Berkeley Engineers and Mentors

BEAM is the Wheel Deal!

Neil Kamdar | Fall 2021

Field(s) of Interest: Industrial Engineering, Mechanical Engineering

Brief Overview:
Mentees will be learning about how cars are produced in factories. They will then learn about what powers cars and the importance of efficiency in increasing range and speed. Mentees will finally experience how a self-driving car works by engaging in a fun simulation.

Agenda:
- Introduction (5 min)
- Module 1: Nerves of Steel (10-15 min)
- Module 2: Mind Over Motor (10-15 min)
- Module 3: It Wheelie Does it All! (10-15 min)
- Conclusion (5 min)

Teaching Goals/Key Terms:	**Mentor Development Goals:**
➔ Production Line: a set of sequential operations established in a factory where components are assembled to make a finished article ➔ Efficiency: the ratio of the useful work performed by a machine to the total energy expended or heat taken in ➔ Sensor: a device that responds to a physical stimulus ➔ Self-driving: a vehicle capable of sensing its environment and moving safely with little to no human input	➔ **Classroom Management:** Because we will be working in teams to build and compete, be sure to keep an eye on mentees that are trying to take on the task entirely by themself or begin to take competitiveness too far. ➔ **Materials and You:** This lesson uses up a fair amount of material; it's important to stress that part of engineering is to not be wasteful. ➔ **Build Confidence!:** Be aware of the way you present your lessons and be confident as you interact with the mentees!

written by MD, not applicable for every lesson

Mentor Development Notes

Written by Insert Name Here

Expand on the MD Goals for the week. What MD concepts or techniques are we trying to practice this week? This could relate to the week's MD presentation.

Classroom Management

This week's lesson gets the kids to be very hands on with the materials. The first and last module can be seen as a "competition" by the mentees. Remember to step in if you see any teasing or otherwise unsportsmanlike conduct while doing the exercise. For the first module, the results of the activity should focus on the advantages of a production line rather than how quickly any individual student can draw. For the third module it's important to divide the tasks evenly and to watch out for any "hogging" of materials or generally any other uncooperative behavior.

Materials and You

As the students will be doing a build in this lesson, it's important to familiarize yourself with the distribution of materials. There are many parts to building the fan-powered car and making sure each student has what they need before starting the activity makes the lesson go much smoother. Physically and mentally prepare for your lesson and be ready to help your site members!

Build Confidence!

By now, you have familiarized yourself with the mentees and your surroundings! Use the space around you effectively and make sure your voice is clear and audible to all your mentors. Especially in virtual sites, your voice and facial expressions will have to do most of the heavy lifting.

