MAKEing STEM More Inclusive

Moe Buckley

Project Blog: u.osu.edu/makemoe

Educational Technology

MA Action Research Project

The Ohio State University

College of Education and Human Ecology

Advisor: Dr. Rick Voithofer

Second Reader: Dr. Ana Correia

Abstract

There is growing concern in the United States that our supply of STEM-workers is unable to keep up with the increasing demands. The Office of Science and Technology Policy (2016) points to "persistent diversity challenges" as one of the major reasons for this STEM employment gap. Despite numerous efforts to incentivize a more diverse group of individuals to pursue a STEM career, the fields are consistently dominated by white and Asian males at disproportionately high numbers. In this study, I explore ways that the maker movement could help.

The Maker culture offers new learning pathways to STEM careers and is founded on principles of openness and inclusiveness. To evaluate this movement, I went on a personal journey to become a maker within the Arduino community. My personal experiences help to shed light on the encouraging aspects of the maker movement, as well as issues that need to be addressed to make the movement more inclusive.

The Diversity Crisis in STEM

Advances in science, technology, engineering, and mathematics (STEM) have revolutionized the way we as humans live. Developments in electrical engineering, for example, have gotten us one step closer to eliminating our carbon foot print by making electric cars more affordable. Innovations in mobile technology have made communication and information sharing instantaneous. And in the medical fields, stem cell research is making transplant surgeries safer and more successful for patients. While these transformations are happening at a global scale, there is growing concern in the United States that our supply of STEM-workers is unable to keep up with the increasing demands. In 2016, the Office of Science and Technology Policy at the Whitehouse reported that there were over half a million unfilled jobs in information technology and economist project that there could be 2.4 million unfilled STEM jobs by the year 2018 (p. 1). This report points to "persistent diversity challenges" as one of the major reasons for this STEM employment gap. Taking a closer look at the data it is clear that the concerns are quite justified.

Groups are considered *underrepresented* if their representation in the STEM work force is lower than that of the U.S. population. According to the National Science Foundation (2017), Women, persons with disabilities, blacks, Hispanics, and American Indians are all considered underrepresented minority groups in STEM (NCSES, 2017).

The National Center for Science and Engineering Statistics (NCSES) releases an annual report called *Women, Minorities, and Persons with Disabilities in Science and Engineering*, which helps to shed light on the participation of each of these groups in science and engineering (S&E). While participation from many of these groups has slowly climbed over recent years, the numbers are still quite shocking. In 2015, Hispanics made up a mere 6% of the S&E workforce, while blacks and American Indians made up 4.8% and 0.2% respectively (NCSES, 2017).

Together, females made up approximately 28.4% of the S&E workforce and only 24.5% of the computer and information sciences sector (NCSES, 2017). Table 1 helps to illustrate the severity of the underrepresentation for some of these groups by comparing the percent of S&E workforce to that of the population.

Table 1

Percent of S&E workforce compared to percent of total civilian population by gender, race, and disability status

Gender, race, and disability status	Percent of civilian noninstitutional population	Percent of S&E workforce
Men	48.3%	71.6%
Women	51.7%	28.4%
White (Non-Hispanic)	64.4%	66.6%
Asian (Non-Hispanic)	5.6%	20.6%
Hispanic or Latino	15.8%	6%
Black (Non-Hispanic)	11.8%	4.8%
American Indian and Alaska Native	1.1%	0.2%
Without disability status	87.4%	92%*
Disability status	12.6%	8%*

Data sources: U.S. Bureau of Labor Statistics and NCSES

**Data only available for 2014*

Why should we care?

Failing to meet this demand for workers will threaten the United States' ability to remain a top global competitor, but more importantly, underrepresented minorities represent a largely untapped talent pool. STEM has a direct effect on our daily culture and advances in these fields are shaping the future for all of us. Therefore, it is essential that everyone has an equal opportunity to be a part of that conversation.

Over the past decade we have seen an increase in both private and publically funded initiatives that target these underrepresented groups and try to recruit them to STEM fields. Despite these efforts we've seen little change in the numbers. This suggests that there are bigger barriers at play for these groups. Instead of trying to change the beliefs of these minority groups perhaps we need to shift our focus to the infrastructure of STEM itself. For a lack of a better term, STEM is in desperate need of a "re-brand". This starts with re-branding education to be more culturally inclusive. I believe that the Maker Movement has already started this battle for us. By harnessing the maker culture in both formal and informal STEM educational settings, we may be able to attract and attain a more diverse group of people to these fields.

The Maker Movement

"Make. Just make. This is the key." (Hatch, 2014, p.11). Put quite simply, the Maker Movement celebrates just that. *Making* encompasses all kinds of activities – from sewing to robotics – and a *maker* can be found in all of us.

To limit this movement to one definition would be doing it an injustice. It is a social phenomenon, a mindset, and it can mean different things to many different people. This movement leans heavily on the idea of learning-by-doing and can be characterized by its "Do-It-

Yourself" (DIY) culture. It celebrates risk-taking and recognizes failure as a vital part of learning. Aligned with the values of the open-source movement, it views openness and sharing as essential to growth. And perhaps the most exciting characteristic of this movement is that it strives to be inclusive and welcoming to all, including those groups that have been consistently underrepresented within STEM.

History of the Maker Movement

The origins of the modern Maker Movement can be traced back to early 2005 when *Make* magazine was founded by *Make Media*. This bi-monthly print features innovations in DIY technology projects, and is believed to be one of the first sources to use the term "maker". In 2006, the readers of this magazine gathered in the San Francisco Bay Area for the first ever *Maker Faire. Maker Faire* provide a way for makers of all trades and skill-levels to showcase their work and celebrate their love for making with others. These events have grown exponentially in popularity since its kick-off, and in 2016, there were over 200 *Maker Faire* across the world, some drawing more than 100,000 attendees (Maker Media, 2017).

The basic activity of making, however, is not a new concept. It emerges from longstanding hobbies and crafts such as gardening, woodworking, sewing, and tinkering with electronics (Martin, 2015, p. 30). While this ability to "make" might not be as treasured as it once was, this trend is once again gaining popularity within the U.S. and around the world.

According to *Make* and *Make Media*'s founder, Dale Dougherty (2012), this movement in part, has come about because of people's need to be more than just consumers and engage passionately with tangible objects. Dougherty believes that "makers at their core are enthusiasts" (p. 12). Unlike the term "inventor," "maker" is something that everyone can identify with.

