

Critical Machine Learning for Young Learners



A Curriculum designed to help
youth gain knowledge and
skills in Critical Machine
Learning (CML)

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For more information or to provide feedback on the document, visit the [IDEA Lab](#) or contact us at idealab@clemson.edu.

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PROGRAM OVERVIEW

Introduction

Welcome to the Critical Machine Learning (CML) Program Guide, a product of the [IDEA Lab](#) at Clemson University. This resource is a part of the CML program designed to help youth gain CML knowledge and skills and was designed using Participatory Design Research methodologies (Bang & Vossoughi, 2016; Robertson & Simonsen, 2013), in which we worked collaboratively with youth and after-school staff to design a program that aligned with their interests and values. This guide involves activities that promote youth knowledge construction of technical and computational concepts with consideration of the critical issues around machine learning. All of the activities in this program were designed to be used by community members and practitioners with no prior professional development and minimal preparation in this area.

These program activities were created for students between 4th and 8th grade. However, activities can be adjusted and adapted for different grade levels. In this program, learners can benefit from activities and discussions that build on key vocabulary and concepts that lead to CML knowledge. This program is flexible, and we encourage you to experiment with it in order to find out what works best for your learners, whether that means completing the curriculum from start to finish or just focusing on going deep into one or two lessons most needed by your learners.

CML Program Objectives

1. Define algorithms.
2. Provide examples of machine learning algorithms in the real world.
3. Share personal beliefs about technology, algorithms, and AI.
4. Identify harmful and helpful examples of technology.
5. Discuss ethical dilemmas surrounding technology and algorithms in the real world.
6. Discuss algorithmic bias issues and solutions that are of interest and of importance to youth and their communities.
7. Train simple machines and robots to classify images.
8. Design and build robots that could solve real-world problems.

Who is this Program For?

This program is designed for youth between the ages of 9 and 13 (grades 4th-8th). However, the activities can be adjusted for and adapted for different grade levels. The program can be used by teachers, after-school

program directors, summer camp directors, homeschoolers, and parents. In other words, the activities can be modified for both formal and informal environments and prior knowledge is not required.

ADOPTING A PARTICIPATORY DESIGN

What is Participatory Design?

In participatory design (PD), all stakeholders co-design learning experiences that take into account ethical, social, and political factors while also exploring relational dynamics that shape processes of partnering and learning (Arastoopour Irgens et al., under review; Bang & Vossoughi, 2016). This process stresses the importance of all stakeholders actively participating in a design process that reflects their needs and interests, giving authenticity to their voices (Ladkin, 2017), and promoting successful educational design outcomes.

Through multiple iterations, we co-designed the activities listed within this guide with the youth and staff from 3 after-school community youth programs. With each iteration, changes were created based on youth and staff input and situational issues. The goal was to co-design a program that addressed the targeted [learning objectives](#) listed within this guide while also allowing for changes specific to each community as they are revealed through the PD process.

Our goal is to have a foundational CML program that can be implemented in a variety of contexts and is flexible in that users of the program are able to modify activities to suit the needs and values of their learners and communities as they navigate through their own PD process.

Why is Participatory Design Important?

In order to engage youth in CML education that is culturally-relevant and aligned with their and their communities' interests and values, it is necessary to include them, their instructors, and their communities and families in the design of their learning. A PD approach (1) creates opportunities for stakeholders (youth, instructors, facilitators, community members) to meet and work together on a shared vision (Frauenberger, 2015); (2) provides the opportunity for critical reflection on behalf of both the learner and the instructor/facilitator (Inguva et al., 2018); (3) creates opportunities for collective social change (Bang & Vossoughi, 2016; Gutiérrez et al., 2016); and (4) allows for the youth's culture and values to be taken into account within the designs of the products of which they will be the ultimate users (Könings et al., 2013).

CRITICAL MACHINE LEARNING (CML)

What is Critical Machine Learning (CML)?

Critical Machine Learning (CML) is about recognizing, questioning, and taking action against inequities in machine learning data practices and understanding the ideological, historical and political dimensions of data production and usage. Both machine learning and artificial intelligence applications are heavily reliant on data and are often used to make automated recommendations and decisions in real world situations that can be harmful for people, especially those from non-dominant populations and those living in poverty. In this program, youth are asked to design an algorithm, train their own machine, and critique and express solutions to harmful consequences of socio-technical systems.

Why is CML Important?

The world is becoming increasingly reliant on digital technologies to navigate our lives. Such technologies collect, store, and analyze data to improve human efficiency and ultimately improve quality of life. One area where data is increasingly being utilized is in the development of machine learning systems. These systems are often used to make socioeconomic, political, and other critical decisions about people and communities. For example, machine learning algorithms are now used to more accurately predict cancer patient outcomes, measure natural disaster damage using social media postings, and quantify traffic dynamics to reduce air pollution (*Data Science for Social Good*, 2014). However, such reliance on machine learning algorithms can also be problematic (Chen & Quan-Haase, 2020). For example, widely used internet search algorithms that distribute knowledge to billions of people daily have been shown to reinforce racial and gender discrimination at large scales (Noble, 2018), value-added models measuring teacher performance were evaluated to be as accurate as random-number generators (O'Neil, 2016), and government software has been used to extrapolate data that preemptively criminalize the actions of low-income populations (Eubanks, 2018). In addition to having harmful effects on marginalized populations, machine learning applications typically are not made transparent about how they function.

For the public to meaningfully engage in conversations about machine learning and shape subsequent designs, they need enough literacy to understand how it works and critique models when it makes mistakes that affect them. This means that citizens would be able to assess the kind of data used in designing a machine learning system, interact with such a system to determine if there are any flaws, and critically think about potential solutions to models that affect them (Register and Ko, 2020).

HOW TO USE THESE ACTIVITIES

Getting the Most from the Curriculum

The Critical Machine Learning Curriculum is designed to be flexible so you can easily make it work in any learning environment with your unique youth group. We encourage you to make instructional changes to any lesson as needed. For example, we might indicate the facilitation of an activity as a whole class in this guide, but, knowing your own youth group, you might feel that the activity would work better if they complete it in small groups. Or, perhaps, you are at home and need it to accommodate your own children and the resources you have available at home.

Overview of Activities

The activities included in this CML Program Guide were adapted activities from [MIT's How to Train Your Robot Curriculum](#) (Williams & Breazeal, 2020) and [MIT's AI Ethics Education Curriculum](#) that were related to youth everyday experiences. Each day, the activities and discussions systematically build on the youths' experiences in activities that occur prior and the knowledge that they gain as they learn new vocabulary, concepts, and skills.

