BRIGHT-CS

LEARNING THE ROPES

Machine Learning Project | Grade 6 | 2 – 3 Weeks

PROJECT OVERVIEW

FINAL PRODUCT
Students will collect data to train a machine learning tool and present their findings about the precision and recall of the resulting model.

TIMEFRAME
2-3 weeks

AGE GROUP
Grades 6

DRIVING QUESTION
"What is Google's Teachable Machine and how can I unlock its power?"

PROJECT DESCRIPTION
Why "Learning the Ropes"?

Computer Science (CS) isn't just about "coding." Increasingly, computer research scientists are using data to "teach" artificial intelligence tools, resulting in machine-made models that influence everything from the ads we see to the results popping up in our search engines. Google's Teachable Machine is a fun and accessible way for young people to learn about this important aspect of CS--and how they, as computer research scientists, can use AI to make the world a better, less biased place.

HOW DOES THIS PROJECT DEVELOP INDEPENDENT LEARNERS IN STEM+CS?

All learners depend on adults at first. To persist in STEM+CS, they must "learn how to learn." Experiences that develop the habits of mind needed to take charge of one's own learning are less often provided to culturally and linguistically diverse students (Hammond, 2015). This project helps educators put all students on-course to becoming independent learners in STEM+CS.

LEADS TO A MEANINGFUL PRODUCT

The first step to independence is engagement. Disconnected exercises that don't culminate in a real-life product are less likely to inspire thoughtful participation than lessons where students apply knowledge and skills to make something meaningful. The more likely they are to use the final product in their own lives, the more motivated they'll be to finish--and they'll end up with authentic proof that "I can" do computer science. The resulting sense of efficacy can inspire even more engagement.

ALLOWS FOR PRODUCTIVE STRUGGLE

Independent learners have developed strategies for tackling new challenges (Hammond, 2015). How? They tell us that in STEM+CS, the process of trial and error is key (Yamaguchi et al., 2021a). Unlike mindless application of teacher procedures, struggling to figure out mistakes ("bugs") or make improvements themselves helps them not only see what strategies work, but really understand why. Of course, productive struggle takes time. A good project is paced to include multiple chances to make, reflect on, and resolve errors--from prototyping and debugging, to user-testing one's product and iterating, to practicing and honing a final presentation.

HELPS EDUCATORS CREATE CONDITIONS FOR SUCCESS

Struggling with challenges on its own is not enough to produce learning. Dependent learners are prone to drop back and let peers take over; even independent learners may shy from making valuable errors when others are watching (Yamaguchi et al., 2021a & 2021b). Educators create the conditions for success by providing the right inputs, feedback, and encouragement to help students embrace difficulties and break through. From building positive attitudes about mistakes, to empowering students get *themselves* unstuck, the "teaching tips" in this document help set up learners for mastering challenging tasks--the experience likeliest to make an impact on their future independence.

PROJECT PATH AND MILESTONES

The Learning the Ropes project begins with a launch and ends when students formally reflect on their experience after presenting their final products. A bird's eye view of the project's path and milestones is provided below and visually summarizes how students will navigate from start to finish. A more in-depth presentation of student tasks follows on the next page.

LAUNCH

1. Student is introduced to the project, presented with the driving question, introduced to a research question guide, and invited to start generating their own set of need to know questions (NTKs).

BUILD KNOWLEDGE

2. Student addresses the question guide and discusses their preliminary findings with the class.

3. Student gets a more in-depth understanding of both Machine Learning (ML) and Google's Teachable Machine, gets in a team, and collectively develops a plan for Google's Teachable Machine.

DEVELOP AND CRITIQUE

4. Student teams execute their Teachable Machine plan, train it on data of their choice, and document their experience. Teams then make plans for a future project and begin drafting their presentations.

PRESENT

5. Student teams share what they've learned about Artificial Intelligence (AI), ML, and the Teachable Machine along with their results to visitors.

PROJECT MILESTONES AND STEPPING STONES

Milestone #1: Student is introduced to the project, presented with the driving question, introduced to a research question guide, and invited to start generating their own set of need to know questions (NTKs).

ENTRY EVENT	PREVIEW THE PROJECT	EXPLORE THE DRIVING QUESTION
Student gets a brief introduction to Artificial Intelligence (AI), Machine Learning (ML), and an understanding of how ML impacts their daily lives.	Student is introduced to expectations for the final product: exploring key concepts in ML, training an ML tool, and presenting their findings.	Student explores the question, “What is Google’s Teachable Machine and how can I unlock its power?”, is given a research question guide, and is prompted to develop NTKs of their own.

Milestone #2: Student addresses the question guide and discusses their preliminary findings with the class.

CONDUCT RESEARCH ON BASIC ML CONCEPTS	DISCUSS RESEARCH FINDINGS
Student begins conducting AI/ML research by leveraging articles, videos and tutorials found on the web to answer a set of foundational research questions. Student will begin to log their NTKs as they materialize.	Student will participate in a group discussion in which they share the answers to the research questions and the additional NTKs they generated.

Milestone #3: Student gets a more in-depth understanding of both ML and Google’s Teachable Machine, gets in a team, and collectively develops a plan for Google’s Teachable Machine.

TEACHABLE MACHINE OVERVIEW	TEACHABLE MACHINE PLAN DEVELOPMENT
Students dive into the Teachable Machine by completing sample tasks.	Students get into teams and begin identifying their plan for exploring the Teachable Machine.

Milestone #4: Student teams execute their Teachable Machine plan, train it on data of their choice, and document their experience. Teams then make plans for a future project and begin drafting their presentations.

TRAIN THE MACHINE	EVALUATE THE RESULTING MODEL	FUTURE WORK
Student teams work together to gather the necessary data and train the Teachable Machine.	Student teams test the Teachable Machine and analyze the precision and recall of the resulting model.	Student teams will collaboratively develop a plan for working with the Teachable Machine in the future.