While this culture continues to grow, universities, tech companies, and even the U.S. government have become key players. The U.S. government, for example, shows its support for the movement by hosting a yearly *Maker Faire* at the White House. This annual celebration was started by President Barack Obama in 2014 and it aims to showcase the work of a diverse group of young scientists from across the country. While these partnerships continue to grow, for most, *Make Media* continues to be the face of this movement.

Qualities of the Maker Movement that could make STEM education more inclusive

Access & Affordability

The Office of Innovation and Improvement within the U.S. Department of Education (2016) points to access and affordability as major challenges for this country's diversity issues in STEM. In their *STEM 2026* vision, they state that "Students who attend high-poverty schools frequently do not have access to experienced teachers in the core subjects of science and mathematics, and many do not even have access to the courses that could put them on postsecondary and career pathways in STEM" (p.27). According to data collected by the Office for Civil Rights, in 2014, only 66% of high schools with the highest percentage of black and Latino student enrollments offered chemistry, and only 74% of these schools offered Algebra II (p.1). Aside from the issues around instructor credentials and course offerings, "teachers in high-poverty schools more often report having to work with outdated textbooks in short supply; outdated computers and other kinds of technology; and inadequate or nonexistent science equipment, materials and labs" (Hudley, 2013).

These disparities in access to quality education and affordable tools "hinder the engagement of a diversity of talent that essentially remains hidden among the nation's youth" (U.S. Department of Education, 2016, p.27). Without access to subject-matter experts and the foundational tools needed for a quality STEM education, these students are at a disadvantage from the start and unable to compete with their more privileged peers.

Fortunately, one of the most exciting features of the Maker Movement is the celebration and use of affordable and accessible tools. In the field of computer science for example, this movement has led to the birth of new digital toolkits which "substantially lower the barriers to engaging in physical computing, while still offering robust pathways for learning about engineering and programming through design and play" (Martin, 2015, p. 32). The Raspberry Pi and Arduino are two examples of maker toolkits.

The Raspberry Pi is a credit-card sized computer that was designed to help teach young people to program. The board, which can be purchased for as little as $20, uses an SD card to store the Linux Operating System and a standard USB plug to power the device. Connect these to any mouse, keyboard, and computer or TV monitor and you have a fully functional computer for a very affordable price (raspberrypi.org).

The Arduino can also be purchased for as little as $20. Arduino is an open-source hardware and software ecosystem, which consists of both a robust microcontroller board (circuit board) and an easy-to-use programing software. Arduino boards sense the environment by "receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators" (Arduino.cc). Arduino has made it more affordable for people to tinker with electronics and take a hands-on approach to learning how objects interact with one another.

In a very literal sense these products are much more affordable then they have been in the past. Additionally, these products have taken sophisticated technology and made the inner workings accessible to a much wider audience.

The birth of online learning communities and maker spaces may also play a role in addressing access and affordability. Online learning communities make use of online forums, blogs, and social media to connect and share resources. Among other things, this network makes access to field experts much more attainable. Maker spaces, such as the Idea Foundry in Columbus, Ohio, provide a physical way to connect with other makers. These meeting places provide another outlet for people to connect and share ideas, and in many cases, these work spaces will house tools, making it more affordable for its members to access the technology or equipment they need.

On a larger scale, this movement has the opportunity to change the face of manufacturing. With the birth of tools like the 3D printer, smaller businesses or individuals with access to shared maker spaces are able to produce and prototype on a much smaller scale and in-house. This may give smaller businesses access to compete in markets typically dominated by larger corporations.

Making fosters learning through a Project-Based Learning framework

The maker culture is heavily founded on the idea of constructivism and learning-by-doing. Project-Based Learning (PBL) provides a framework for making to be incorporated into STEM education (Waters, 2014).

PBL is a student-centered instructional method in which students learn by developing solutions to real-world problems. Both PBL and Making are supported by three core principles

of constructivism: “learning is context-specific, learners are involved actively in the learning process and they achieve their goals through social interactions and the sharing of knowledge” (Kokotsaki, Menzies, & Wiggins, 2016, p.267). In this framework, students investigate an authentic problem, identify solutions, collaborate with other students and subject-matter experts, then apply their new knowledge to create an end product in response to the original problem. It is through this active learning process that students can acquire a deeper knowledge. Aside from creating a more enriching learning experience, utilizing this PBL framework to incorporate making culture into STEM education may also help to attract a more diverse group of students.

In 2013, the Worcester Polytechnic Institute (WPI) conducted a study to measure *Gender Differences in Long-Term Impacts of Project-Based Learning*. WPI studied 38 years of engineering graduates who participated in a technology-focused, PBL curriculum. Surveys were used to gauge students’ beliefs on how the PBL curriculum had an effect on their professional lives, world views, and personal life. Overall, the results showed that 90% of the respondents believed PBL had a positive impact on their life, and the numbers were even higher for women. Women tend to be more motivated by the social context and collaboration aspects of PBL, and perhaps, “more application and integration of context in the engineering curriculum could help attract and retain women” (Heinricher, Rissmiller, Quinn, & Vaz, 2013, p.3)

In a literature review of PBL, Muhammad Khan and Zain Sobani (2012) also discovered a positive relationship between racial diversity and effectiveness of PBL. According to their findings, “when it comes to diverse student bodies, PBL is an effective method to enhance cross-ethnic socialization, resulting in improved interpersonal dynamics and effective learning amongst students” (Khan & Sobani, p.124).

Can this movement help us address the diversity crisis in STEM?

The Maker Movement opens new possibilities for STEM learning pathways. Implementing maker activities into traditional education may enrich the learning experience for everyone, while also attracting more females based on the social nature of the activities and connection to real world issues. Additionally, making as an informal learning activity (or hobby) may offer adults without a former STEM education a new pathway to STEM-related careers.

Many universities, communities, and school districts across the country have already identified this potential and have begun creating shared maker spaces and/or incorporating making and PBL activities into their curriculum.

This movement is still quite young, but its benefits for education and STEM in general are very promising. In 2016, Agency by Design did an investigation of the *promises, practices, and pedagogies of maker-centered learning* which included interviews with maker educators and thought leaders, as well as site visits to maker-centered learning environments. This study found that not only is maker-centered learning helping to develop proficiency in STEM subjects, it is also helping to develop agency and build character (Agency by Design, 2016). With this in mind, why are more schools not jumping on board? And why are underrepresented minorities not participating more?

In this project explored these questions from a unique and personal angle. I have been very interested in joining this movement for many years now, yet something has held me back from diving in. In my case, interest was certainly not the issue. I have been interested in science and technology my entire life and am currently working as a graphic designer and web developer. I am very proud of where I am today, but I would be lying if I said it was an easy journey. I have experienced first-hand some of the challenges of being a female in a

predominately male industry. So before answering the above questions in a broader sense, I wanted to first figure out why *I* had not participated in this movement. Were these previous experiences holding me back from jumping in? Or is the making community not as inclusive as it claims to be?