PROGRAM IMPLEMENTATION PHASES

This program is separated into three phases: *Initial Exploration, Activities and Discovery, and Youth Design.*

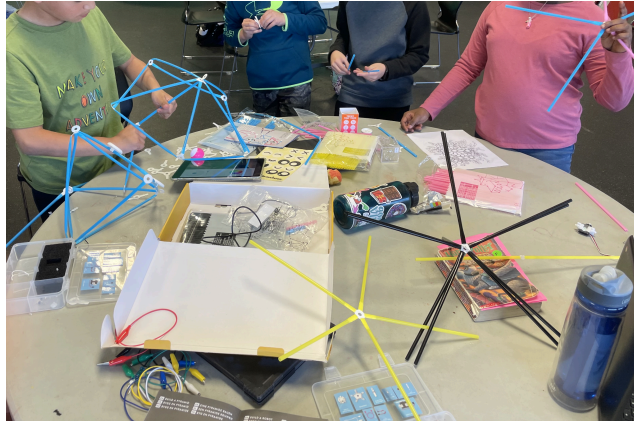
Initial Exploration

During this phase, the objectives include: decide where and how to initially implement the project; build relationships with youth and staff; determine youth, staff, and community values and interests; analyze planned curriculum and adjusting as needed; and determine youth baseline knowledge about algorithms and machine learning.

- This Get to Know You phase can last anywhere between 4-7 sessions, depending on the context. The goal is to observe the normal routines and activities that normally occur within the context in which the program is to be implemented. During this time, the values and interests of the stakeholders are determined as much as possible. In this case, the stakeholders are often the youth and staff involved in the program. This is also a time to start to build a relationship with the staff and youth prior to implementing the activities. Depending on the context, you might help with homework, chat with the youth, ask youth about what they were doing on the computer (in many cases, kids have Chromebook or other technological devices), and help staff conduct any normally planned activities. If this is in your normal classroom, take time to observe your students at play and re-evaluate their everyday interests. Talk to them about their families, communities, and hobbies. Try to imagine how these could be implemented in later activities.
- Another suggestion would be to bring in a variety of technological, computational, and robotic tools for the youth to explore during this period. Observing these explorations allows you to determine what previous knowledge and skills the youth have in the areas of technology, robotics, algorithms, and machine learning. Second, key concepts may be introduced during this period. This is done during playtime; so, it often makes learning these concepts a bit more fun, while helping youth start to develop a mindset toward computational concepts. Finally, using playtime with hands-on experimentation allows for the development of relationships through trust, co-construction of knowledge, and valuing of the youth's opinions and ideas. A few examples of toys that could help youth develop a mindset toward computational concepts: [Strawbees](#), [Sphero](#) robot balls, and [Specdrums](#).

Figure 1 (Arastoopour Irgens et al., under review): a) three boys and one girl creating figures using Strawbees straws and connectors with optional robotics, b) a boy programming and moving a Sphero robot ball using a tablet, c) two girls using the Specdrums app and physical kit to create music remixes.

a)



b)



c)



- **Pre-Drawing Worksheet: Assessing Learners' Baseline Knowledge of Algorithms and Machine Learning**

After initial exploration, Facilitator provides learners with a means for assessing their algorithmic and ML knowledge: [Algorithm and ML Drawing Worksheets \(Appendix A\)](#). This will be repeated at the end of the CML activities. This is a helpful way of determining how the learners' knowledge changes after implementing the CML activities.

Prompt:

I am interested in what you already know about algorithms and machine learning. I want you to draw me a picture of what you think algorithms and machine learning is or means. There are no wrong answers. Use your imagination and any information you have about what these terms might mean and then draw me a picture.

- Each learner completes the [Algorithm and ML Drawing Worksheet \(Appendix A\)](#). They will need drawing tools like crayons, markers, and/or pencils.

- **Interest Boards:**

Next, learners visualize their interests and values through the use of an interest board. These are handmade creations by the learners illustrating what they are interested in or what they value (see **Figure 2** for examples). This is done with construction paper, markers, crayons, magazine cut outs, or even digitally if this is the focus of your learning environment. These interests can be incorporated in the discussions throughout the activities as a means to help learners relate what they are learning to things they value.

Figure 2: Examples of youth “Interest Boards” created during the CML program



Activities and Discovery

During the *Activity and Discovery* phase, the objectives include: continue to grow relationships with youth and staff; continue to discover youth and staff values and interests and implement them into the activities, if possible; develop and support mutual learning through group activities and discussions; and provide activities and tools that could assist youth in knowledge construction regarding algorithms, machine learning, and algorithmic bias. This is done using both plugged and unplugged tools to scaffold youth learning in small increments at a time. Activities include: (1) *Pizza Algorithm Activity*; (2) *Harmful/Helpful Technology Activity*; (3) *Google Search Activity*; (4) Google's "Quick, Draw!" Activity; and (5) *Cat and Dog Activity: Google's Teachable Machine*

Activity One: Pizza Algorithms

In this activity, youth learn that algorithms, like recipes, are a set of instructions that modify an input to produce an output. Youth are then asked to write an algorithm to make the “best” pizza. This creates an opportunity for the youth to explore what it means to be the “best” and see how their opinions are reflected in their algorithms. This activity was adapted from [MIT’s AI Ethics Education Curriculum](#).

Keys words: algorithms, differences, input, instructions, opinions, output

Learning Objectives

- Define algorithms and provide an example
- Understand that algorithms have embedded opinions and assumptions
- Create algorithms to produce a pizza and determine the best type of pizza
- Write a recipe for making a pizza to better understand the components of an algorithm
- Reflect on how to optimize their pizza algorithm in order to make sure it is the best set of instructions that anyone can use and make a pizza

Time Required: 20-30 minutes depending on length of discussion. This activity can be completed on the same day as the [Harmful/Helpful Technology Activity](#) if time allows.

Materials/Resources Needed:

- Large construction paper or giant Post-It notes
- Markers or crayons
- Examples of instructions that could represent algorithms (see **Figure 3**)

Introduction

Welcome youth to the first day of the CML program and introduce them to what they will do in the program:

Example:

“Over the next several days (weeks, classes, etc.), we are going to talk a little bit more about algorithms and how we use them in our everyday lives in things like internet searches, facial recognition, and smartphones/ smart cars. We are going to talk about how we can teach machines like computers or robots by training and testing them using [algorithms](#). We are also going to talk about how our opinions and the amount and type of data we train our machines with can affect what the machines do or affect the results we get in an internet search-in other words, our [output](#).”