Milestone #5: Student teams present what they’ve learned about AI, ML, and the Teachable Machine to visitors; they close the project by reflecting on their experience.

PREPARE	PRESENT	REFLECT
Student teams draft their presentations and practice in front of other teams.	Student teams present their process and results to a set of visitors either virtually or in person.	Student and teacher reflect on the research questions, NTKs, and students’ perspective of what they learned in this process.

- **LAUNCH** – introduce students to the project and get them excited about it.
- **BUILD KNOWLEDGE** – provide the baseline knowledge, activate the baseline skill necessary to complete the project, and allow students to build their plan.
- **DEVELOP AND CRITIQUE** – allow students to implement their plan and provide opportunities for them to receive feedback from their peers.
- **PRESENT** – allow students to develop and deliver presentations for an audience outside of their teacher/peers.

GETTING STARTED

Where

This project is appropriate for any setting, from a core STEM class, to an elective course in computing, to a homeroom, extracurricular club, or camp. Educators do not need to be experts in computing to lead it. All of the content knowledge and skills necessary to complete the project are outlined in linked PowerPoint presentations and other resources that are freely available on the web. We do, however, recommend that educators take time to familiarize themselves with these resources, and even attempt to complete the project on their own first. The experience of creating one's own computing product can provide valuable insight for supporting students through the process.

Who

Student recruitment is an important consideration for educators seeking to engage diverse students in this project, particularly when planning to teach it as part of an elective course, club, camp, or other setting outside a core STEM class. Relying on interested students to identify themselves may result in missing out on some who could develop an interest if only for the right kinds of outreach. Effective recruitment methods include: 1) asking influential adults (such as parents of, and school staff popular among, culturally and linguistically diverse students) to personally invite students to participate; 2) organizing recruitment sessions to show students a finished exemplar of the final product they will create; and 3) asking attendees to bring a friend to the sessions with them.

It's also worth considering how to ensure a diversity of prior CS skills and experiences among your students. Research suggests that among culturally and linguistically diverse students, both dependent and independent learners find it helpful to work with like peers at different levels of skill (Yamaguchi et al., 2021b). That's because peers with more skill allow students to seek support and experience perspectives on the material beyond what their teacher can provide alone; peers with less skill offer students the opportunity to build confidence by explaining the material to others. Since there may be few culturally/linguistically diverse students in any given grade level, and particularly few diverse students of the same gender, it could be worth recruiting across different grade levels--even different schools--to create a cohort where diverse students can find a number of peers like them who also bring different skills and experiences to the table.

When and What

After recruiting a cohort of diverse students, survey them to see which potential meeting times work best (assuming you are teaching the project as part of an extracurricular club or camp). Then secure the necessary hardware. While all of the software recommended for this project is freely available on the web, students will need access to individual, internet-enabled devices (preferably laptops) during each session of the class, club, or camp. Consider what existing devices may already be available to students, whether through school issue, computer labs, local public libraries, or other facilities.

END STATE

More than completing a final product, this project is about helping students develop the academic, cognitive, and social-emotional tools they need to take charge of and propel their own learning in STEM+CS. But what does that really look like? How can you tell which students haven't yet had experiences to develop those tools, in order to better support them? And what does it look like when you've done your job to coach them towards greater independence?

BASED ON RESEARCH (Hammond, 2015; Yamaguchi et al., 2021a):

Dependent learners...		**Independent learners...**
• **Often think mastery means being able to name and remember procedures for completing a task** (i.e., rote learning) • **May engage when asked to reproduce teacher-modeled skills/knowledge with minimal cognitive effort** (e.g., answering simple recall questions, copying a teacher's steps) • **Stop engaging when challenged to "figure out" new content themselves** Zaretta Hammond (2015) calls this "depend[ing] on the teacher to carry most of the cognitive load of a task."	***Acquiring new skills and knowledge***	• **Usually appreciate that mastery means knowing *why or how* "it works"** (i.e., conceptual understanding) • **Often prefer to jump in and "figure out" new skills/knowledge after minimal instruction** (e.g., through trial and error). Hammond (2015) calls this "rel[ying] on teacher to carry some of the cognitive load temporarily."
• **Tend to engage less on aspects of their project that challenge them to develop new skills in STEM+CS** (e.g., coding) **than in aspects where they already have skill** (e.g., visual presentation) • **When working in groups, sometimes avoid performing tasks requiring new STEM+CS skills**, allowing others to carry the cognitive load • **Sometimes declare their work "finished" before it reaches their original goal**, when further improvements would require pursuing skills or knowledge beyond those provided by teacher	***Managing independent work time***	• **Tend to spend more time on aspects of their project that require new skills in STEM+CS** • **Are likelier to continue working on their products when there are still improvements to be made,** even if those improvements require pursuing skills or knowledge beyond those provided by teacher
• **When running into challenges in their work, are more likely to get "unstuck" by receiving help from a teacher** than to use any other strategies	***Getting "unstuck"***	• **Are less likely than dependent learners to ask their teacher for help and more likely to try other strategies for getting "unstuck,"** such as creating a plan of attack, rereading materials provided, conducting their own research, tackling easy parts first, or using trial and error

MILESTONE #1: LAUNCHING INQUIRY

This milestone is designed to fuel the interests, excitement, and creative curiosities of students and provide the support they need to be ready for and invested in the process ahead of them. Specifically in Milestone #1, students begin having foundational discussions and participating in activities that will set them on a path to answer the driving question:

"What is Google's Teachable Machine and how can I unlock its power?"