Background for Mentors

<table>
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<td>Module 1

Production Line
Specialization
Assemble
Robotics

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<td>Production lines have been around well before the 19th century when the first automobiles were created. Essentially, they are formed around the basis of division of labor, where instead of each individual doing a job from start to finish, each worker does a smaller part of the whole until the full product is completed. In the olden days, products relied on craftsmanship, where a specialist would create a good from start to finish. However, this was a time-consuming process for an individual to gain all the skills to become a skilled craftsperson. This was eventually noticed, and semiskilled workers began to specialize in a specific part, making them easy to train and faster in getting the finished product.
Going to the topic of cars, Henry Ford improved the assembly line model by slaughterhouses. Ford's line assigned workers to one specific production task. Each task had a production station. A car would arrive at the station, and the worker would perform the specified task -- over and over again on each car that came by. Because each worker had one task and worked on just one car at a time, it meant that hundreds of cars were being built simultaneously throughout the factory. At Ford's original factory, a Ford Model T could be assembled in 93 minutes from start to finish. In fact, every three minutes, a completed car rolled off the production line.
Each worker specialized in what skills they knew the best. It was easy to train them on a skill since they would be practicing it consistently, leading to a higher quality. With specialization came assembly, bringing together each individual’s contribution to form a finished automobile.
We see how this works for car production. Cars themselves don’t always produce the parts they need, such as displays, transmission, brakes just as this holds for tech companies like Apple and Samsung. Instead, they rely on suppliers who also specialize in a small number of products, like tires and paint. These come from all over the world, such as Germany and Japan, and are manufactured in factories. Going back to the production line, modern-day production relies heavily on robotics to automate the process.</td>
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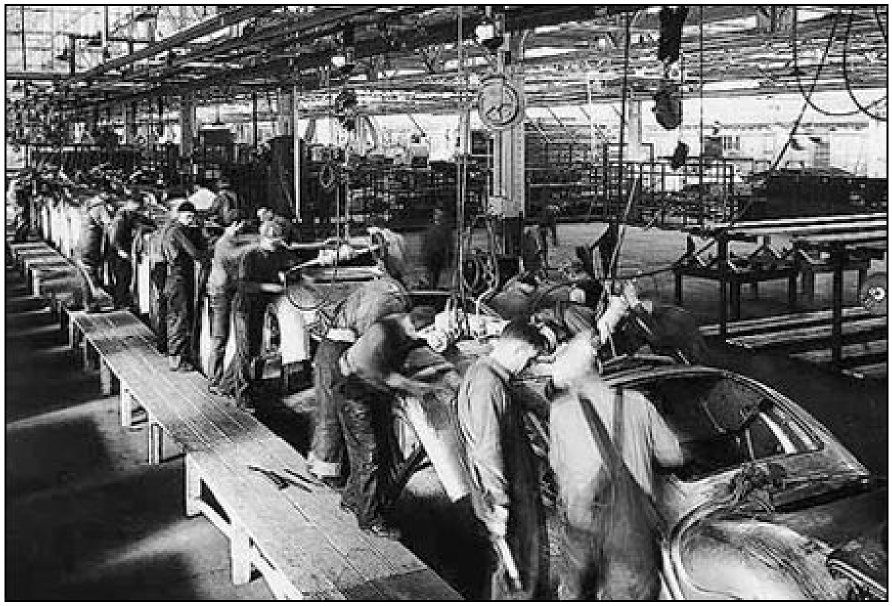


Figure 1: Production lines from the 1920s used human labor

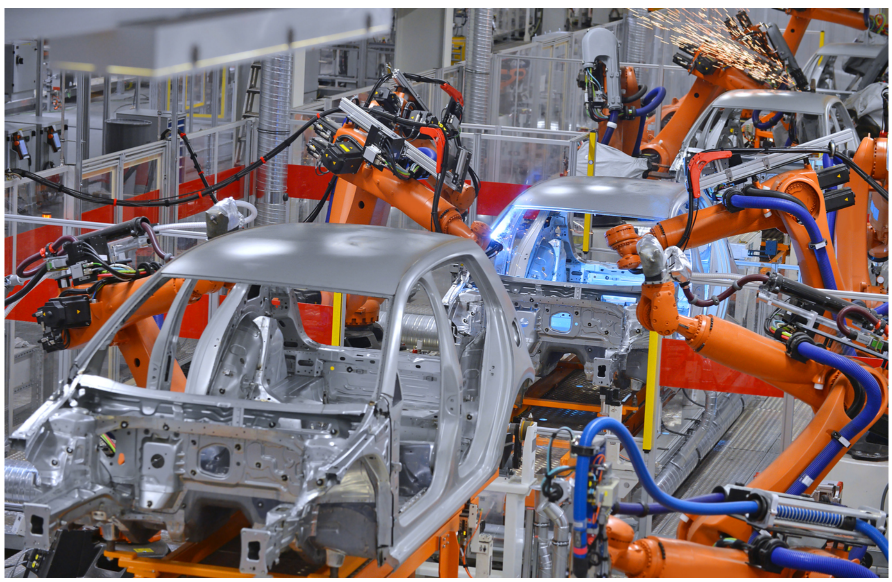


Figure 2: BMW's automated robots handling all sorts of tasks simultaneously

They too focus on specialization, where robots are design specifically to handle one part (ie. placing the steel panels). This makes it easier for maintenence checks and keeps the process streamlined and fast since it requires minimal human intervention.