Introduce Activity:

Introduce the activity.

“Today we will learn what algorithms and machine learning are.”

Steps to the introductory activity:

- The words “algorithm” and “machine learning” are written or projected large enough for all learners to see it.
 - Learners share what comes to mind when they hear these words. This is a good opportunity for a discussion during which learners take turns discussing what they think algorithms and machine learning means.
 - As a facilitator, you can help guide thoughts and opinions toward the definitions of these terms.
- Learners are provided with the definition of “algorithm.” For example:

“An algorithm is steps to complete a task, like instructions. You can think of it like a recipe with ingredients and steps that lead you to a final product or output like a cake or a pizza.”
- To help youth understand better, you can share some examples of algorithms, such as math algorithms, recipes, or maybe processes used in the classroom for specific purposes (e.g. the “start the day” algorithm might include putting belongings away, getting breakfast, and then start “do now” activities before a morning meeting).
- Next, a few of the learners are given written or drawn examples of algorithms. They each take turns holding up their examples. Some have examples of algorithms (see **Figure 3** for examples) and some have images that do not represent algorithms (i.e. examples of classification or group comparison) (see **Figure 4** for examples). Learners read it to the group with assistance as needed.
- Group discussion:

Do these images represent algorithms? Why? Why not?

Figure 3: Examples of algorithms. a) An example of an algorithm for instructions (Image by Holland, 2022); b) An example of an algorithm as a flowchart (Image by Onaolapo, 2022); c) An example of an algorithm as a recipe (Image by Newman, 2022).

a)

Algorithm for cleaning teeth

When you are in the bathroom and if you need to clean your teeth

Pick up your tooth brush

Put tooth paste on the tooth brush

Put the tooth brush under the tap to make it wet

Brush your teeth at the top

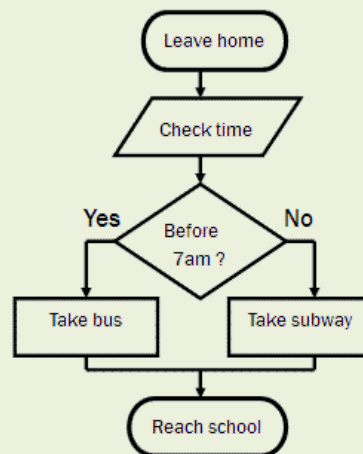
Brush your teeth at the bottom

Keep brushing until they are clean

Rinse your tooth brush

Put the tooth brush away

b)



c)

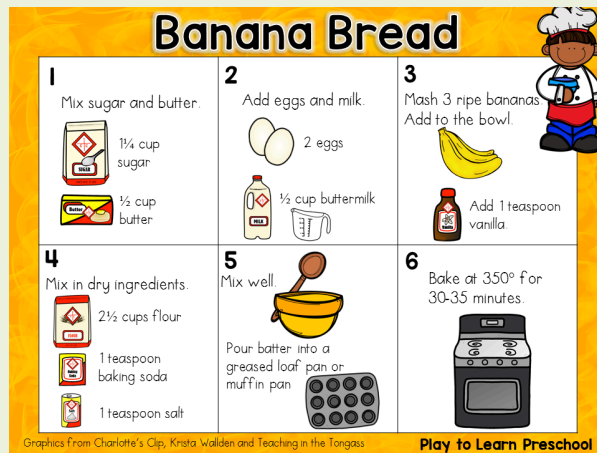


Figure 4: Example of a Venn Diagram that is not an algorithm (Image by Crumpton, 2022).



Pizza Algorithm

The goal of this activity is to provide learners with hands-on experience to help them understand the concept of an [algorithm](#). In this activity, learners create an algorithm that determines the best type of pizza to create based on their own opinions.

Learners work individually or in groups.

Prompt:

“Remember when we looked at examples of algorithms? Today, we are all going to write algorithms for making the best pizza. You have 5-10 minutes to create this algorithm. Remember that you are writing for a computer that knows nothing about the world, so be sure to write out the instructions very carefully.”

Steps:

- Each group (or individual learner if not working in groups) is given a giant post-it and markers, which is used to display their pizza algorithm. By doing it on larger pieces of paper and sticking these to the wall, it allows each group to see each other's pizza algorithm in order to discuss what makes a good algorithm and why. It also allows each group to see how the input for the recipe (algorithm) is based on opinions and everyone has different opinions. Refer to **Figure 5** for an example.
- Learners select a representative in each group to explain their pizza algorithm to the entire group at the end of the activity.
- Group Discussion:

What is an algorithm?

Did you agree with their algorithm? Could you make the pizza following their set of instructions exactly?

What was different and what was the same between each group?

Are algorithms opinions? Why or why not?

*Would this algorithm work if you did not cook the dough?
or open the can/jar of tomato sauce? Or turn on the oven?*

Figure 5: Examples of youth artifacts created during Pizza Algorithm Activity.



Activity Punchline

Remember, an algorithm is a set of step-by-step instructions for solving a problem or completing a task. They are something a human person develops and it is based on their opinions. We can make our own algorithms like we did with the pizza activity, or we can teach computers or machines to do tasks using algorithms.

Activity Two: Helpful and Harmful Technology

In this activity, youth have the opportunity to discuss the technologies they use or see in their everyday lives. They also reflect on whether these technologies are harmful and helpful and why.

Keys words: artificial intelligence (AI), digital technology, facial recognition, technology

Learning Objectives

- Share personal beliefs about technology, algorithms, and AI
- Discuss algorithmic bias and sociotechnical issues and solutions that are of interest and of importance to them and their communities.
- Identify harmful and helpful examples of technology.

Time Required: 20-30 minutes depending on length of discussion.

Materials/Resources Needed:

- Large construction paper with tape or giant Post-It notes
- Markers or crayons

Introduce Activity:

Introduce the activity.

Harmful and Helpful Technology

The goal of this activity is for learners to reflect on the potential of **technology** for being helpful or harmful to themselves and their communities.

In this activity, youth create a list of technology that they use in their daily lives and discuss with each other whether or not it is helpful or harmful technology and why.

Learners work individually or in groups.

Prompt:

“We are now going to make a list of technologies we see or use everyday. You have 10 minutes to answer the following questions so that we can talk about it.”

Steps:

- Each group needs to have a giant post-it and markers, which they will use to create their technology helpful and harmful list (use poster

board or whiteboards if you choose; the purpose is to make sure each learner is able to see their peer's reflections).