I decided it was time to start the journey to become a maker. By assessing my own experiences in this journey, I was able to gain a better understanding of what it means to have a maker mindset, how the community plays a role in shaping my identity as a maker, and most importantly, what it feels like to go on this journey as a female. My personal experience also helped to shed light on the promising aspects of the movement as well as some of the community's own diversity issues.

It would be impossible to assess the entire movement in one study; therefore, I decided to focus on the Arduino board and its online learning communities.

Qualitative Assessment of the Arduino Community

The *Arduino* is an open-source electronics platform built on user-friendly hardware and software that was developed to make interactive projects and tinkering with electronics more accessible and affordable. Arduino is most well known for their robust microcontroller boards that come with numerous digital input/output pins, analog pins, connectors and sensors that allow you to build digital devices that can sense and interact with other objects in the world. Arduino's most popular boards can be purchased for as little as $20 (arduino.cc). For this project, I used the Arduino Uno Rev3 board that comes with the Arduino Starter Kit (Figure 1).

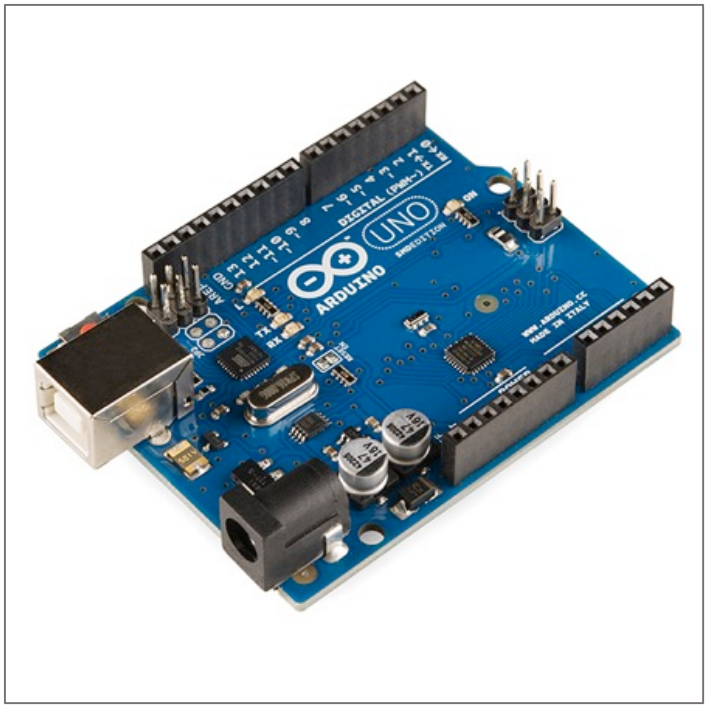

Figure 1. Arduino Uno Rev3 Board. An inexpensive, open-source microcontroller board. (SparkFun Electronics, 2013).

The *Arduino community* is an ever-growing group of individuals who, like most makers, share common interests in tinkering with technology, creative problem-solving, and experimentation. This community welcomes everyone from "hobbyists and students to designers and engineers all across the world" (arduino.cc). While local meetups and larger events such as the annual *Maker Faire* conference provide opportunities for Arduino enthusiasts to gather in a physical space, the community continues to have a stronger presence online. For this project, I focused on the online forums, blogs, social networks, and virtual learning platforms that make up this online community.

Why I chose this community

I chose to focus on the Arduino community for two reasons. First, with my true interest in this movement being around STEM learning pathways, I wanted to select a tool that was suitable for both formal and informal educational settings. Arduino boards are inexpensive, open-source, and backed by a large community of support for educators. As part of Arduino's Creative Technologies in the Classroom (CTC) program, for example, instructors are provided with all of the tools, supplies, and resources needed to get them and their students started with learning the foundations of programming, electronics, and mechanics. There are currently 536 schools participating in CTC across three countries (Arduino.cc). The volume of resources and support also make this tool optimal for informal learners.

The second reason that I chose this community, is because I felt it was important to focus on a field of STEM that was new to me so that I could experience some of the challenges that come with entering the community as someone new. Circuitry, microcontrollers, hardware and software development were all very foreign to me.

Assessment Methods and Results

Observations, self-reflection journals, transcripts, and field notes were all used to collect data. Additionally, the following questions were used to help guide the assessment:

- *What does it mean to develop a maker mindset?*
- *How do interactions with the Arduino community contribute to how I define the maker mindset?*
- *How is gender exposed and perceived within the online community?*
- *What does a feminist mindset look like in the Arduino Community?*

Self-reflection was a key component to this journey, therefore, I consolidated all of my data and documentation into a portfolio that can be viewed online at u.osu.edu/makemoe. This portfolio gives a chronological view of my development as a maker and my beliefs of the community and culture.

My journey was broken into three phases, each with a different objective. Below is an overview of each phase:

- *Phase 1: Familiarize myself with the Arduino board and community resources*

  The goal of this phase was to get a foundation of knowledge about the tool and community that surrounds it.

- *Phase 2: complete a project contributed by someone within the Arduino community*

  The goal of this phase was to complete a project that was contributed by another member of the community. I used the knowledge gained in phase 1 to inform the project selection in phase 2.

- *Phase 3: Create a project on my own and share with the maker community*

  The goal of this final phase was to use the knowledge gained in phase 1 and the project from phase 2 to inform the creation of my own project. After completing the project, I contributed back to the community by sharing the tutorial on instructables.com.

Phase 1: Familiarize myself with the Arduino board and community resources

In this first phase, I relied heavily on the resources provided by the Arduino company itself. I started by completing 9 projects from *The Arduino Project Book* produced by Arduino

LLC (2015). I hand selected projects that progressed in difficulty and covered a wide variety of subject areas. Table 2 outlines these projects and the key lessons from each.

Table 2

Projects from Arduino Project Book completed in Phase I.

Project Name	Lessons
Get to Know Your Tools	Learn the basics of electrical theory and how a breadboard works by making a simple circuit using switches, an LED, and a resistor.
Spaceship Interface	Learn about digital input/output and variables by making a simple control panel with a switch and lights.
Love-O-Meter	Learn about analog input and IDE's serial monitor tool by creating a machine that will react to various temperatures.
Color Mixing Lamp	Learn about analog output and mapping values by making a lamp that will change colors depending on external lighting.
Mood Cue	Learn about servo motors and using built-in libraries.
Digital Hourglass	Learn about the long data type by creating a timer.