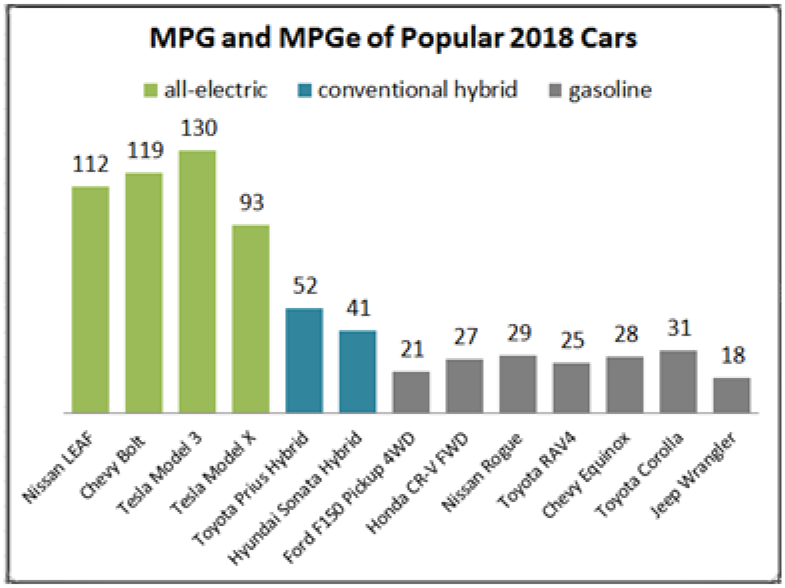
Module 2

- Efficiency
- Combustion Engine
- Electric Motor
- Drag

Building efficient cars is tough. **Efficiency** is the ratio of inputted energy to outputted energy. We see this as miles-per-gallon (MPG), usually. There are countless factors that go into how efficient a car is, but the most important is the source of energy that powers the automobile. Traditionally, society has worked with cars with an **internal combustion engine** (ICE), which is a heat engine in which the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine, the expansion of the high-temperature and high-pressure gases produced by combustion applies direct force to some component of the engine. The force is applied typically to pistons, turbine blades, a rotor, or a nozzle. This force moves the component over a distance, transforming chemical energy into useful work. This process is highly complicated, and it is terrible for the environment since it relies on either petroleum or natural gas, which are both fossil fuels.

Figure 3: An Internal Combustion Engine is complicated!

Now, there must be alternatives, right? Correct! There are plenty of other renewable energy sources, such as electricity and hydrogen, which form the basis of up-and-coming cars that harness them to increase efficiency. Given the minimal moving parts, **electric motors** are also highly reliable and require little to no maintenance. Their simplicity also means that almost no energy is lost in friction between moving parts, making them far more efficient than internal combustion engines. This gives them insane torque and fast acceleration that beats an overwhelming number of sports and hypercars. However, they tend to have lower top speeds, although more advancements are being made to amend that. We see the efficiency of electric motors be a huge step up from ICE cars -- electric cars convert 85% of mechanical energy while ICE cars only convert 40%. On a side note, they are also safer as they have a battery pack underneath the body of the car, lowering their center of gravity and decreasing the change of a rollover in the case of an accident.

	 **Figure 4: Efficiency table of gas vs hybrid vs all-electric** There are also aerodynamic factors that go into efficiency. After all, wind is one of the biggest natural inhibitors of efficiency, and building a car that reduces **drag**, a force acting opposite to the relative motion of any object moving with respect to a surrounding fluid, leaves a noticeable impact on efficiency and slows down a car's acceleration.

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Module 3

- Artificial Intelligence
- Self-driving Car
- Sensors
- Ethics

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We live in a day and age where car advancements are seemingly continuous whether it's new sustainable sources and a transition to superior batteries or cars with new driverless technology. Self-driving cars are no doubt the most cutting-edge of them all. A self-driving car is a vehicle that is capable of sensing its environment and moving safely with little or no human input. Imagine telling your car where you want to go, and the car takes you immediately there as you nap in the driver's seat. Or even further, the car can predict where you want to go and take you there. Self-driving cars require an insane amount of technology and are driven (pun-intended) by Artificial Intelligence. Artificial Intelligence is simply defined as smart decisions made by machines. With an immense amount of data, cars can learn to differentiate between a cyclist and car, traffic cone and barrier, green light and red light. Self-driving cars allow for a car to stay in lines on the freeway and predict accidents before they happen.