- Each poster is displayed so that each group can see each other's list in order to discuss together what makes the technology helpful or harmful and why. This allows each group to see how everyone has different opinions. Refer to **Figure 6** for examples.
- Display posters throughout the remaining activities so that they can be referred to during future activities.
- On the giant post-it notes or large construction paper, learners answer the following questions by writing or drawing:

What are some examples of technology you use or see throughout the day?

What are some ways we use these technologies that are helpful and harmful?

- Learners are then provided examples of how technology could be helpful or harmful in order to spark discussion and encourage further reflection on why the technology is helpful or harmful. This is a good time to provide examples of technology that uses machine learning.

- Examples of why technology might be helpful or harmful:

- Helpful Technology: technology can be used for entertainment; technology can be used as an information source; technology can be used to connect with people around the world; AI can enhance automation; AI can help humans perform tedious tasks; AI can improve weather predictions
- Harmful Technology: people can become addicted to technology; using too much technology limits our face-to-face interactions; facial recognition technology not recognizing some faces (usually non-white, non-males); invasion of privacy

- Examples of technology that use machine learning

- Social media websites that use ranking systems
- "Tagging" in social media (image recognition)
- Virtual personal assistants (Google, Alexa)
- Self-driving cars and automated transportation

- [illegible]

Activity Punchline

Technology has both good and bad effects. Throughout the week, we will see, talk about, and design what we think of as helpful technology, but it's important for us to know that technology could be harmful as well. It's important for us to be aware of advantages and disadvantages when we make and use any technology or when we teach machines/technology to perform a task.

Activity Three: Google Search

In this activity, youth search different topics using Google search engine and discuss representation and bias issues related to these searches. They also discuss the meaning of machine learning and provide examples.

Keys words: algorithms, algorithmic bias, artificial intelligence (AI), facial recognition, input, machine learning, output, representation, search engine, technology, training

Learning Objectives

- Define machine learning
- Provide examples of machine learning algorithms in the real world.
- Discuss ethical dilemmas surrounding technology and algorithms in the real world.
- Identify harmful and helpful examples of technology.
- Share personal beliefs about technology, algorithms, and AI

Time Required: 20-30 minutes depending on length of discussion.

Materials/Resources Needed:

- Computers, laptops, iPads, or Chromebooks
- Google Search Worksheets ([Appendix B](#)),
- Pencils

Introduce Activity:

Introduce Activity.

Learners reflect further on the last activity by discussing if they came across any examples of technology or AI at home or in their community since completing the [Helpful/Harmful Technology Activity](#). Learners explain to peers why they think the technology was helpful or harmful as they add these items to their poster from the last activity. Learners also discuss whether the technology learned how to do a task from a human.

Google Search

Prompt:

Remember when you created your own Pizza Algorithm?

Discussion with the groups is facilitated by referring to some of the ingredients and steps they discussed during the *Pizza Algorithm Activity*.

“Now we are going to see what Google thinks the ‘best’ pizza algorithm is along with looking at algorithms for other items we might want to search. We are also going to move on to machine learning and learn a little more about what that is.

We can play around with machines that people have designed. They use algorithms and training data to make them. Training data are the images you use to teach the machine how to recognize new images.

Today we are going to talk a little bit more about training datasets and dig into the “learning” algorithm aspect of machines and AI a little more. Finally, we will discuss some problems that may occur when using applications that have AI in them.”

Steps:

- Learners give examples of how computers or artificial intelligence might be trained by a human. The key idea is for learners to be able to see that machine learning is different from typical programming because in machine learning, **the machine is trained beforehand and then interacts with the real world**. In other words, the machine **makes a decision based on what it “sees” or “hears” in the world**. And sometimes, we do not know what this decision will be!

- Examples:

image recognition, facial recognition, speech recognition, smart cars, robots, smartphones

- Group Discussion:

What is machine learning?

What are examples of machine learning?

How do machines learn?

Who helps machines learn? Does it matter who is training machines and who isn’t training machines? Why?

Next Prompt: Today, we are going to do a few searches on Google in order to see what our searches bring up. Open up your Chromebooks/Computers to the Google Search site. Type in the word pizza and pull up the first 5 images that Google provides you.

Next Steps:

- There is then a group discussion regarding the first 5 images each learner sees in the Google search results.

Did everyone get pepperoni pizza mostly? How about pineapple pizza or _____ (talk about a flavor of pizza mentioned in their algorithms during the last activity)?

- Each learner is given a [Google Search Worksheet \(Appendix B\)](#).
 - They search for the words “Teacher” and “Professor” and then answer the questions on the worksheet. Questions include: *Are there enough images of people like you? Does this Google Search harm you or others you care about? Does that matter to you?*
 - The worksheet can be modified to address the individual learners’ interests in your group. For example, your group of learners could be interested in “basketball”, or perhaps your group is more into “singing”. This can be determined for each group of unique learners. A good place to look is at the learners’ “[Interest Boards](#)” they completed in the Initial Exploration phase. The main thing is that the words the youth search show potential bias or lack of representation, such as the exclusion of girls or African-Americans.
- Next, learner’s are given giant post-it notes and are asked: *What do they envision when they think of a “smart person” ? They write their answers on their Post-It.*
 - *Learners compare their answers*
- Next, learners use Google search engine to look for the words “smart person” and based on the images that come up on their computer, answer: *What does Google think a smart person looks like?*
- During the activity, prompting questions to the whole group are asked.

Does that person look like you?

Who might not be represented in this group?

Why do you think we are seeing the images we are seeing?

Who or what decides what we see?

Are the images on your computer the same as the images on your partner’s computer?

	The discussions are then connected back to algorithms, machine learning, input, and output. Introduce bias and algorithmic bias. Questions include: <i>If you had to guess what the algorithm was for Google searches, what would you guess?</i> <i>What is the input data that Google may use to train their search algorithm?</i> <i>Where does the input data come from?</i> <i>Is the data used fair?</i> <i>Should Google change what they are doing with their searches?</i>
Activity Punchline	Google's output is related to the input. This input data is generated from humans and originates with their opinions. Not everyone's opinion is the same. This can cause unfairness in representation and the result depends on WHO is programming in the algorithm and WHO is in charge. Machine learning (ML) is a type of artificial intelligence (AI) that allows software applications to become more accurate at predicting outcomes without being explicitly programmed to do so. Machine learning algorithms use historical data as input to predict new output values. It is important for students to understand that computers do not see the world the same way that humans do. We may see shapes and colors, computers see grids of numbers, or pixels.

Activity Four: Google’s “Quick, Draw!”

In this activity, youth learn the concepts of training data, input, and output. Learners focus on the direct interaction of humans with machines in machine learning and algorithmic processes. They have the opportunity to construct knowledge regarding algorithms, machine learning, search engines, and algorithmic bias.

