to teach students in grades six through eight about science, technology, engineering, and mathematics (STEM). We are using a farming robot and a computerized sand table to inspire greater interest in STEM through engaging activities.

Procedure:
Our activities session will take no longer than an hour, and you are welcome to remove your child at any point during the session. We will carry out the activities in the Santi Cosma e Damiano. The exact address is Giudecca 624/625 Campo S.Cosmo, Giudecca 30133 Venice.
In this session, we will ask for your child's participation in the laboratory. Your child will be guided through the activities by our team members.
We will write about this program in a final report, but we will not use your name or your child's name in the report. During the activities session, we will be engaging with the students and recording our observations of their experience. We will end the session with an optional sticker-board survey! Following the session, we will use our observations and feedback to redesign and revise our activities.

Risks to study participants:
Participants will be asked to get their hands dirty when planting their own seed using soil as well as playing with the sand in the Simtable's sandbox.

Benefits to research participants and others:
There are no expected benefits from the research.

Record keeping and confidentiality:
Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or its designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

Compensation or treatment in the event of injury:
Participate at your own risk. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of research-related injury:
Our contact information can be found above. You may also wish to contact:
IRB Manager, Ruth McKeough at 508 831-6699 or email irb@wpi.edu
Human Protection Administrator, Gabriel Johnson at 508-831-4989 or email gjohnson@wpi.edu

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

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

You must be a parent or legal guardian to consent to allow your child to participate in this activity. If you consent to your child's participation in this activity and to the terms above, please sign your name and indicate the date below.

Study Participant(Please print):___________________________________

Parent/Guardian Signature(s): ______________________ Date: ________

The informed consent procedure has been followed.

Investigator Signature(s): _________________________ Date: _________

Appendix C: Observation Sheet

Student Observation Sheet		
Observer:	**Activity:**	**Student Name & Age:**
Excitement		
Laughter		
Engagement		
Smiling		
Confusion		
Frustration		
Boredom		
Notes:		

Student Observation Sheet		
Observer: Kaleigh	**Activity:** Topography	**Student Name & Age:** Bianca 5 years old
Excitement	Bianca is excited about building their landscape and using the laser pointer to simulate rain and fire	
Laughter	Bianca laughs a lot throughout the activity, she appears to be intrigued and enjoying it	
Engagement	She’s engaged throughout the activity, she appears to be less engaged when she is confused	
Smiling	She is smiling throughout the activity	
Confused	She seems to be confused with some of the activities that the other two understand	
Frustrated	She seems to get frustrated when the other students are using the laser pointer	
Bored	Bianca appears to get bored when she doesn’t understand, she asked Fabio to take her back to her mom	

Notes: ● she was about five years younger than the younger side of our target age group for the beginner activities ● As she got frustrated when the other students are using the laser pointer, we are thinking about recommending the next team to get a second and maybe even third laser pointer

Student Observation Sheet		
Observer: Kaleigh	**Activity:** Topography	**Student Name & Age:** Ata 8 years old
Excitement	Ata seems excited, he seems super into the Simtable and it looks like he would want to continue working with this. He understands the topography, and the meanings of the different colors on the table	
Laughter	Ata laughed as the other students were laughing	
Engagement	He appears to be very engaged, he wants to learn more about the activity, and wants to continue the simulations	
Smiling	Ata is smiling a lot during the activity	
Confused	He does not appear to be confused, he is even doing very well with the language barrier	
Frustrated	He does not appear to be frustrated at all	
Bored	He does not appear to be bored	
Notes: ● Ata spoke with his dad which was loosely translated to us as “He wishes to remain” ● He was disappointed to leave the lab ● Ata was very engaged throughout the whole time he was in the lab		

Student Observation Sheet		
Observer: Kaleigh	**Activity:** Topography	**Student Name & Age:** Fiore 10 years old

<table>
<tr><td>Excitement</td><td>He seems excited during the simulations on the table of rainfall and fire on the topography they created</td></tr>
<tr><td>Laughter</td><td>He is laughing with the other students</td></tr>
<tr><td>Engagement</td><td>He is engaged and it seems like he wants to learn more about this</td></tr>
<tr><td>Smiling</td><td>He has been smiling throughout the entire demonstration</td></tr>
<tr><td>Confused</td><td>He is not confused, he understands the topography lesson even with the language barrier</td></tr>
<tr><td>Frustrated</td><td>He isn’t frustrated at all</td></tr>
<tr><td>Bored</td><td>He does not appear to be bored</td></tr>
<tr><td colspan="2">Notes:
● Fiore’s understanding throughout the experiment was very important to us, as he is directly in the age range for beginner Simtable activities
● He was astonished by the capabilities of the Simtable simulations</td></tr>
</table>