How does it know all this? Well, a sensor detects or measures a physical property and records, indicates, or otherwise responds to it. Raining? It knows and will turn on wipers. Pedestrian crossing? Lidar sensors know exactly how far and how fast they're going. Cars use this data not only to make decisions but to learn from and improve their understanding (called Machine Learning, but not in scope for this).

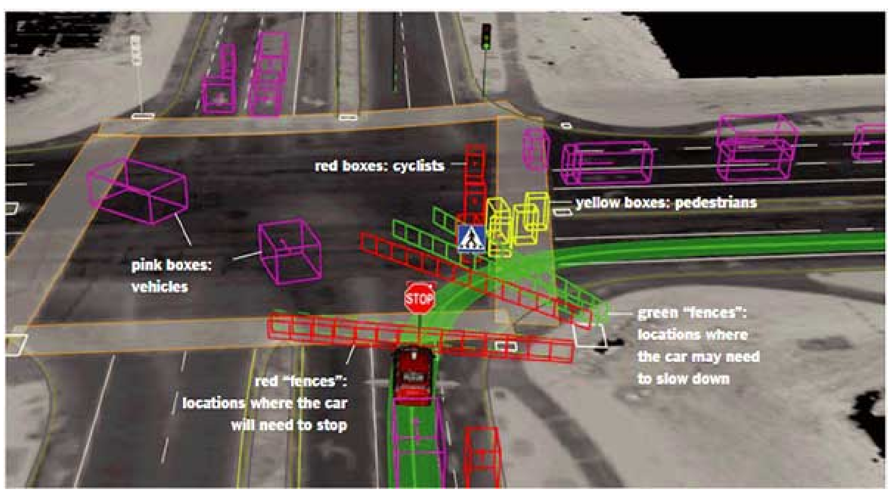

Figure 5: POV: you're a self-driving car

Why is this needed or even important? Imagine a world with all self-driving cars, where they have been trained on billions of miles. They've seen far more than the average driver, and they act perfectly, by following rules and making good decisions. Ultimately,

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	this means saving lives from errant accidents and reckless drivers. Further, it means drivers can relax and do other things in the car as it drives itself (imagine sitting in a plane). However, just as important as this technology is a discussion on the ethics of Artificial Intelligence and self-driving cars. Does a self-driving car whose brakes have failed run into and kill a bank robber who has committed several misdemeanors or a family of 3? This is a moral decision that the car has to make. Ultimately, this falls at the hands of Machine Learning engineers who create the models and are forced to face these tricky and ethical dilemmas. Furthermore, how will we know humans and the government will have the trust to take our hands off the wheel and lets cars do the driving? Government regulation is also a hot topic and goes into the idea of ethics in the field.

Introduction

Currently, we live in a period of rapid advancement in vehicle technology. As the world shifts to electric cars for sustainable benefits, it's exceedingly important to understand how electric cars work differently from the cars we've been used to. At the same time, living in the Bay Area, we need cars to commute long distances, which makes them essential to study. Given our location, Silicon Valley is a significant contributor to self-driving technology.

Concepts to Introduce
• Self-driving: a vehicle capable of sensing its environment and moving safely with little to no human input
• Internal Combustion Engine
• Electric Motor
• Production Lines
• Efficiency
	Current or Past Events
	• Birth of Motor City - Detroit (1900)
	• Automotive Assembly Line (1913)
	• Material of construction (1914)
	• Automatic Transmission (1939)
	• Safety
	    ○ Seatbelts (1968)
	    ○ Airbags (1970s)
	• Hybrids (1990s)
	• Smart Cars and Tech (2000s)
	• Self-driving Cars and Electric Cars (2010s, 2020s, future)

Questions to Pique Interest • Would you like your car to drive you one day? Would you trust your car to do that? • Is it possible to never have accidents? • Toyota makes nearly 11 million cars every year. How can they make so many? • Does your family own an electric car? • What car brands do you know of?	**Inspiring Scientists, Careers, Applications** • Elon Musk: Pushing for normalization of electric cars (Tesla) • John Krafcik: CEO of Waymo, self-driving innovator • Mechanical Engineer: Motors, design • Software/Electrical Engineer: Controls, safety systems, infotainment • Industrial Engineer: Eliminate wastefulness in production system • Production Engineer: Supervise and improve production in factory • Lots of engineers work in the automobile industry. Cars are extremely complex, and each engineer works on making it all work flawlessly

Module 1: Nerves of Steel

Students will be learning about specialization in production lines and how materials fall together through assembly. Modern times have called for advancements in production, namely in how it has shifted form human labor to autonomous robots.