Keys words: algorithmic bias, algorithms, input, machine learning, output, search engines, training data

Learning Objectives

- Define machine learning
- Provide examples of machine learning algorithms in the real world.
- Discuss ethical dilemmas surrounding technology and algorithms in the real world.
- Identify harmful and helpful examples of technology.
- Share personal beliefs about technology, algorithms, and AI

Time Required: 20-30 minutes depending on length of discussion.

Materials/Resources Needed:

- Computers, laptops, iPads, or Chromebooks
- Internet source: <https://quickdraw.withgoogle.com/>
- “Quick, Draw!” Worksheet ([Appendix C](#))
- Pencils

Introduce Activity:

Introduce the activity

Learners work individually and ask for assistance as needed.

[Google Search Activity](#) is revisited as a group.

Why is this important? How does this affect people/the world/you?

Google’s “Quick, Draw!”

Prompt:

“Google’s “Quick, Draw!” is a game built with machine learning. You draw, and a neural network tries to guess what you’re drawing. Of course, it doesn’t always work. But the more you play with it, the more it will learn. It’s just one example of how you can use machine learning in fun ways.”

“Quick, Draw!” is a form of [artificial intelligence \(AI\)](#) that is an online, browser-based game by Google.

In this activity, learners explore “Quick, Draw!” in order to see an example of machine learning with drawing.

With “Quick, Draw!”, the learners draw a randomly assigned object. As the learners draw, the AI attempts to identify what the object is. The AI guesses by extracting from a database ([dataset](#)) of drawings that other players have contributed to the game (see **Figure 7** for an example of drawings that “Quick, Draw!” guess right and **Figure 8** for an example of a drawing that “Quick, Draw!” guessed wrong).

Steps:

- Learners explore Google’s Quickdraw.
- Learners then complete the [Quick, Draw Worksheet \(Appendix C\)](#).
- Group discussion on the worksheets:

Did it always guess correctly? Why or why not?

Who uses this app to draw pictures?

Who or what provided the data to help the machine learn?

- Reflection might also include determining what “Quick, Draw!” got wrong and whether or not these items were drawn from people of different cultures.
- Additional Suggestion: Learners also explore [Autodraw](#) if there is time. In this app, the learner draws freehand and the app tries to guess the drawing by providing suggestions.

Figure 7: Example of drawings that “Quick, Draw!” guessed right (Image by Google Quick, Draw!)

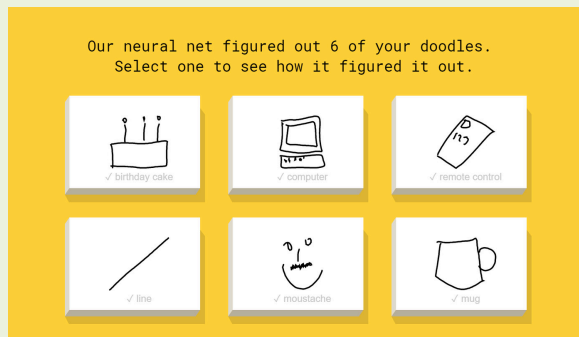
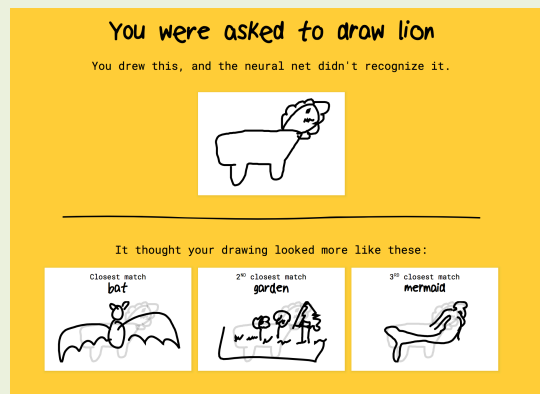


Figure 8: Example of a drawing that Google’s “Quick, Draw!” guessed wrong (Image by Google Quick, Draw!).



Activity Punchline

“Quick, Draw!” is a form of AI that learns from the drawings that people create when they are playing with this tool. It continues to learn as new players continue to test this machine with their drawings that then get added to the database. Whether the machine guesses the drawing correctly depends on the types of drawings that the other players contributed to the database. This input data is based on players' **opinions** of what different items should look like. It is important to have training data from a variety of cultures and people because people understand the world differently and thus, may draw these images differently. If the training data is not **representative**, then the app may not work for some people.

Activity Five: Cat and Dog Teachable Machine

In this activity, youth work on activities that help them understand that machine learning is dependent on the training data that is being used which in turn, determines the effectiveness of the algorithm. Youth are introduced to the concept of **classification**, which is a method in machine learning where a machine learns to label images with the objects they represent. By exploring [Google's Teachable Machine](#), youth learn about [supervised machine learning](#). In this activity, youth build a cat-dog [classifier](#) but are unknowingly given a biased [dataset](#). When the classifier works better on cats than dogs, youth have the opportunity to retrain their classifiers with their own new datasets.

This activity was adapted from [MIT's AI Ethics Education Curriculum](#).

Keys words: algorithm, training data, testing data, dataset, input, output, supervised machine learning, classification, classifier, biased dataset

Learning Objectives

- Use data sets of pictures to train image classifiers.
- Identify potential biases in training datasets.
- Minimize potential biases by altering training datasets.
- Explain how the composition of training data affects the outcome of a supervised machine learning system.

Time Required: 40-60 minutes depending on length of discussion.

Materials/Resources Needed:

- Computers, laptops, iPads, or Chromebooks
- Cat/Dog Worksheet ([Appendix D](#))
- Internet source: Teachable Machine: <https://www.teachablemachine.withgoogle.com/>
- Image sources:
 - Cats and Dogs Image Data:
Train: [Download Cat and Dog images](#)
Test: [Download Test Images](#)
 - More Cats and Dogs:
[Download More cats and dogs images here](#)

Introduce Activity:

Introduce the activity.