Milestone #1 ignites an inquiry cycle that will ultimately be shaped by a set of research questions as well as students' own creative curiosities. The research questions will help students establish foundational knowledge about Artificial Intelligence (AI) and Machine Learning (ML); students' creative curiosities will help them to develop a list of Need to Know (NTKs) questions driven by the experience and knowledge gaps they identify during the research process. Since NTKs can help students be more mindful about the inquiry cycle, it is important to encourage this process and help students to see the value in it. In all, it is important to strategically and deliberately create a learning environment that is a safe and supportive space for students to tap into and explore their curiosity. For this project, Learning the Ropes, the research questions focus on foundational definitions, capabilities of computers in comparison to the human brain, and fairness in ML (among other things). Although you may be able to leverage the research questions to predict a large majority of NTKs in advance, students will likely venture into unanticipated territory, generating questions that are unique, unexpected, and novel. Helping students value this creative curiosity and understand how to channel it would be a significant outcome of this project.

LAUNCH

1

Student is introduced to the project, presented with the driving question, introduced to a research question guide, and invited to start generating their own set of need to know questions (NTKs).

STEPPING STONES

ENTRY EVENT

Student gets a brief introduction to artificial intelligence (AI), machine learning (ML), and an understanding of how ML impacts their daily lives.

PREVIEW THE PROJECT

Student is introduced to expectations for the final product: exploring key concepts in ML, training an ML tool, and presenting their findings.

THE DRIVING QUESTION

Student explores the question, "What is Google's Teachable Machine and how can I unlock its power?", is given a research question guide, and is prompted to develop NTKs of their own.

RESOURCES

PROJECT SUPPORT

- Slide Deck: Milestone 1

ARTICLES

- How I explained ML to a 6th grader
- Deep-Learning As Explained To A 6th Grader
- Introduction to Machine Learning
- AI 4 All
- Black in AI

VIDEOS

- Machine Learning & Artificial Intelligence: Crash Course Computer Science
- Google's Teachable Machine

ACTIVITIES

- Research Question Guide
- Student Planning Sheet
- Project Rubric
- Know-Need To Know Chart
- Jot thoughts

DESIGNING AND EXECUTING THE LAUNCH

Designed and executed carefully, Milestone #1 provides an opportunity to pique students' curiosity, encourage discussion, and help participants start building confidence that they are capable of success in open-ended problem solving in general and AI/ML in particular. The accompanying slide deck provides one way to execute the launch; the text below provides more context about what each component of the launch is to accomplish. In general, the key is to introduce and emphasize the decision-making, planning, and end-product development process in an engaging way. The remainder of this document provides more detailed insight into the launch components, desired outcomes, and insight into how you might implement each *component* to achieve critical *outcomes*.

ENTRY EVENT

From a high-level perspective, the entry event should capture students' interest and light a match that will spark excitement.

PREVIEW THE PROJECT

By previewing the project, students should be able to get a vision for the end-state and gain awareness of expectations.

THE DRIVING QUESTION

Students should begin exploring the driving question during the launch by taking inventory of what they know.

THE RESEARCH GUIDE

A critical goal of the Learning the Ropes project is to strengthen students' ability to independently conduct research and share their results. Very early on in this project, that means starting with a question, gathering information from multiple sources, integrating the information gathered into one coherent thought, and ultimately communicating findings with colleagues. To promote that process, a Research Question Guide was developed that includes questions relating to foundational definitions, humans vs. machines, machine learning concepts, fairness/bias in machine learning, and Google's Teachable Machine. If carried out as expected, completion of the research guide will help students build key insight, pool knowledge, and generate new Need to Know (NTK) questions. The list of questions in the research guide are listed below.

FEATURED QUESTIONS

- What is artificial intelligence (AI)?
- What is machine learning?
- What are some examples of machine learning and artificial intelligence in everyday life?
- How do human brains compare to computers?
- What is an algorithm?
- What is a black box (in software engineering)?
- What is bias (in general)?
- Considering your definitions of bias and machine learning, how might bias affect machine learning?
- Who is Timnit Gebru and what is her relationship to fairness/bias in artificial intelligence?
- What is Google's Teachable Machine and what can it do?

SAMPLE LAUNCH: STUDENT VIEW

LESSON LAUNCH

THE ENTRY EVENT

Artificial Intelligence (AI) and Machine Learning (ML) have permeated just about every aspect of our daily lives. ML, in particular, guides everything from spam filters to medical diagnoses; having a working knowledge of what it is and how it can be affected by bias is extremely important, especially for culturally and linguistically diverse students.

This entry event is designed to help you learn more about AI and ML by starting the conversation about what they are and making you more aware about how you have interacted with each in the past.

Quick Tip!

From the start of your first lesson, students will begin assessing their interest level in what you'll teach and the work you'll ask them to do. This often influences how much effort they put in later, or even--if the experience is optional (as with an afterschool or summer program)--whether they return for the next session. So it's important to consider how you'll ensure that students leave Milestone 1 excited to come back and roll up their sleeves.

INVESTIGATE

PREVIEW PROJECT EXPECTATIONS

In this project, you will do research into basic AI/ML and apply ML concepts via Google's Teachable Machine. In particular, you will train the teachable machine on a set of data of your choosing and, ultimately, present both your research experience and findings.

The final product will be a discussion of your (1) answers to the basic research questions, (2) approach with the Teachable Machine, (3) and a presentation that captures both. The audience for the final presentation will be a group of visitors. However, you will present to your peers in the interim to get practice and feedback.

You can access the specifications and expectations for the project (via the **Student Planning Sheet** and **the Rubric**) now and you are encouraged to leverage each in understanding how to define, plan for, and achieve success in the project.

Build interest in the final product

The more meaningful the final product to students, the more likely they are to stay engaged. For both dependent *and* independent learners, a meaningful product is one that feels relevant to their lives. Do they have a personal use for it? As early as possible, make sure not only that students are clear on what their final product could look like but also that they've begun to imagine how the product could be useful to them right here where they live, right now at this age.

INVESTIGATE (CONT'D)

EXPLORING THE DRIVING QUESTION

Navigate to the Teachable Machine's home page and get a sneak peek of it by completing a quick **three-minute** review:

https://teachablemachine.withgoogle.com/

More specifically, after you navigate to the URL listed above, take about three minutes to learn as much as you can about the Teachable Machine, jot down your initial thoughts, and then brainstorm ideas for what you would like to do with it in this project.