Motorized Pinwheel	Learn about high current/voltage loads and transistors by using a motor to spin a pinwheel.
Touchy-Feely Lamp	Learn about touch sensors and how to install third party libraries.
Tweak the Logo	Learn how to use serial communication to control a program on your computer.
Source: The Arduino Projects Book (2015)	

After completing the projects in *The Arduino Project Book,* I began my exploration of the community by reviewing popular maker blogs, forums, and tutorial sites. My primary goal in this exploration was to gain a better understanding of how this online community is structured.

Arduino blogs are comprised of short articles submitted by users. These articles are sometimes used to highlight important makers in the community or innovative projects. The two most popular blogs in the community are Blog.arduino.cc and Arduino.org/blog.

In contrast to blogs, the *Arduino forums and tutorial sites* have a much bigger focus on interaction between community members. I focused primarily on three sites due to their activity level and high number of users: Reddit.com/r/arduino, Arduino.stackexchange.com, and Forum.arduino.cc (Arduino Forum).

Each site had something unique to offer, but the Arduino Forum was the most organized, in my opinion. Within this forum, posts are nicely structured into predefined topics, which makes it more efficient to search through old posts and quicker to get a response on new posts. As a member of the forum you can comment and ask questions on the existing posts or start a new

one. I found their "how to use the forum" post extremely helpful for getting started and learning proper etiquette in the forum. I made an account on this site under the name "Makemoe".

Experts can easily be identified in this community based on their rank name and the number of stars they have on their profile. It is not entirely clear how you move up, but I've read that it is related to activity in the forum. Ranks include a wide variety of names like newbie (the default for new members), Jr. Member, Edison Member, all the way up to God Member. I have not been active long enough for my status to go up.

Phase 2: Complete a project contributed by someone within the Arduino community

The Arduino company itself does a great job at getting people started, but the most creative and innovative projects are contributed by users within the communities. After familiarizing myself with the major blogs, websites, and other ways that makers interact with one another, I started my search for a new project to try.

I was particularly interested in the ways that making can be used as a tool to foster learning through PBL, and a key component to PBL is learning by developing solutions to real-world problems. While brainstorming various directions to go with my first project, I tried to keep this idea in mind – what real-world problem can I address with the Arduino?

I used my experiences from the projects in Phase 1 to inform my project selection in Phase 2. I also let my interests guide me in this search. Therefore, I narrowed my search to projects that involved web development and/or Internet of Things (IoT). IoT is essentially a giant network of connected "things". These "things" include all of the machines, devices, and even people that connect to the internet and exchange data back and forth. Not only was this an area

that I found interesting, but since it relates to my job, I thought it would be easier for me to be able to identify real-world issues to solve.

The final and most important factor in selecting a project was my skill level. I enjoy continuously challenging myself, but jumping into a more advanced project too early proved to be discouraging. I found that reflecting on my learning and being realistic about my skill level was a very important exercise to do throughout this journey. I learned this very quickly after attempting (and failing) my first project.

The first project that I attempted was on instructables.com and was called *Arduino Powered Lucky Cat as Physical Webcounter* (janhimself, 2012). The author of this project describes how he used a Gif with a fixed IP address as a web counter for his site. When someone visits the site, Arduino is notified, and triggers a servo motor to move. The servo motor in his example was connected to a Lucky Cat's arm, so every time someone visited his website, the cat would wave. I thought this was a very interesting concept so I gave it a try.

I very quickly ran into issues and realized I was not quite ready for this project. At this point I had yet to use the Arduino to connect to anything besides the breadboard that came with the starter kit. The breadboard is used to house the circuits themselves for these projects. I also knew so little about connecting to the internet that I didn't even know where to begin with trouble shooting.

That night I ordered the *Arduino Ethernet Shield* and began familiarizing myself with Arduino internet connections. The Arduino Ethernet Shield is a device that clips onto the top of the Arduino and allows the board to connect to the internet. This addition also allows the board to read and write to an SD card. Figure 2 below shows what this shield looks like.

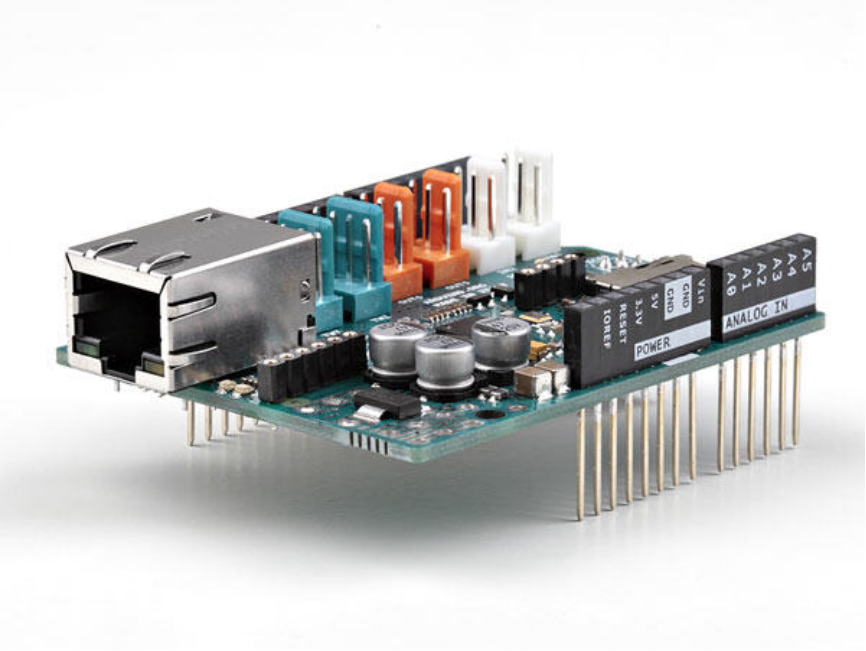

Figure 2. Photo of the Arduino Ethernet Shield 2 (Arduino.cc).

A week later I was able to successfully complete my first web-related project that was contributed by another community member. The tutorial was called *Arduino Web Server LED Control* and was found on startingelectronics.org (2013). In this project, the Arduino and Ethernet Shield are used as a web server. Together they serve up a simple HTML page with a form that allows you to control an LED on the breadboard that is also powered by the Arduino. The project was a success! Figure 3 is a picture of the Arduino Circuit set up and Figure 4 is a screenshot of the web page that was served up by the Arduino to control the LED.