Teaching Goals 1. **Production Line**: a set of sequential operations established in a factory where components are assembled to make a finished article 2. **Specialization**: method of production where production focuses on a limited scope of goods to gain a greater degree of efficiency 3. **Assemble:** fit together the separate component parts of a machine 4. **Manufacturing Robots:** Fully autonomous robots in production needed for high-volume, repetitive processes **Tips for Virtual Sites** **written by MD, not applicable for every module** List and explain how to reinforce MD goals during the module.	**Materials (In-person and Virtual)** • Blank, white printer paper - 1 per mentee • Any writing utensil, such as marker, pencil, pen, colored pencil. Three per mentee in site.

Procedure - In Person and Virtual

1. Hand each mentee a piece of a paper, folded into four quadrants. Also, give them 3 colored utensils (pens/colored pencils/markers).
2. If there is a whiteboard available, mentors can demonstrate the instructions below.
3. Time how long it takes for all of the students to finish completing step 3 below and compare it with the time it takes for all of the students to finish step 4.
4. No Assembly Line
    a. Mentees will be drawing a stick figure in each of the 4 quadrants on one side of the paper
    b. They have to follow the instructions:
        i. First, draw the figure itself with the first color. This includes the head, body, arms, and legs
        ii. Put color 1 back and pick up color 2. Draw in a shirt with the second color.
        iii. Put color 2 back and pick up color 3. Third, draw

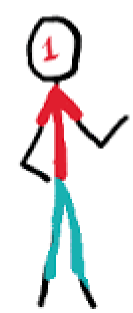

Figure 1: *Stick-figure the students will be drawing*

in pants with the third color.

iv. Repeat steps i-iv for each of the next 3 quadrants.

v. Notice that they will have to pick up a new color each time they draw something new for each stick figure (total of 12 times, including the first color).

5. Assembly Line
    a. Students will be drawing the same figure, but now with different instructions. This will be done on the 4 quadrants on the back of the paper they just used for the “No assembly line” section.
        i. Draw the figure in each of the 4 quadrants with the first color.
        ii. Draw a shirt with the second color on each of the four stick figures.
        iii. Draw in pants with the third color on each of the four stick figures.
        iv. Notice that they have to pick up a new color far less than the “No assembly line” approach (total of only 3 times, including the first color)
6. Compare the times for both approaches. If it was done correctly and without any interruptions/exceptions (ie. pencil snaps), the assembly line would have been faster.
7. Hopefully, the students will have realized that the Assembly Line format is far less work than not having an Assembly Line. Ask them why they think so or any observations they made.
    a. Possible answers: Less picking up colors, faster to draw, less steps
8. Why is this important? If we used an assembly line to do easy tasks, what benefit do we get from it?
    a. Possible answers: Lot faster to do laborious things, better use of time, can make more of one thing, can get people/machines to specialize in only doing one task quickly and well

Module 2: Mind Over Motor

Mentees will be learning about sustainable car energy sources. They will learn the importance of how the car is powered and drag in determining efficiency.

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Teaching Goals

1. **Efficiency:** the ratio of the useful work performed by a machine to the total energy expended or heat taken in
2. **Engine:** gas-powered engine that uses high pressure to move mechanical parts (for advanced sites, can also call it an **Internal Combustion Engine**)
3. **Electric Motor:** highly efficient battery-powered mechanism to drive electric cars
4. **Drag:** force that opposes the motion of a car

Tips for Virtual Sites

written by MD, not applicable for every module

List and explain how to reinforce MD goals during the module.