Appendix D: WPI Summer Camp Calendar

	WEEK 1						
TIME	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
	7/20/03	7/21/03	7/22/03	7/23/03	7/24/03	7/25/03	7/26/03
7:30		Breakfast Morgan Dining Hall	Breakfast Morgan Dining Hall	Breakfast Morgan Dining Hall	Breakfast Morgan Dining Hall	Breakfast Morgan Dining Hall	Breakfast Morgan Dining Hall
8:00			Optional Computer Time Atwater Kent 120d and Fuller Labs 222	Optional Computer Time Atwater Kent 120d and Fuller Labs 222	Optional Computer Time Atwater Kent 120d and Fuller Labs 222	Optional Computer Time Atwater Kent 120d and Fuller Labs 222	Pack for trip and relax in residence hall
9:00		Introduction to Design Projects Atwater Kent 219	Forensics Workshop Congregate at end of brick walkway nearest to Goddard Hall. Divide into five groups and go up to Goddard Hall 311.	Forensics Workshop Groups gather on brick walkway. Go to location of next rotation station: Goddard Hall 311, 109a, or 110	Automotive Engineering Workshop Intro: Atwater Kent 219, then move to far end (shaded) of Library Parking Lot (rain location: WPI garage, 91 Prescott St.)	Rehabilitation Engineering Workshop (Mobility for the Disabled) Higgins Lab 116	
10:00		Group 1: Computer Orientation Kaven Hall 202 Groups 2,3: Teamwork, Design a Birthday Party Atwater Kent 218, 219					Bus leaves for Cape Cod In front of Alumni Gym Boxed Lunches Stop at Massasoit State Park
11:00							
12:00		Lunch Morgan Dining Hall	Lunch Morgan Dining Hall	Lunch Morgan Dining Hall	Lunch Morgan Dining Hall	Lunch Morgan Dining Hall	
1:00		Group 1: Teamwork, Design a Birthday Party Atwater Kent 219 Groups 2,3: Computer Orientation Kaven Hall 202	Visits to customer sites Bus leaves from front of Alumni Gym	Forensics Workshop Goddard Hall 227	Design Projects Brainstorm alternatives Atwater Kent 218, 219, 233	Design Projects Evaluate alternatives using decision matrix Atwater Kent 218, 219, 233	Ocean Engineering: Visits to Woods Hole Oceanographic Institution (WHOI) Exhibit Center and Other WHOI Sites
2:00	Registration In front of Daniels or in Wedge if rain			Design Projects Gather information Atwater Kent 218, 219, 233			
3:00	Welcoming Remarks Alden Hall	Break	Break	Break	Break	Break	
3:30	Campus Tours	All groups: Continue Birthday Party Design Brainstorm objectives for Tuesday site visits Atwater Kent 218, 219, 233	Design Projects Develop problem statement and goal Atwater Kent 218, 219, 233	Design Projects Gather information and develop specifications Atwater Kent 218, 219, 233	Design Projects Atwater Kent 218, 219, 233	Design Projects Start preparing for Monday presentation Atwater Kent 218, 219, 233	
4:00	Orientation Parents: Alden Hall; Campers: On the Quad					Sandcastle Building Video Atwater Kent 219	
4:30	Parents depart						
5:00	Welcome BBQ Higgins House Courtyard	Dinner Morgan Dining Hall	Dinner Morgan Dining Hall	Dinner Morgan Dining Hall	Dinner Morgan Dining Hall	Barbecue with Alumnae Higgins House Courtyard (Rain location: Higgins House Great Hall)	Picnic Dinner (pizza)
6:00	Ice Cream Sundae Building followed by Floor Meeting- get to know roommates and residential staff	Free Time	Free Time	Free Time	Free Time	Segway Demos and Karaoke Campus Center patio and stage area	Overnight at First Congregational Church Falmouth
6:30		Teambuilding on the Quad	Arts & Crafts/ Door Decorating / Picture Frames Odeum A	Swimming 6:30-8:30 pm	Movie Night Popcorn and drinks, Hagglund Room (6-9 pm) TA Night Out		
9:30	Lights Out	Lights Out	Lights Out	Lights Out	Lights Out	Lights Out	Lights Out

Appendix E: Example Farmbot Activity Worksheet

STEM Lab Worksheet - FARMBOT

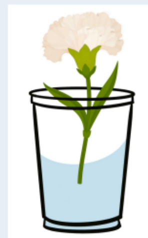
Names: ____

Group Name: ______________________________________

Activity : Water (Color Changing Flowers)

Materials Needed:

- **2** White carnations or other white flowers
- 2 Cups
- Water
- Food coloring



Instructions:

1. Trim down the stems of the flower so they fit your cups
2. Add water in each of the cups
3. Put 10-15 drops of food coloring in the cups with water
4. Place one flowers into the cups with water and food coloring
5. Allow flowers to sit for at least 20 minutes
6. Watch and record results

Hypothesis: What I think will happen

____

____

____

Evidence: What I Observed

STEM Lab Worksheet - FARMBOT

Activity : Nutrients (Color Changing Flowers)

Reasoning: Why I think it happened

____

____

____

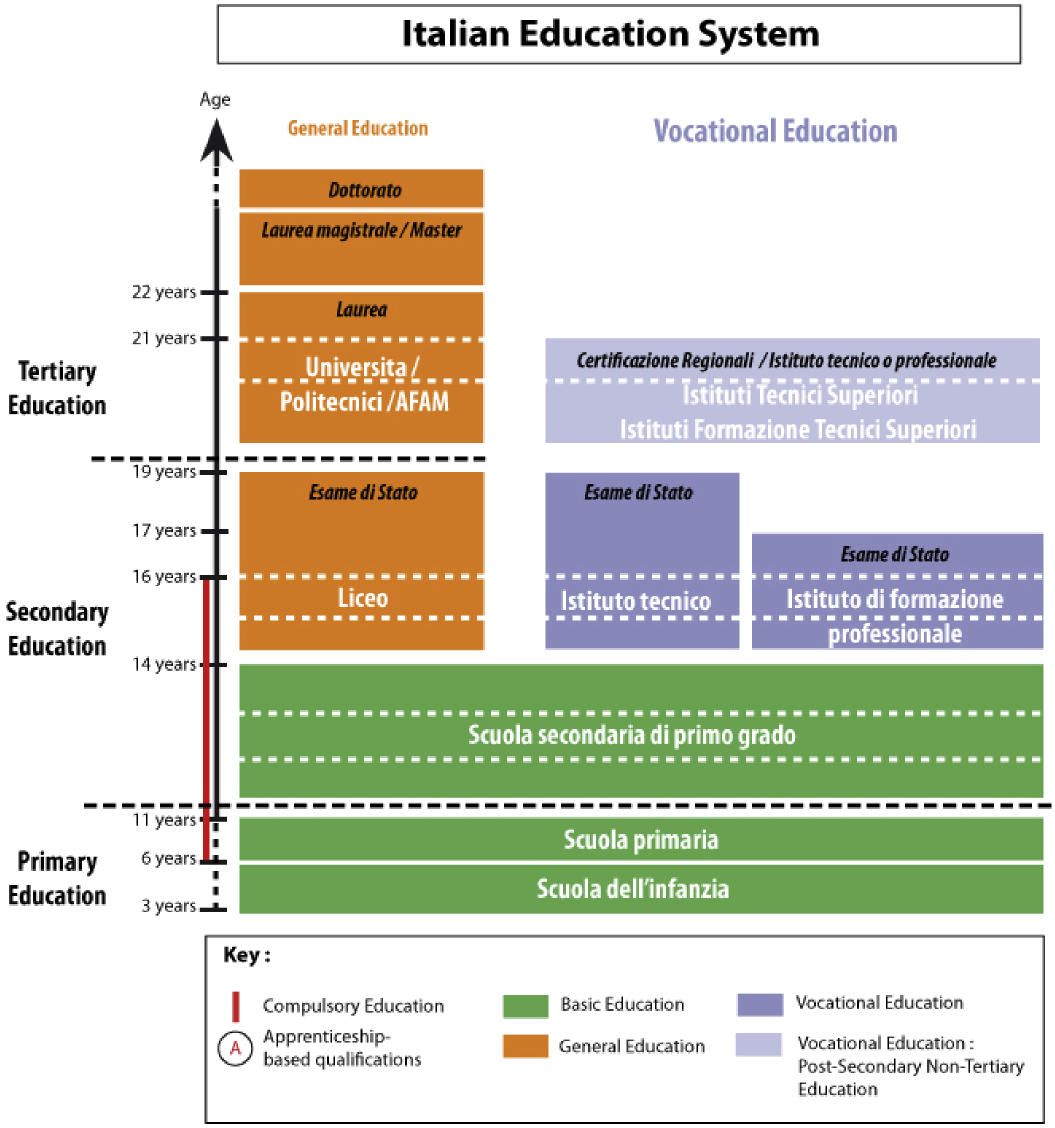
Claim: What I learned

____

____

____

Appendix F: Venice School District Structure



Credit: (Albanesi, 2020)