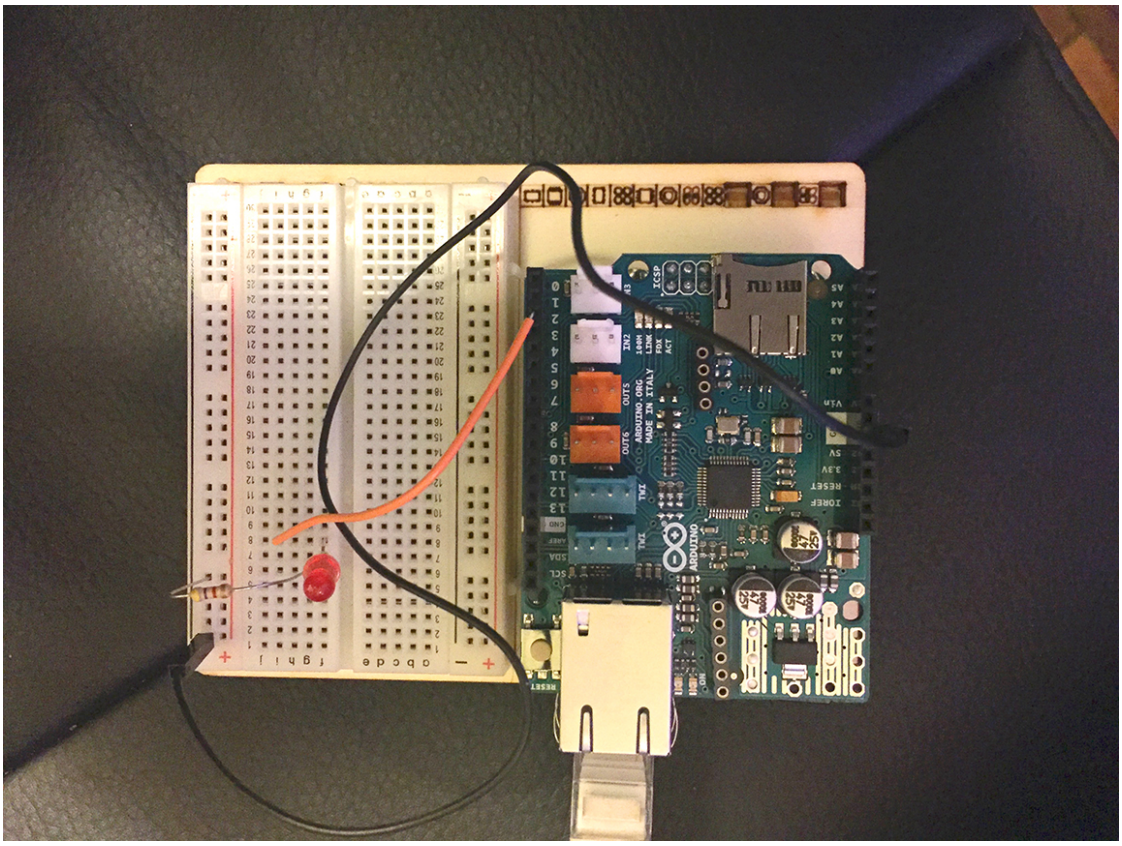

Figure 3. Picture of Arduino circuit set up for Arduino Web Server LED project

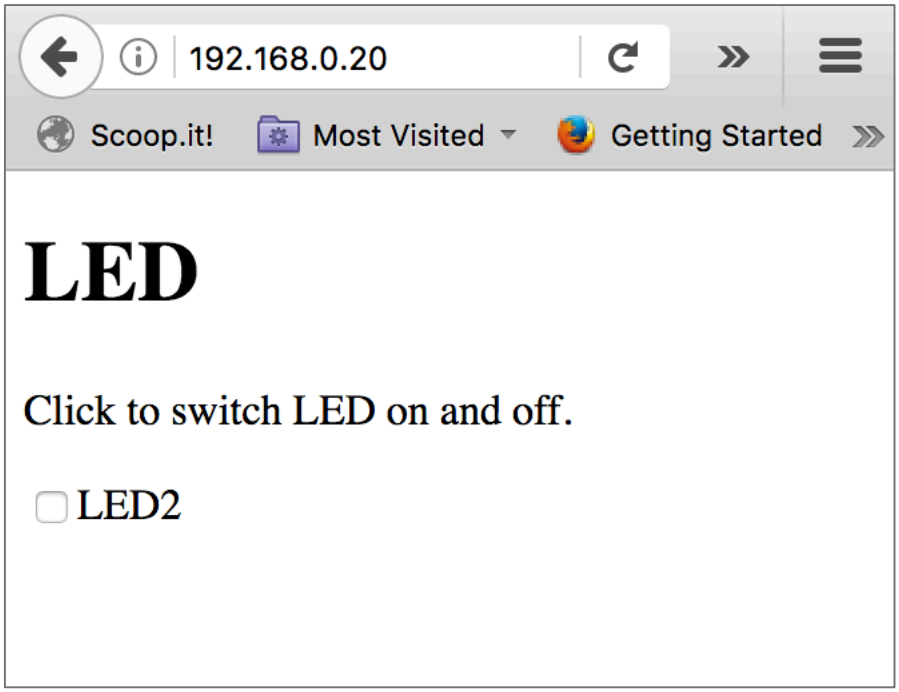

Figure 4. Screenshot of webpage served up by Arduino to control LED.

Taking a step back after my first failed project was key to the success of this one. Rather than getting discouraged, I recognized that I was entering an area of the Arduino world that was completely foreign to me. While learning about circuits, *The Arduino Project Book* started by giving an overview of how circuits work in general, and then more advanced topics were slowly introduced. I took a similar approach when learning how to connect to the internet. I began by reviewing the basics of web servers, clients, and DNS, and then followed introductory tutorials with the Ethernet Shield before attempting the project described above.

Phase 3: Create a project on my own and share with the maker community

Since sharing is one of the essential elements of this movement, the goal for the final phase of my journey was to create a project of my own and make it available for anyone to access online. I used the project that I completed in Phase 2 as a starting place for this one. The following outlines the modifications that I made to make this project my own.

- Adding Styles – With my design background, I was interested in learning ways to add Cascading Style Sheets (CSS) to the web page. CSS is the language used to style all web pages. I explored ways to add both HTML and CSS files to the SD card and also learned how to add styles directly to the Arduino sketch code. I felt that this addition to the previous project could be very helpful for new developers who are not familiar with CSS. Styling is rarely addressed in tutorials that I have seen. The styling that I added was very minimal, but it gets newbies set up to easily add more as needed.
- Adding a second LED light – To get more familiar with the code from the original project I decided to add a second LED to the breadboard and adjust the sketch accordingly. This required me to create a new LED variable, a new HTML form element, and define a new

ProcessCheckbox function. After making these changes, the webpage had two checkboxes that separately control the two LEDs on the breadboard.