EXPLORING THE RESEARCH GUIDE AND INITIATING THE NEED TO KNOW PROCESS

This project features a self-guided research component that will help you seek out answers to foundational questions about AI and ML. The driving goal is for you to get acquainted with the research process and to convene later in the project to share your answers.

To make the most out of this experience, you should keep track of any questions that arise as you navigate the research process and keep a log of them as Need to Know (NTKs) questions. When you have extra time, you should explore the answers to your NTKs but, at the very least, revisit them in their own time.

SYNTHESIZE AND REFLECT

CLOSING THE LAUNCH

The skills exercised in this project, including conducting research and applying a tool to explore a new concept, are all very valuable in the real world. To close the launch, let your instructor know if you have any questions about how to move forward! Enjoy the experience!

MILESTONE #2: SELF-GUIDED RESEARCH AND GROUP DISCUSSION

This milestone immerses students in a self-guided research process that will help them to get more acquainted with foundational AI/ML concepts and get a little more exposure with a tool that applies AI/ML in real time, Google's Teachable Machine. Overall, this milestone is designed to stoke AI/ML interest for students, help them build/exercise important research skills, and help them get just a little more acclimated to the Teachable Machine. These steps will allow them to establish key knowledge and skills that will be helpful throughout the rest of the project.

BUILD KNOWLEDGE

2 Student addresses the question guide and discusses their preliminary findings with the class.

3 Student gets a more in-depth understanding of both ML and Google's Teachable Machine, gets in a team, and collectively develops a plan for Google's Teachable Machine.

STEPPING STONES

CONDUCT RESEARCH ON BASIC AI/ML CONCEPTS

Student begins conducting AI/ML research by leveraging web searches to answer a set of foundational research questions. Student will also begin/continue to log their NTKs as they materialize and learn about career opportunities for Computer and Information Research Scientists.

DISCUSS RESEARCH FINDINGS

Student will participate in a group discussion in which they share the answers to the research questions and the additional NTKs they generated.

RESOURCES

PROJECT SUPPORT

- Slides: What is AI/ML?
- Slides: Let's Discuss Research Results!

ARTICLES

[Listed at the end]

VIDEOS

- Fairness in Machine Learning
- Machine Learning and Human Bias
- Top 10 Applications of Machine Learning - 2021

ACTIVITIES

- A-CLAP
- K.I.M.S.
- I Think/ We Think
- Jot Thoughts
- Generative Summarizing
- Reflection Organizer-Student Learning Activity
- Ask Your Authentic Guiding Questions
- Develop Critical Thinking Questions
- KWL Chart

STEPPING STONES TO RESEARCH AND GROUP DISCUSSION

Build students' muscle for independent research

Independent learners tell us that one strategy they use for tackling challenges in their work is to conduct research. But to track down the knowledge or skills they need, students must learn to articulate what their specific questions are (*What now?* doesn't count!), then practice searching out answers among the endless resources available online. Give students a chance to flex this muscle by offering the linked texts and videos as a starting place to explore their NTKs. Then, in the likely case they still have unanswered questions, encourage them to go further by asking their own questions to spur reasoning about what to do next (e.g., "What search terms might you try?"). This can produce greater independence in the long run than simply telling them what steps you'd take or, worse, what the answers are.

	1. CONDUCT RESEARCH ON BASIC ML CONCEPTS
Standards	CCSS.ELA-LITERACY.WHST.6-8.7; CCSS.ELA-LITERACY.SL.6.1.D; CCSS.ELA-LITERACY.L.6.4
Accompanying Slides	Slides: What is AI/ML?
Students will be able to....	• Answer foundational questions about AI and ML via web searches, citing their sources. • Generate a list of NTKs as they conduct research.
Ideas for activities	• Help students get acclimated to AI and ML by providing a baseline set of questions, (potentially) a set of key resources, and enough time to answer the questions. • Discuss how to cite sources found on the web. • Leverage the A-CLAP approach to analyzing information sources. • Have students keep track of new words and concepts they learn during this process for later reflection using the K.I.M.S. framework.
Reflection and Synthesis Prompts	• What aspects of artificial intelligence interest you? • What aspects of machine learning interest you? • What aspects of AI and/or ML were most surprising to you? • Are you interested in a career as a Computer Research Scientist?
Formative Assessment Ideas	• Invite students to explain what AI is in their own words. • Invite students to explain what ML is in their own words. • Choose any of the research questions in the set and ask students to explain the answer in their own words.
Suggestions for Feedback and Support	Have students discuss the new keywords, phrases, and ideas they've learned as a result of this module leveraging the K.I.M.S. framework and help them to identify instances where they may need to conduct further research.

STEPPING STONES TO RESEARCH AND GROUP DISCUSSION

Sustain motivation by linking activities to the final product

Both dependent and independent learners can become disengaged or confused if assigned activities feel as though they lack purpose or don't clearly connect to a final product. Make sure to sustain the motivation engendered in Milestone 1 by asking students to consider ways the research they're doing now will help them complete the final product. As the research increases their understanding of machine learning concepts, they should be able to provide more specific answers to this question. If they struggle to make connections, use questions that bridge between the concepts they are researching and the task of training the Teachable Machine, like "Can a computer 'think'? … If a computer can't think, how does it 'learn'?" If you find that students are reluctant to answer in front of the whole group, build their confidence by having them discuss in pairs first, then share out what they discussed to the group afterwards.