Remember the activity we did during which we made a pizza algorithm? And last time when we played with "Quick, Draw!"? Can you tell me what an algorithm is? How did

	someone make that Google Quickdraw machine you played with last time? What did they have to do to train the machine to guess images like how people do? Discussion about what machine learning is in relation to algorithms, testing data, and training data: <i>Machine learning is the steps we use to teach a computer to do something. We write an algorithm, then we give it some data to learn. Then, we put it in a new situation and hope it does what we want it to do. The machine doesn't always do what we tell it to do. It makes its own decision based on what it sees and recognizes.</i> Examples: Autocorrect when we are typing, facial recognition technology to unlock phones, hand-writing recognition technology to recognize and respond to written text, and a computer that can guess what you are drawing.
Cat and Dog Teachable Machine	Learners are told that they are going to train a machine to recognize images of cats and dogs. You can describe the activity as “A facial recognition machine for cats and dogs.” Learners use Google's Teachable Machine for this activity. Teachable Machine is a web-based tool that helps learners create machine learning models. See Figure 9 below for a visualization of Google's Teachable Machine homepage. The website provides videos for each step and are available for the youth to help them through this machine learning activity. In this activity, learners train their machine to identify whether an image is a cat or a dog using a training dataset of images of cats and dogs that is provided to them. Steps: • Before the activity starts, images of cats and dogs are placed in two different envelopes: one labeled “Training Data Set” and the other labeled “Testing Data Set”. • Learners use Google's Teachable Machine for images to train the machine to recognize dogs versus cats with the training images provided in an envelope with the label “TRAINING DATA”. • After they create their machines, they test them with the test images provided in an envelope with the label “TEST DATA”.

- Youth then fill out the Cat/Dog Teachable Machine Worksheet ([Appendix D](#)) to keep track of what the machine is doing.
- **IMPORTANT:** The training dataset contains **more variety** and **more images** of cats, and thus, the resulting trained machine misclassifies dogs more often than cats.
- Group Discussion about worksheets and why dogs were being misclassified. Define **bias** and discuss how it applies to the training activity. Questions include:

What was the input data used to train the machine?

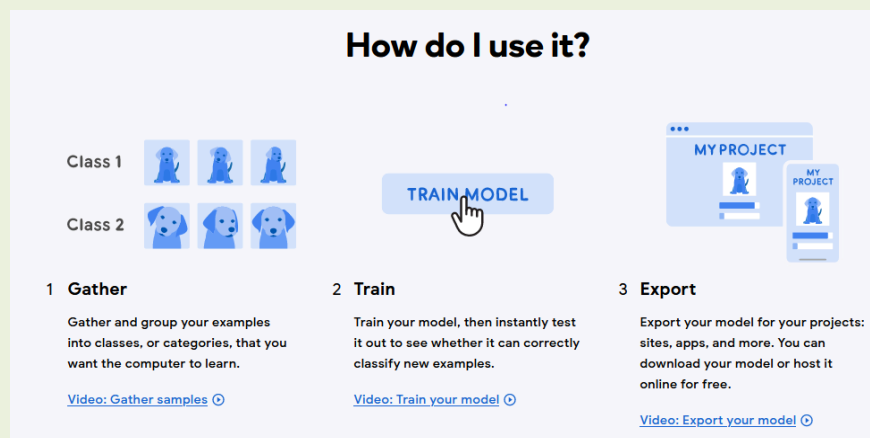
Was the data biased? How?

What was the consequence of the biased data? How effective was your machine at classifying cats? Classifying dogs?

What if this was used in a product that scanned your pets' faces to let them in the house? What would happen to the dogs?

What if this was used in a product to scan human faces and it didn't recognize some of the faces because the dataset was biased? What do you imagine the training dataset would look like? What would be the consequences of a biased dataset in this case?

Figure 9: Homepage of Google's Teachable Machine (Image by Google).



Activity Punchline

Google's Teachable Machine is a classifier, which uses the webcam of your computer to identify images, sounds, or movements. The way the machine classifies images, sounds, or movements is dependent on the training data that is being used and this helps determine the effectiveness of the algorithm. If the training data is biased, which in this

	case it was because there were more images of cats than dogs, this will affect whether the machine makes an accurate prediction for different groups.
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Youth Design

During the *Youth Design phase*, the objectives include: provide learners with the tools they need to design their own teachable machine; guide learners in understanding algorithm bias; support learners as they design and build their own teachable machines and train their own robots; and support youth choice in their two designed products. In this phase, youth are encouraged to take a hands-on approach to incorporating all that they learned during the activities and discussions up to this point. Activities include: (1) *Build Your Own Teachable Machine*; (2) *Superhero Robots*; and (3) *Tiny:bit Robots*.

Activity Six: *Build Your Own Teachable Machine*

In this activity, youth create their own machine that recognizes images, poses, or sounds using [Google's Teachable Machine](#). Youth train their machines using items or images that they choose. They also test their peers' machines for functionality and bias.

This activity was adapted from [MIT's AI Ethics Education Curriculum](#).

Keys words: machine learning, testing data, training data, differences, input, output, instructions

Learning Objectives

- Find and use data sets of pictures to train image classifiers.
- Identify potential biases in training datasets.
- Minimize potential biases by altering training datasets.
- Explain how the composition of training data affects the outcome of a supervised machine learning system.

Time Required: 40-60 minutes depending on length of discussion.

Materials/Resources Needed:

- Computers, laptops, iPads, or Chromebooks
- Internet source: Teachable Machine: <https://www.teachablemachine.withgoogle.com/>
- Items or images youth want to use to train and test their teachable machine

Introduce Activity:	Introduce the activity.
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	Youth work in pairs or individually.
<i>Build Your Own Teachable Machine</i>	Prompt: Last time we played with Teachable Machine and saw how the machine was trained with Cat and Dog images and then tested to see what it guessed right. Today, we are going to design our own teachable machine. Steps: • It is suggested that you create your own teachable machine in order to show your learners how to create a teachable machine (model the creative/design process). • You can choose to give prizes if your learners are motivated by competition. For instance: (1) the most creative and fun machine; 2) the machine that works the best/most functional; and 3) best effort. • Youth build their own teachable machine using Google's Teachable Machine. Youth choose the items or images they want to use to test and train their machine. • After creating their own teachable machines, learners then help their peers by testing each other's machines and checking for functionality and algorithmic bias. • Group discussion about how the amount and type of data training data affects how successful their machines are at predicting/classifying. • Youth then present and demo their teachable machine. • Depending on your group of learners, this might be a good opportunity to invite parents and community members to see the youth's designs.
Activity Punchline	Machine learning involves using training data to help a machine learn how to classify certain items, sounds, or images. Whether or not your machine is able to classify new examples depends on the type and amount of training data you use.

Activity Seven: Coded Bias and Superhero Robots

In this activity, youth further learn what bias is and how some image/facial recognition technologies / AI technologies are biased. Youth make a proposal for how a robot can be trained to complete a task and help people (i.e. SuperHero Robots)

Keys words: algorithms, opinions, differences, input, output, instructions, artificial intelligence (AI), bias, facial recognition

Learning Objectives

- Design a superhero robot
- Explain how the composition of training data affects the outcome of a supervised machine learning system.
- Share personal beliefs about technology, algorithms, and AI. Identify harmful and helpful examples of technology.
- Discuss ethical dilemmas surrounding technology and algorithms in the real world.
- Discuss algorithmic bias issues and solutions that are of interest and of importance to them and their communities.