Figure 5 is a picture of the final Arduino circuit set up for this project and Figure 6 is a screenshot of the web page that was served up by the Arduino.

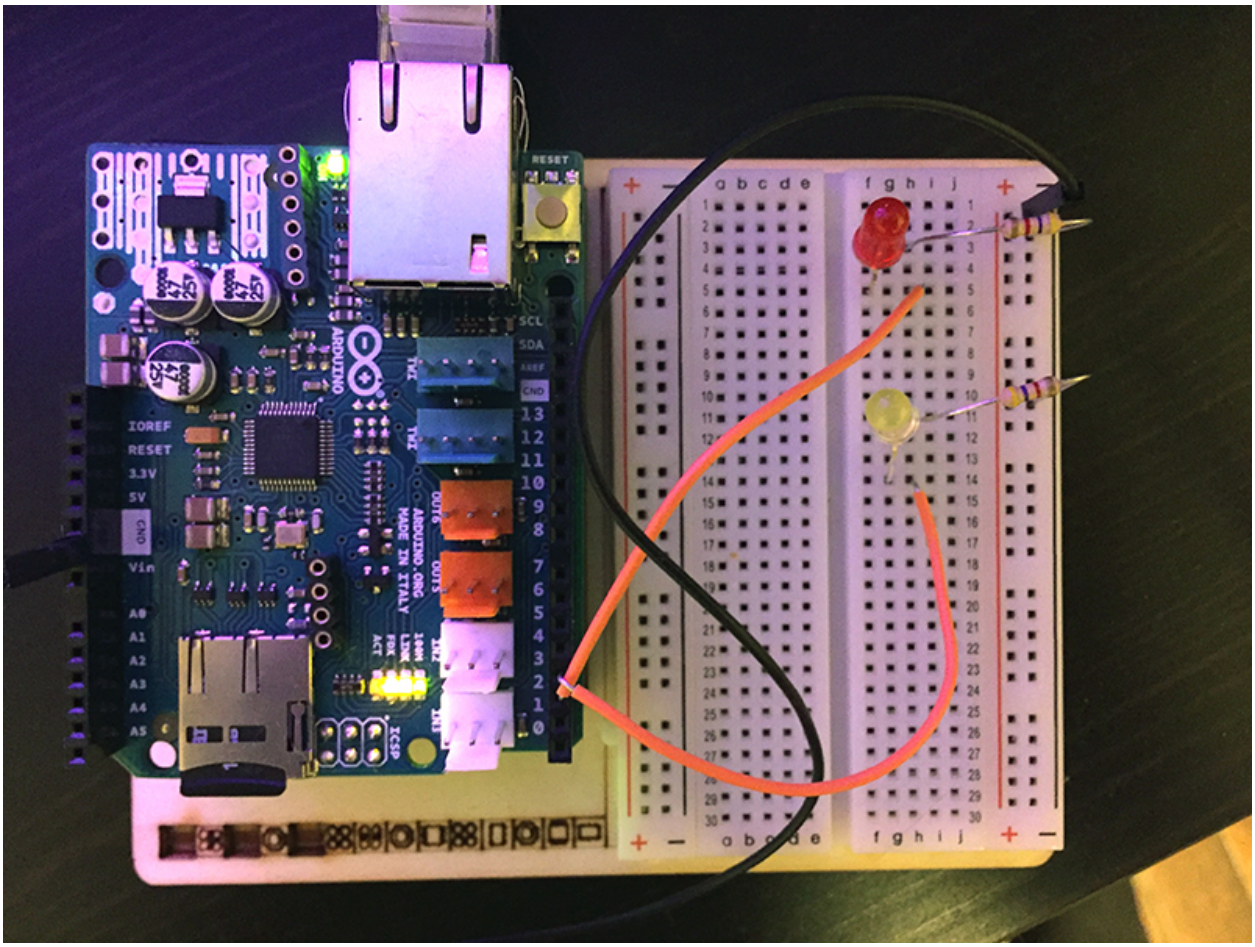

Figure 5. Picture of Arduino circuit set up for the modified Arduino Web Server LED project

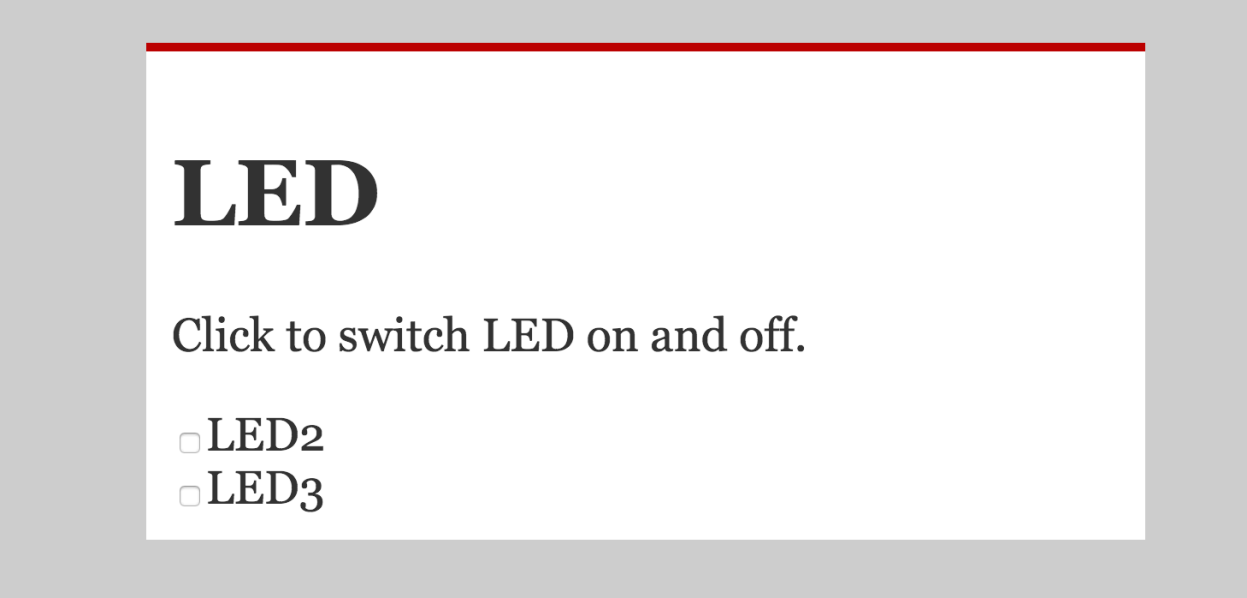

Figure 6. Screenshot of webpage served up by Arduino to control two LEDs.