	2. DISCUSS RESEARCH FINDINGS
Standards	CCSS.ELA-LITERACY.SL.6.1.A; CCSS.ELA-LITERACY.SL.6.1.B; CCSS.ELA-LITERACY.CCRA.SL.1
Accompanying Slides	Slides: Let's Discuss Research Results!
Students will be able to....	● Present their research findings in a group discussion. ● Share a list of NTKs generated as they conducted research. ● Increase their understanding of AI/ML by listening to their classmates' research findings.
Ideas for activities	● List all of the questions students addressed in the previous module and call on students to share their answers with the whole group leveraging the I Think/ We Think activity. ● Break students up into groups and ask them to share their answers with each other before having a larger group discussion using the Inverted Pyramid approach. ● **Note 1**: to ensure that students get the most out of this activity, challenge them to reference key terms at least once in their final presentations. ● **Note 2**: It may also be helpful to assign students to small, temporary groups and have each group attack one to two questions at most. Upon completion of the activity, the class can reconvene into a whole and the groups can present their findings.
Reflection and Synthesis Prompts	● Which of the questions in the research set would you like to explore more? ● Were you able to answer any of your NTKs as a result of your research?
Formative Assessment Ideas	Ask students to put their notes away, give them some subset of the research questions, and ask them to answer the questions based on their knowledge. Next, go over the answers together so that they can identify and fill any gaps in knowledge.
Suggestions for Feedback and Support	Leverage the KWL worksheet to further review what has been learned so far and figure out how it can be applied toward the project. Meet individually with students to review what they've written and help to fill in any blanks (or, at the very least, point them in the right direction).

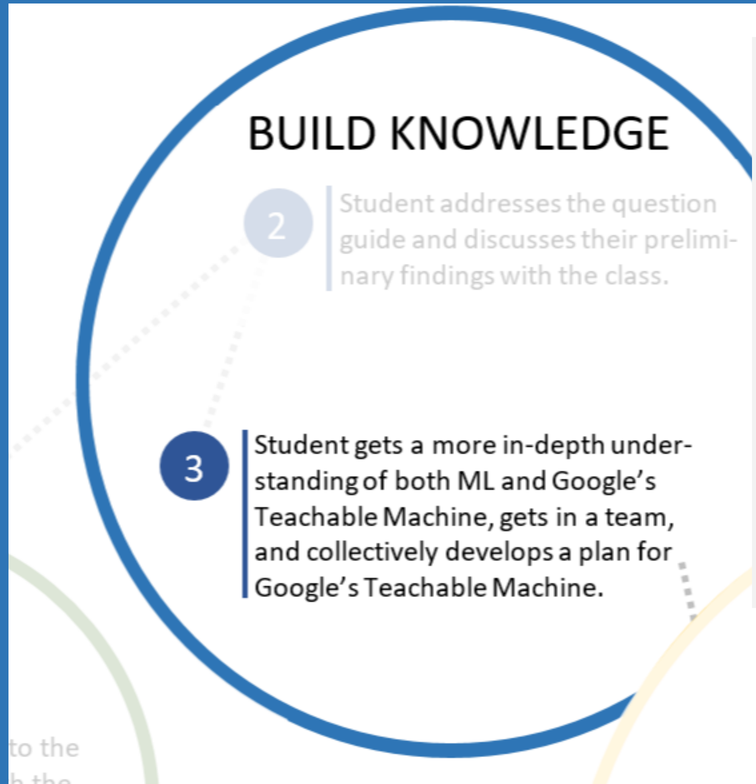
ADDITIONAL RESOURCES: ARTICLES

- Career Information: Computer and Information Research Scientists
- How does the Human Brain compare to a Computer
- The Human Brain Vs. Computers
- Computers Vs. Brains
- 7 Popular Applications of Machine Learning in Daily Life
- Machine Learning and Bias Concerns Weigh on Data Scientists
- Machine Learning and Bias
- 5 Types of Bias & How to Eliminate Them in Your Machine Learning Project
- AI / Machine Learning Bias Explained with Examples
- Bias in Machine Learning
- Unintended Bias in Machine Learning
- Algorithmic Bias Detection and Mitigation
- 5 Unexpected Sources of Bias in Artificial Intelligence
- Ethical AI: Real-World Examples of Bias and How to Combat It
- The Six Online Research Skills Your Students Need

MILESTONE #3: GOOGLE'S TEACHABLE MACHINE

This milestone gets students fully acclimated with the Teachable Machine and working in teams to draft their plan for training and evaluating the tool.

Given that the latter part of this milestone is done by a team, collaboration and ideation are inherent parts of this activity and will allow students to exercise and strengthen soft skills in the process.



STEPPING STONES

TEACHABLE MACHINE OVERVIEW

Students dive into the Teachable Machine by completing sample tasks.

TEACHABLE MACHINE PLAN DEVELOPMENT

Students get into teams and begin identifying their plan for exploring the Teachable Machine.

RESOURCES

PROJECT SUPPORT

- Slides: Teachable Machine Overview
- Slides: Teachable Machine Plan Development

ACTIVITIES

- Think-Pair-Share

ARTICLES

- Experiments with Google: Teachable Machine
- Train the Teachable Machine: Banana Ripeness
- Train the Teachable Machine: Head Tilt
- Train the Teachable Machine: Snap, Claps, and Whistles
- Teachable Machine From Google Makes It Easy To Train And Deploy ML Models
- Precision vs. Accuracy
- Precision vs. Accuracy
- Accuracy and Precision: They Mean Slightly Different Things
- Accuracy, Precision, Recall, or F1?

VIDEOS

- Google's Teachable Machine
- Teachable Machine Introduction

Set expectations for partner work

When partners bring different levels of independence to their work, it's common for more independent learners to take over the cognitive burden, while dependent learners sit back or focus on aspects of the project that don't require them to practice the new skills it seeks to teach. Now is the time not only to set expectations that partners share the work equally, with each student getting the chance to attempt new STEM skills individually--but also to emphasize why it's important. Use the Project Rubric provided in Milestone 1 to lead a class discussion where students develop "pair work norms" to ensure each partner gets to demonstrate all of the competencies outlined in the rubric.