Time Required: 40-60 minutes depending on length of discussions.

Materials/Resources Needed:

- Projector and 1 computer
- Paper
- Markers or crayons
- Internet Source: *Coded Bias* Trailer: <https://www.youtube.com/watch?v=jZl55PsfZJQ>

Introduce Activity

Introduce the activity.

Coded Bias and Superhero Robots

There are two activities on this day: ***Coded Bias*** and ***Superhero Robots***

- **Coded Bias**

This activity focuses on [bias](#) and how some [facial recognition technologies](#) are biased. It involves critical reflection.

Steps for Coded Bias Activity:

- Group Discussion:

Youth engage in discussions about bias.

What is bias?

[Bias](#): opinions, assumptions, prejudices that can

be harmful and unfair to others.

What is an example of bias or prejudice?

- Youth watch the [Coded Bias](#) film trailer (Kantayya, 2020), which features Joy Buolamini's realization of racist facial recognition technologies (Metz, 2021).

We will watch a movie trailer from Netflix about facial recognition software and how they can have bias in them and exclude people or be unfair to people.

- Group Discussion and Critical Reflection
 - Youth engage in discussion about the film.
 - **IMPORTANT NOTE:** This film and film trailer reference issues of racism, sexism, classism. These discussions will bring up topics around privilege, slavery, historic and current oppression of people of color, and White Supremacy. The instructors' racial/gender/class identities and the subsequent identities of the learners will impact and shape the discussion. For more information on engaging these ideas with elementary or middle school level learners, please refer to [Hollingworth, 2009](#), [Bolgatz, 2005](#), and [Classroom Discussions on Race: Hear What 5 Black Students Say They Need, 2020](#).

Prompting Questions:

What was interesting in this video?

Have you had experiences like this or heard about this happening?

Who was being mistreated in this video and how?

Who was creating the technology that was harmful?

Who should be held responsible? What should be done?

Can you relate to Joy in the video?

Did you write about any of this on day 1 with harmful technologies?

Do you see any issues like this in your community?

- Discussion requires youth to think critically about racial discrimination embedded in machine learning technologies, such as facial recognition.

- **Superhero Robots**

After thinking critically about such harmful technologies, youth are asked to create narrative stories about robots who can be helpful to people.

Steps for the Superhero Robot Activity

- Youth are provided blank sheets of paper on which they can draw and write. Giant Post-it notes can be used also. This allows all of the learners to see each other's designs during discussion
- Youth are asked to think of a technology that could change the world or provide good to other people. The fun part is that youth are encouraged to think of a technology that might not exist yet! And youth are told that it doesn't matter if they have no knowledge or understanding of how it might work. For examples of Superhero Robot drawings, see **Figure 10**.
- Learners individually draw a robot/machine that does something/performs a task, which they think is important and can change the world
- Learners then create a narrative about their robot's "super powers"
- Group Discussion:
 - Learners present their Superhero Robots to the group

Prompting Questions:

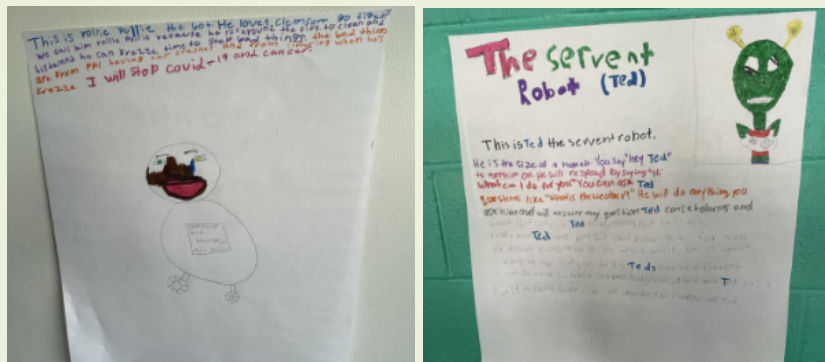
What does your robot do?

What is your robot's super power?

Who does your robot help?

Why did you decide to design this robot?

Figure 10: Examples of youth artifacts created during the Superhero Robot Activity



Activity Punchline

Bias can exist in many machine learning applications that you and other people use everyday. These technologies can be very harmful to people who are not included or considered by the people who are making them. But there are ways that people, such as you, can design technologies that are helpful and minimize harm. The robots that you designed might not exist yet, but we need to consider how we might need to design the algorithm that helps your machine learn in order to attempt to make it less biased and more equitable.

Activity Eight: Building a Superhero Robot

In this activity, youth use machine learning block-based programming to train a robot. For their final design, youth experiment with tiny:bit robots using block-based programming software from [MIT's How to Train your Robot Curriculum](#).

Keys words: algorithms, block-based programming, differences, input, instructions, machine learning, opinions output, robot

Learning Objectives

- Train simple machines and robots to classify images.
- Find and use training data to train a classifier.
- Program a robot using a combination of classifiers and block-based programming.
- Design and build robots that could solve real-world problems.

Time Required: 40-60 minutes depending on length of discussion.

Materials/Resources Needed:

- Computers, laptops, iPads, or Chromebooks
- Internet source: <https://mitmedialab.github.io/prg-extension-boilerplate/http/>
- [tinybit robot](#) sold by Yahboom
- [BBC Micro:bit](#)

Optional Resources:

- [MIT and I2 Learning How to Train Your Robot Programming Guide](#)
- [MIT and I2 Learning How to Train Your Robot Educator Guide](#)

Introduce Activity:	Introduce the activity.
<i>Tiny:bit Robots</i>	In this activity, youth use machine learning block-based programming to train a robot. Steps: • Do demo of teachable machine face/no face model with the tiny:bit robot. Download the model and upload into the Block-Based

	programming interface. You must pair the robot to the computer using a Bluetooth connection. Using the webcam, the model will detect whether there is a face present or not a face present. If there is a face detected, the robot will turn its headlight color to cyan. If there is not face detected, the robot will turn its headlight color to red. - Youth work on their robots and receive assistance as needed. It is important that youth use the Machine Learning blocks which are the Teachable Machine or Text Classification categories of blocks. - Emphasize the difference between a programmed algorithm that does the same thing every time and a trained machine learning program that takes input from the real world and can be unpredictable! - Group Discussion: - Youth demo their robots to the group. - Youth engage in group discussion with regards to what went right and what went wrong and why. <i>What did you train your robot to do?</i> <i>Who does your robot help?</i> <i>How close is your actual robot to your superhero design ideas?</i> <i>How does your robot interact with the real world?</i> <i>Is it doing what you wanted it to do?</i> <i>If you could continue building, what would you do next?</i> <i>How did you consider bias in your training data?</i>
Activity Punchline	<i>You have the ability to design and build robots that use machine learning that are helpful for people. As you grow and learn, it is important to think about who designs technologies and for what reasons. Sometimes people design technologies but do not think carefully about who might be excluded or even harmed. But if more people thought carefully about these questions, just like you did, we can make and design technologies that are more helpful than harmful.</i>