Sharing My Project

I made a tutorial for the final project and posted it on instructables.com. Instructables ended up being one of the easiest sites to use and one of the quickest ways to get the tutorial shared. A detailed list of steps and downloadable code for this project are available online at https://www.instructables.com/id/Arduino-Web-Server-LEDs/.

Within one week of being posted, the project was featured in the site's technology section, viewed over 820 times, favorited 18 times, and positively commented on by another member.

Key Findings

What does it mean to develop a maker mindset?

The first phase of this project has taught me that to be a maker, you must take chances. It is important to be cautious and well informed, but a maker must also be willing to try things that are out of their comfort zone.

The maker mindset is a sponge, always ready to absorb new knowledge. There is almost always more than one way to do something. A maker should use good design thinking principles and be willing to continuously improve on what they know.

A Maker must hold the same values as the community; openness and sharing. As part of this, a maker should be respectful of others, regardless of their skill level. Vulnerability often comes hand and hand with openness and sharing, however, overcoming this makes you stronger and helps to build trust within the community.

Finally, this process has also taught me that a maker must embrace failure as a vital part of the learning process, and not view it as a sign of weakness. I believe the use of the affordable tools in this movement has helped to make failure less intimidating. Working with the Arduino is not free, but it did prove to be very low cost. By the end of this project I had spent about $130 on the Arduino board, the starter kit, and the Ethernet Shield. My fear of failure decreased when I realized that the cost of replacing broken pieces and starting over was very low.

How do interactions with the Arduino community contribute to how I define the maker mindset?

The Arduino community fully embraces the social aspect of learning. There is active participation between members of all levels and access to experts. This was especially noticeable in the forum and tutorial sites. Communication is literally constant, as people from time-zones all across the world are contributing to conversations. The online platform makes the collaboration between members more visible as well. One member's questions may lead to a new idea for someone else which may then lead to even more questions for others. But the most encouraging thing for me was the fact that members were typically very respectful, and appeared to be generally interested in helping one another. The kindness and patience towards new members was also evident, and is refreshing to see in the tech community. That being said, I think there are aspects of the community that create a steep learning curve for makers.

I would first like to applaud Arduino LLC for developing such a user-friendly starter kit. The kit that I used really did have everything needed to get started with the Arduino Uno Rev3 board. But after completing *The Arduino Project Book*, making that next step into the vast online community was quite scary. Learning to work with circuits, microcontrollers, and programing is a feat in itself. However, unlike in a more formal educational setting you have the added challenge of driving your own learning while simultaneously navigating this new online space. At the end of the day I believe this is a positive – you develop new skills and become fully engulfed in active learning. But I think it is important that this barrier does not get ignored.

The part of the community that I found particularly challenging stems from the fact that it is open-source. It is common for people to iterate on tools and projects and it can be difficult to keep track of everything. This became evident for me early on when I realized there are two

Arduino companies. In early 2015, disagreements amongst Arduino's original founders and the manufacturers who produced the board caused the company to split into two separate groups (Allan, 2015). Arduino LLC (aka Arduino.cc) was led by Massimo Banzi and the spin-off, Arduino srl (aka Arduino.org) was led by Federico Musto. One of the benefits of open-source technology is that it gives people an opportunity to replicate and improve on the original product. Unfortunately, in this particular case the two companies went down such a similar path (especially for site design and branding) that it did nothing but cause confusion.

How is gender exposed and perceived within the online community? What does a feminist mindset look like in the Arduino Community?

Gender and race are not a big part of identity in the online Arduino community. In fact, both gender and race were left entirely out of user profiles on the Arduino Forum. User accounts can include a photo and can be connected to social media accounts, but I found that very few people make use of these features. It is much more common to see abstract cartoon avatars or images of funny pop culture references then it is to see an actual headshot being used for the profile picture. Activity level, member ranking, and projects shared are the primary things that form the online identity of members.

While technically this may put men and women on a level playing field, it results in a lack of diversity for potential role models. This poses problems for people like myself who's belonging is reassured by seeing that there are other members in the community like them (female). This also poses a challenge for new members in general. Since expertise, projects, and merit equate to identity, it can leave newbies feeling like they are just one in a million.

As a new member, I did not feel that the community was preventing me from expressing my femininity, but I also did not feel it was in any way encouraging me or making it easy for me to do so. I felt stuck somewhere in the middle, just hoping to blend in. Underrepresented minorities are coming into this movement with a preconceived idea of what a "scientist" looks like. If one of the goals of this movement is to have the "maker" label be more inclusive, then perhaps the online communities should find more ways to incorporate racial and gender into the online maker identity.

Limitations of my assessment

I realize that my assessment focused solely on the online Arduino community, and my experiences may have differed with other maker groups. In the future, I think it would be beneficial to continue this assessment by exploring some of the physical gatherings that take place in community maker spaces or *Maker Faire*. I believe gender and race identity would play a bigger role in this physical space.

It is also important to point out that I am not attempting to speak for all underrepresented minority groups, or even all females with my key findings. Every individual is different and will have a different experience.

Final Conclusions & Recommendations

This journey has made me very optimistic about the future of Making in education. In general, I found the members of this community to be very welcoming and encouraging of one another, which was refreshing to see in the technology world. However, before this movement

can be used to help address the diversity crisis in STEM I think the leaders of this movement need to do more to show the *many* faces that make up this community.

Gender and race had little to no effect on identity within the online community. When looking for female role models I turned to blogs and larger scale publications like *Make* to find inspiration. Unfortunately, these sources usually just served as a reminder that I was a female trying to navigate a very white male dominated world. If the maker community is as diverse as they claim to be, then they need to start showing it. And I mean that quite literally.

Dr. Leah Buechley, an Arduino developer and former associate professor at the MIT Media Lab, discussed this issue in a Keynote address at the *Third Annual FabLearn conference at Stanford University* in 2013. In this presentation, she said "the movement has grown large enough and influential enough that it's time to turn a critical eye to the culture and the community and think about what we really want it to be and what it actually is." Her issues stem from the fact that our definition of the word "make" is too closely tied with the for-profit business *Make Media*. She believes that their definition of a maker and what constitutes making is too narrow, and I could not agree more.

At the time of her keynote, *Make* had produced 36 issues over the span of 9 years. Over these 9 years, they have focused on a very narrow scope of traditionally masculine themes. Table 3 shows the themes that came up on the Make covers.