	1. TEACHABLE MACHINE OVERVIEW
Standards	CCSS.ELA-LITERACY.WHST.6-8.7; CCSS.ELA-LITERACY.RST.6-8.3; CCSS.ELA-LITERACY.RST.6-8.7; CCSS.ELA-LITERACY.SL.6.1; CCSS.ELA-LITERACY.SL.6.2; CCSS.ELA-LITERACY.CCRA.W.7; CCSS.ELA-LITERACY.CCRA.W.8; CCSS.ELA-LITERACY.CCRA.W.9; MS-ETS1-1; MS-ETS1-2
Accompanying Slides	Slides: Teachable Machine Overview
Students will be able to....	Complete baseline tasks with Google's Teachable Machine and discuss foundational aspects of the technology based on the self-guided research they completed in Milestone #2.
Ideas for activities	● Play the Teachable Machine video for students and have a discussion afterwards, reminding them about their goals for the project. ● Revisit the link for the Teachable Machine and, as a group, complete tasks for training the machine on images, motions, and sounds. ● In advance, select sample data that students can use to complete tasks for each. This can help to make the session run smoother (and somewhat more predictably).
Reflection and Synthesis Prompts	● What ideas do you have about how to use the Teachable Machine? ● What AI/ML concepts (if any) do you understand better after working with the Teachable Machine?
Formative Assessment Ideas	Have students discuss a concept they learned in Milestone #2 in the context of the Teachable Machine.

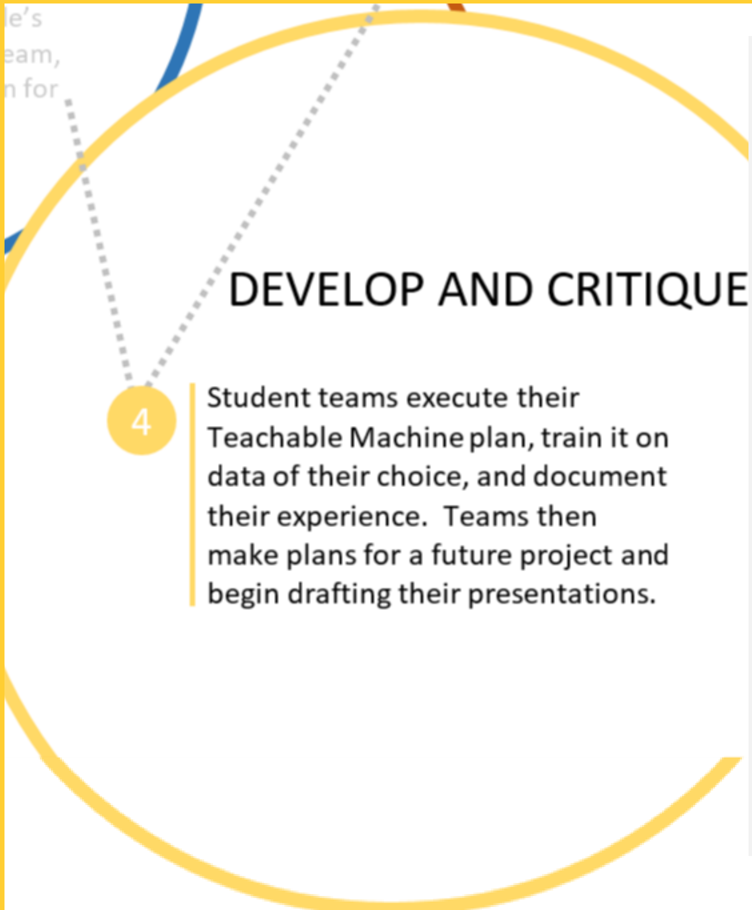
Resist carrying all of the cognitive burden for students

As educators, it's tempting to break new skills into steps we can model while students follow along. But this can lead students to reproduce our steps passively with little mental effort, limiting their understanding and eliminating a chance to develop habits of mind for tackling new challenges independently. Instead, explain precision and recall by calculating them for one of the Teachable Machine baseline tasks as students watch--without letting them copy you. Then set students loose in pairs to try calculating them for a different TM baseline task.

	2. TEACHABLE MACHINE PLAN DEVELOPMENT
Standards	MS-ETS1-3; MS-ETS1-4
Accompanying Slides	Slides: Teachable Machine Plan Development
Students will be able to....	Work with a partner to develop a plan for training and evaluating the Teachable Machine.
Ideas for activities	• Have students determine whether they want to train the machine on images, motions, or sounds. Next, have them identify what data they will need to collect to train the machine and how they will retrieve it. • Have students research how to evaluate machine learning algorithms/processes using the measures of precision and recall. The goal here is to drive home the idea that machine learning algorithms make mistakes and that precision and recall are calculations that can be used to represent the number of mistakes.
Reflection and Synthesis Prompts	• How did you and your partner decide what kind of data you wanted to work with? • What do you hope to learn/experience/get better acquainted with as a result of working with the Teachable Machine?
Formative Assessment Ideas	• Have students submit an overview of the skills they think they've learned since the start of the project and those they think they've improved since the beginning of the project. Consider using the KWHL framework to support this process. • Have students also anticipate what other skills they may learn/strengthen in the rest of the project and modify the assignment (as applicable) to foster those anticipated experiences.

MILESTONE #4: UNLOCKING THE TEACHABLE MACHINE'S POWER

The goal of this milestone is to have students apply the foundational knowledge and exposure to the Teachable Machine from Milestones #2 and #3, respectively, and the plan they developed in Milestone #3 toward training and evaluating the model generated by the Teachable Machine.



STEPPING STONES

TRAIN THE MACHINE

Student teams work together to gather the necessary data and train the Teachable Machine.

EVALUATE THE MODEL

Student teams test the Teachable Machine and analyze the precision and recall of the resulting model.

PLAN FOR FUTURE WORK

Student teams will collaboratively develop a plan for working with the Teachable Machine in the future.