KEY WORDS AND DEFINITIONS

Words	Definition as used in this program guide
Algorithm:	A set of steps or rules to follow in order to solve a problem or accomplish a specific goal.
Algorithmic Bias:	Errors in algorithms, often caused by skewed data sets, that create unfair outcomes, such as privileging one arbitrary group of users over others, or discriminating against particular groups.
Artificial Intelligence (AI):	A program made by people that makes computers do things that seem intelligent (or smart) in the same way that humans are intelligent.
Bias:	Opinions, assumptions, or prejudices that may be harmful and unfair to others.
Block-Based Programming	A type of programming language where instructions are mainly represented as blocks (drag and drop learning environment).
Classification	Classification is a task that requires the use of machine learning algorithms that learn how to assign a class label to examples. For example, email can be classified as “spam” or “not spam.” So, a machine is able to classify a data set into categories. It is basically a form of pattern recognition.
Dataset:	A collection of inputs, outputs, or both. We can use these collections to train a system to detect patterns.
Discrimination:	Treating one group of people differently than another group in an unfair way.
Ethics:	Moral guidelines for how people in society should behave if they want to be fair.
Input:	Something that goes into an algorithm, often some kind of data.
Machine Learning:	A form of AI that makes predictions from data. Humans provide the initial data to the machine and allow the machine to learn from that dataset.
Output:	What comes out of an algorithm, the end result.
Participatory design:	In participatory design (PD), all stakeholders co-design learning experiences that take into account ethical, social, and political factors while also exploring relational dynamics that shape processes of partnering and learning.

Programming:	The process or activity of writing computer programs to the end of getting a particular result or achieving a task.
Robots:	Machines that sense their environment, do calculations of some kind, and then perform an action.
Software Application:	A software that employs the capabilities of a computer/machine to accomplish a dedicated task.
Speech Recognition:	The process of taking a voice recording, analyzing its audio spectrum, and translating it into text.
Supervised Machine Learning:	This is a type of machine learning that uses available training data to get feedback on its performance as it learns. It is “supervised” because there is a desired output and the programmer can supervise the process to adjust the training to obtain the desired outcome.
Technology:	Skills and tools that people use to achieve goals, often to make life easier.
Testing Set:	A collection of inputs given to machine learning algorithms to measure their accuracy.
Training Set:	A collection of inputs and outputs given to machine learning algorithms to have them learn from patterns in data.

RESOURCES

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ADDITIONAL RESOURCES

Appendix A

Algorithms and Machine Learning Drawing Worksheet

Name: _____

Instructions

Complete these drawings the best that you can. There are no wrong answers! If you are unsure, draw whatever comes to mind.

Drawings

An **Algorithm** is a set of instructions designed to perform a specific task.
Draw a picture that shows a **Computer Algorithm**.

Machine Learning is using algorithms and examples to teach a computer to complete a task.
Draw a picture that shows an example of **Machine Learning** with computers.

Appendix B

Google Search Worksheet

Name:		
What do you think you will see if you did a GOOGLE IMAGE SEARCH for “Teacher”?		
Now, type in “__ Professor _____” into Google Search		
What did your search show you?		
Was it what you expected to see?		
Why do you think it happened?		
1	Are there enough images of people like you?	Yes / No / Maybe
2	Does that matter to you?	Yes / No / Maybe
3	Does this Google Search harm you or others you care about?	Yes / No / Maybe
	Explain:	

Now search for anything you want!

I searched for: _____
What do you think you will see?
What did your search show you?

Was it what you expected to see?		
Why do you think it happened?		
1	Are there enough images of people like you?	Yes / No / Maybe
2	Does that matter to you?	Yes / No / Maybe
3	Does this Google Search harm you or others you care about?	Yes / No / Maybe
	Explain:	

Appendix C

Google's "Quick, Draw!" Worksheet

Go to <https://quickdraw.withgoogle.com/>

Click on Let's Draw to get started

What are three things that you drew that the machine guessed correctly?

- 1.
- 2.
- 3.

What did the machine get wrong?

Will this machine work for everyone? Give an example of how someone might draw something differently that the machine doesn't recognize.

Appendix D

Cat/Dog Worksheet: Google's Teachable Machine

Go to Google's Teachable Machine: <https://teachablemachine.withgoogle.com/train/image> to make one.

- 1) Change CLASS 1 to DOG.
- 2) Change CLASS 2 to CAT.
- 3) Use your webcam and the "TRAINING SET" images to add samples to your machine.
- 4) Click Train Model when you are done adding all the samples.
- 5) Test your model out using the "TESTING SET" images and fill out the table below.

Image	Did the Machine think it was a CAT or a DOG? (circle one)	Was the Machine correct? (circle one)	Machines's Confidence Score (%)
	CAT DOG	YES NO	
	CAT DOG	YES NO	
	CAT DOG	YES NO	
	CAT DOG	YES NO	

	CAT DOG	YES NO	
	CAT DOG	YES NO	
	CAT DOG	YES NO	

What did your machine work better on? (circle one)

CATS

DOGS

Why do you think that is? (Look back at your training data to answer this question)

Appendix E

Examples of Artificial Intelligence

Google Doodle of Johann Sebastian Bach:

<https://www.google.com/url?q=https://www.google.com/doodles/celebrating-johann-sebastian-bach&sa=D&ust=1565097339237000&usg=AFQjCNHm3RJGyUcCU-aMSf-eDkTw88fSMA>

Example of robot dog:

<https://www.youtube.com/watch?v=sJciRIZQTg4>

Example of self-driving car:

<https://www.youtube.com/watch?v=uHbMt6WDhQ8>

Example of AI learning to play games:

<https://www.youtube.com/watch?v=kopoLzvH5jY>

Explanation of Go playing AI:

<https://www.youtube.com/watch?v=PUaCQUal7rM>