Table 3

Make magazine cover themes

Theme	Percent of covers
Electronics	53%

Vehicles	31%
Robots	22%
Rockets	8%
Music	5%
Source: Buechley, 2013	

Of the 36 covers that Buechley examined, 40 people were featured. 85% of the covers featured males, 15% featured females, and 0% featured people of color. The editorial staff for *Make* at the time reflected similar stats; of the 15 editors, 87% were male, 13% were female, and 0% were people of color (2013). As one of the leaders in this movement, this lack of diversity is problematically limiting our definition of this community, implying that white men and boys are the only people who make things. I agree with Buechley's challenge to *Make Media*. They can do better, and it is there responsibility to do so.

Vincent Purcell, a teacher and maker whose work focuses on social and environmental issues, has similar concerns. Purcell argues that, "to truly realize the ethos of an open-source, democratic community, we need to educate those most in need, highlight role models who look as diverse as we as humans are, and shift power to underrepresented people who themselves can design and build appropriate solutions to critical social challenges" (2015).

After experiencing the Maker community first hand, I have remained optimistic about the movement and its potential to help us reimagine STEM education in the U.S. This movement is already helping to break down access and affordability barriers, and its foundations in openness and sharing is promoting collaboration across disciplines and encouraging people of varying skill levels to work together. However, it is hard to imagine what you cannot see. If the leaders of the

maker movement can begin to show the *many* faces that make up this community, then I think we can attract a more diverse group of people. Makers are stronger together, and if we can diversify the making community I think we will be well on our way to rebranding STEM.

Sources

Agency by Design. (2016, August 17). *The Promises, Practices, and Pedagogies of Maker-Centered Learning: An Updated Preview of the Findings from the Agency by Design Project*. Retrieved from http://www.agencybydesign.org/the-promises-practices-and-pedagogies-of-maker-centered-learning-an-updated-preview-of-the-findings-from-the-agency-by-design-project/

Allan, A. (2015, March 6). Arduino Wars: Group Splits, Competing Products Revealed? *Make*. Retrieved from http://makezine.com/2015/03/06/arduino-vs-arduino/

Arduino. (2017). Retrieved from Arduino website https://www.arduino.cc/

Buechley, L. (2013). Closing Keynote. [Presentation]. *Presented at the Third Annual FabLearn conference at Stanford University*. Stanford, California. Retrieved from http://edstream.stanford.edu/Video/Play/883b61dd951d4d3f90abeec65eead2911d

Dougherty, D. (2012). The Maker Movement. MIT Press Journals, 7.3, 11-14. http://www.mitpressjournals.org/doi/pdf/10.1162/INOV_a_00135

Fitzgerald, S. & Shiloh, M. (Eds.) (2015). *The Arduino Projects Book*. Arduino LLC.

Hatch, Mark. (2014). *The Maker Movement Manifesto*. McGraw Hill Education. Retrieved from http://www.techshop.ws/images/0071821139%20Maker%20Movement%20Manifesto%20Sample%20Chapter.pdf

Heinricher, A., Rissmiller, K., Quinn, P., & Vaz, R. (2013, June). *Gender Differences in the*

Long-Term Impacts of Project-Based Learning. Paper presented at: 120th ASEE Annual Conference & Exposition, Atlanta. Retrieved from https://www.asee.org/public/conferences/20/papers/6899/view

Hudley, C. (2013, May). *Education and urban schools*. Retrieved from the American Psychological Association website http://www.apa.org/pi/ses/resources/indicator/2013/05/urban-schools.aspx

Janhimself. (2012). Arduino Powered Lucky Cat As Physical Webcounter. *Instructables*. Retrieved from http://www.instructables.com/id/Arduino-powered-Lucky-Cat-as-physical-Webcounter/

Kokotasaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, 19.3, 267-277. DOI: 10.1177/1365480216659733

Make Media. (2017). Retrieved from http://makermedia.com

Martin, Lee. (2015). The promise of the Maker Movement for education. *Journal of Pre-College Engineering Education Research*, 5.1, 30-39. http://dx.doi.org/10.7771/2157-9288.1099

National Center for Science and Engineering Statistics (NCSES). (2017, January). Data Tables. *Women, Minorities, and Persons with Disabilities in Science and Engineering*. Arlington, VA. Retrieved from the National Science Foundation website https://www.nsf.gov/statistics/2017/nsf17310/data.cfm and https://www.nsf.gov/statistics/2017/nsf17310/digest/introduction/

Office of Science and Technology Policy. (2016, February). *STEM Depiction Opportunities*. Retrieved from the White House website (Archived from Obama administration)

https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/imageofstemdepictiondoc_02102016_clean.pdf

Purcell, V. (2015, November 18). What the Maker Movement Needs to Learn. *Impact Design Hub*. Retrieved from https://impactdesignhub.org/2015/11/18/what-the-maker-movement-needs-to-learn/

Raspberry Pi Foundation. (2016). *Raspberry Pi – Teach, Learn, and Make, with Raspberry Pi*. Retrieved from Raspberry Pi website https://www.raspberrypi.org/

SparkFun Electronics. (2013). *Arduino Uno – R3*. Retrieved from Wikimedia Commons https://commons.wikimedia.org/wiki/File:Arduino_Uno_-_R3.jpg

Startingelectronics. (2013). Arduino Web Server LED Control. *Starting Electronics*. Retrieved from https://startingelectronics.org/tutorials/arduino/ethernet-shield-web-server-tutorial/web-server-LED-control/

U.S. Bureau of Labor Statistics. (2016, September). Labor Force characteristics by race and ethnicity, 2015. *Report 1062*. Retrieved from https://www.bls.gov/opub/reports/race-and-ethnicity/2015/pdf/home.pdf

U.S. Department of Education, Office of Innovation and Improvement. (2016, September). *STEM 2026: A Vision for Innovation in STEM Education*. Washington, DC: Author. Retrieved from https://innovation.ed.gov/files/2016/09/AIR-STEM2026_Report_2016.pdf

U.S. Department of Education, Office for Civil Rights. (2014). *Civil Rights data collection: Data snapshot: College and career readiness* (Issue Brief No. 3). Washington, DC: Author. Retrieved from https://www2.ed.gov/about/offices/list/ocr/docs/crdc-college-and-career-readiness-snapshot.pdf

Waters, P. (2014, July 9). Project-Based Learning Through a Maker's Lens. *Edutopia*. Retrieved from https://www.edutopia.org/blog/pbl-through-a-makers-lens-patrick-waters