Pose students' questions and problems back to the class

As students begin tackling more technical aspects of their project, it's likely they'll have questions or run into problems. A key skill of independent learners is being able to get themselves "unstuck" using strategies besides just asking the teacher how. Take this opportunity to add to students' strategies for getting unstuck, by challenging the whole class to reason through ways to resolve individual pairs' questions or problems. As students discuss, make observations about the problem or ask your own questions to prompt student thinking about the underlying concepts. This approach also has the added benefit of helping to normalize experiences of difficulty as a regular part of the learning process.

	1. **TRAIN THE MACHINE**
Standards	CCSS.ELA-LITERACY.WHST.6-8.7; CCSS.ELA-LITERACY.RST.6-8.3; CCSS.ELA-LITERACY.RST.6-8.7; CCSS.ELA-LITERACY.SL.6.1; CCSS.ELA-LITERACY.SL.6.2; CCSS.ELA-LITERACY.CCRA.W.7; CCSS.ELA-LITERACY.CCRA.W.8; CCSS.ELA-LITERACY.CCRA.W.9; MS-ETS1-1; MS-ETS1-2; MS-ETS1-3; MS-ETS1-4;
Students will be able to....	Train the Teachable Machine on a data set of their choosing.
Ideas for activities	Based on their experience and the plan they developed in Milestone #3, have students enact the to-do list they generated to help them organize and keep track of the training process.
Reflection and Synthesis Prompts	• What did you find interesting about the training process? • What do you like about the Teachable Machine? • What, if anything, surprised you about the training process?
Formative Assessment Ideas	• Have students describe the training process for the Teachable Machine in their own words. • Ask students to revisit the idea of a "black box" and why the Teachable Machine fits that definition.

Provide strategic support so students feel a sense of mastery

Experiences of success in overcoming challenges, or "mastery experiences," are critical to developing confidence--a key quality of independent learners. But students may attribute success to their teacher's help rather than their own efforts, if given the wrong types of support. At this stage of the project, students are especially likely to run into challenges so it's important for teachers to provide support that preserves students' chance to experience personal success. When they ask you for help with these challenges, resist the urge to give them solutions. Instead--along with questions or observations to prompt their thinking as described in the previous teaching tip--provide encouragement that "you can do it," based on specific evidence of the student's past success (for example, in their work on Milestone 3). In the end, they will be more likely to feel they resolved their challenges "themselves"--and can do so again in the future.

	2. EVALUATE THE RESULTING MODEL
Standards	CCSS.ELA-LITERACY.SL6.1.C; CCSS.ELA-LITERACY.SL6.1.D; CCSS.ELA-LITERACY.WHST.6-8.7; CCSS.ELA-LITERACY.RST.6-8.3; CCSS.ELA-LITERACY.SL.6.1; CCSS.ELA-LITERACY.SL.6.2; CCSS.ELA-LITERACY.SL.6.4; CCSS.ELA-LITERACY.CCRA.W.7; CCSS.ELA-LITERACY.CCRA.W.9; CCSS.ELA-LITERACY.CCRA.SL.1; CCSS.ELA-LITERACY.CCRA.SL.2; MS-ETS1-1; MS-ETS1-2; MS-ETS1-3; MS-ETS1-4
Students will be able to....	Leverage the Teachable Machine to classify novel data and evaluate the precision and recall of the results.
Ideas for activities	• Have students identify novel examples of the training data and have the Teachable Machine classify it. • Have students keep track of the examples that were correctly and incorrectly identified so that they can calculate the precision and recall of the model the machine developed given their input.
Reflection and Synthesis Prompts	• Did you notice any evidence of bias in the results? • How, if at all, could the bias have been introduced by the data used to train the Teachable Machine the model it created? • Or, if you think it was caused by the algorithm, why is that? • Note: Encourage students to include the answers to the questions above in their final presentations.
Formative Assessment Ideas	• What does precision measure? • What does recall measure? • Why do we need both precision and recall to measure classification results?

Push students who need more of a challenge

Succeeding at tasks that feel easy doesn't increase students' confidence. For students who speed through the previous Stepping Stones without much struggle, this one is especially crucial. It adds a new layer of challenge by pushing students to synthesize their learning up to this point into a new plan of attack for training the Teachable Machine. Consider introducing this Stepping Stone before all groups have finished analysis of their original data set, to allow those who finish early to move on. That way more students will experience the appropriate level of challenge to feel a true sense of mastery by the end of the project.

	3. **FUTURE WORK**
Standards	CCSS.ELA-LITERACY.SL6.1.C; CCSS.ELA-LITERACY.SL6.1.D; CCSS.ELA-LITERACY.WHST.6-8.7; CCSS.ELA-LITERACY.RST.6-8.3; CCSS.ELA-LITERACY.SL.6.1; CCSS.ELA-LITERACY.SL.6.2; CCSS.ELA-LITERACY.SL.6.4; CCSS.ELA-LITERACY.CCRA.W.7; CCSS.ELA-LITERACY.CCRA.W.9; CCSS.ELA-LITERACY.CCRA.SL.1; CCSS.ELA-LITERACY.CCRA.SL.2; MS-ETS1-1; MS-ETS1-2; MS-ETS1-3; MS-ETS1-4
Students will be able to....	Identify concrete plans for training and evaluating the Teachable Machine for a new data set to set the stage for further data exploration.
Ideas for activities	• Allow students to identify how they want to train the Teachable Machine in the future by explicitly indicating what data they will use, how they will collect it, how they will train the machine, and what (if anything) they will do differently moving forward. • Allow students to generate a list of to-dos and NTKs for analyzing a new data set. The to-dos and NTKs should take their experience to date into consideration. The goal is to put students in the position where exploration of a new data set is within reach and they have the basic tools and confidence needed to explore on their own.
Reflection and Synthesis Prompts	• How did your experiences to date factor into the data set you chose and your plan for moving forward? • What experience/knowledge helped to make the process easier or, potentially, harder? • What challenges do you anticipate in exploring the new data set?
Formative Assessment Ideas	Allow teams to share their plans for future data analysis with each other and offer suggestions for improvement.
Suggestions for Feedback and Support	Ask students if they think they have enough information to explore the new data set they selected on their own (outside of this class/workshop). If not, ask them what they feel they are missing and help to fill in the gaps.

MILESTONE #5: PRESENTATION AND REFLECTION

The goal of this milestone is to have students present their work to an audience and receive feedback.

PRESENT

5 Student teams share what they've learned about AI, ML, and the Teachable Machine along with their results to visitors.

STEPPING STONES

PREPARE

Student teams draft their presentations and practice in front of other teams.

PRESENT

Student teams present their process and results to a set of visitors either virtually or in person.

REFLECT

Student and teacher reflect on the research questions, NTKs, and students' perspective of what they learned in this process.

RESOURCES

TOOLS

- Presentation Overview
- What, So What
- Plus, Minus, Interesting
- I Used to Think – Now I Think

	1. **PREPARE**
Standards	CCSS.ELA-LITERACY.WHST.6-8.2; CCSS.ELA-LITERACY.WHST.6-8.5; CCSS.ELA-LITERACY.WHST.6-8.6; CCSS.ELA-LITERACY.SL.6.1; CCSS.ELA-LITERACY.SL.6.2; CCSS.ELA-LITERACY.SL.6.4; CCSS.ELA-LITERACY.SL.6.5; CCSS.ELA-LITERACY.CCRA.SL.1; CCSS.ELA-LITERACY.CCRA.SL.4; CCSS.ELA-LITERACY.CCRA.SL.5; CCSS.ELA-LITERACY.CCRA.W.3; CCSS.ELA-LITERACY.CCRA.W.4; CCSS.ELA-LITERACY.CCRA.W.5; CCSS.ELA-LITERACY.CCRA.W.6; CCSS.ELA-LITERACY.CCRA.W.8; CCSS.ELA-LITERACY.CCRA.W.9;
Students will be able to....	● Present foundational knowledge about AI and ML. ● Summarize what the Teachable Machine does. ● Summarize the process they have taken to train and analyze the Teachable Machine. ● Present their plan for future work ● Present a draft presentation to other team members for initial review/critique. ● Edit their presentations based on critiques received.
Decision points	● When and where will students share their presentations? ● How will the presentation space be set up? ● What roles will individual groups/students play in the overall event for setup and takedown, as well as any other necessary tasks. ● **Note**: if you would like to engage students in the decision-making process, consider leveraging the Establishing Norms and Standard Operating Procedure frameworks.
Ideas for activities	● Film practice runs for students to self-assess. ● Have students self-assess based on the **Presentation Rubric**. ● Work together to identify what the components of the presentation should be. Share a Presentation Overview for the structure for the presentation and allow students to begin ideating. ● Have the students develop their presentations. ● Have a practice session where students present and receive feedback from other teams.
Logistics	● Create a guest list and send out invitations. ● Identify non-participant support to manage tech support, tend to guests, and/or troubleshoot when potential issues arise. ● **Decide how the audience will be invited, greeted, and** seated/placed **at the venue.** Deciding whether to invite o**ther guests**, **such as administrators and other classes**, is also an important **consideration.**

	2. PRESENT
Standards	CCSS.ELA-LITERACY.SL.6.1; CCSS.ELA-LITERACY.SL.6.2; CCSS.ELA-LITERACY.SL.6.4; CCSS.ELA-LITERACY.SL.6.5; CCSS.ELA-LITERACY.CCRA.SL.1; CCSS.ELA-LITERACY.CCRA.SL.4; CCSS.ELA-LITERACY.CCRA.SL.5
Students will be able to....	● Present foundational AI/ML information, their process training/analyzing the Teachable Machine, and their plan for future work to a group of visitors.
Decision points	● Depending on audience, some presentations may be virtual. Filming final presentations ahead of time would serve as a back-up for unanticipated absences and issues. ● How will students present: one group at a time or simultaneously while stakeholders move around? ● What will students do when they are not presenting? ● How can the experience be structured so that visitors can give meaningful feedback on the teams' approach/presentations?
Ideas for activities	● In-person or virtual presentations.
Logistics	● If you serve as the host of the event, it may be necessary to prepare a program. You also may need to step in when/if students cannot present for some reason. Enlisting the help of another adult will help to ensure the event runs smoothly. ● Outline the process for setup and take-down.

	3. REFLECT
Standards	CCSS.ELA-LITERACY.SL.6.1; CCSS.ELA-LITERACY.CCRA.SL.1; CCSS.ELA-LITERACY.CCRA.SL.4;
Students will be able to....	**Reflect with the teacher on the project and their original NTKs through collaborative discussions and writing.** A key focus of this activity will be to help them understand how much they have advanced since Milestone #1.
Ideas for Reflection on Work Product and Process	● Allow students to develop **individual written reflection** and then confer with their team to round out their recollection of key activities. Once everyone has submitted his or her reflection, **follow the written activity up with a whole-group discussion on the project.** ● Leverage the following the **Plus, Minus, Interesting** worksheet to support these discussions/writings: ● Do the **What, So What?** exercise to frame the discussion of how the knowledge and experience gained as a result of the project will be leveraged in the future and explicitly state the next steps. ● Deliberately and strategically encourage students to continue with the project by suggesting that they work with a second data set/questions in their own time as an independent study.
Reflection on Presentation	Discuss how the presentations evolved over time and how the event with visitors went, overall.
Formative Assessment Ideas	Allow teams to critique plans for future data analysis and offer suggestions for improvement.
Ideas for Reflection on NTKs and Key Knowledge	● **Individually revisit NTKs and write about what they have learned, what they have yet to discover, and a plan for addressing the latter.** ● Leverage the following frameworks to support reflection: ○ **3-2-1 Bridge** ○ **I Used to Think – Now I Think** ● Provide reflective prompts for discussion including: ○ **I was surprised when** I learned/understood that**...** ○ **I'm still wondering about...**

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