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Materials (per group of 5)

- 4 cardboard wheels
- Scissors
- 1 wooden skewer
- 2 wooden dowels
- 1 plastic straw
- 1/4th construction paper
- 1 electric fan
- Masking tape
- Cardboard

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Procedure (In person)

1. Have mentees for groups of around 4. Divide the work below, where each mentee completes a part.
    a. 1 student on each axle, 1 for sail, 1 for base (students can also draw on base/sail using Module 1 materials)
2. A mentor will have to assemble the parts together (due to COVID guidelines).
3. Tape a wheel to one side of the wooden stick
4. Cut the straw in half
5. Push the stick with wheel through a straw and tape a second wheel to the other side of stick
6. Tape the straw to the cardboard base
7. Repeat step 5 to make the other axle.
8. Make sure the axles can spin and the car can roll smoothly without getting stuck. If needed, adjust the wheels so they are not too wobbly.
9. Insert a wooden skewer upright into the cardboard to form a mast. Secure it at the base

Figure 1: *One of the two axles*

Figure 2: *Body of the car with axles taped on*

with a small amount of tape.

10. Poke the upright skewer through both ends of the sail to hold it in place.
11. **DON'T BLOW THE SAIL.** Go outdoors if easily accessible and see if the car moves or use provided fan.
    a. Regardless, ask the students how easily they think the car would move.
    b. Do they think it would be faster if they switched it out for a battery or an engine?
    c. Is it good for the environment? Can you replace wind?
12. Experiment with your car. Can you change the design to make it faster? Think about drag. Does the sail go against drag?

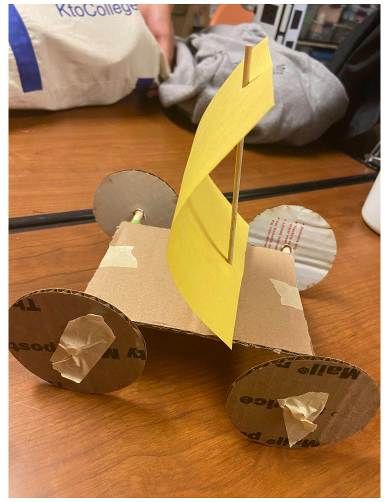

Figure 3: *Completed car*

Procedure - Virtual

1. Have students watch a video on a car engine (Internal Combustion Engine): https://www.youtube.com/watch?v=5tN6eynMMNw
2. Students will be presented with slides. On each slide, there are two options that pose a dilemma.
    a. For example, do you choose a car with a round or square-shaped front?
3. Mentees will answer which they think is better.

Module 3: It Wheelie Does it All!

Students will learn about how cutting-edge self-driving cars work, why they're so cool, and the high-tech artificial intelligence that gives them minds of their own. However, with this comes tough decisions regarding ethics, so that forms some of the problems and perhaps cons of this new technology.

Teaching Goals	Materials
Teaching Goals 1. **Artificial Intelligence:** the simulation of human intelligence processes by machines, especially computer systems 2. **Self-driving Car:** a vehicle capable of sensing its environment and moving safely with little to no human input 3. **Sensor:** a device that responds to a physical stimulus 4. **Ethics (of Artificial Intelligence)**: a concern with the moral behavior of *humans* as they design, make, use and treat artificially intelligent systems, and a concern with the behavior of *machines,* in machine ethics. **Tips for Virtual Sites** **written by MD, not applicable for every module** List and explain how to reinforce MD goals during the module.	**Materials** ● 1 Crumpled up paper ball per site

Procedure (In person)

1. Have all students form pairs outdoors. If outdoors isn't accessible, you can do this indoors, but just make sure classroom is clear of any backpacks. Have them stand at any edge of the classroom so as to maintain a degree of social distance. If there are too few students or your site is running short on time, you can also have mentors play the role of Student A while they are paired with a student who is Student B.
2. One student (Student A) stands next to their partner (Student B). Student A closes their eyes while Student B leaves them open.
    a. Have Student B maintain a distance of around 3 feet (per CDC) from Student A. Be sure to intervene during the activity if a pair is too close to one another.
3. Have a mentor place the paper ball somewhere outside that's accessible. All Student Bs should know where the ball is but the Student As should not know.
4. Countdown from 3, and have Student As look for the ball with their partner standing next to them. The trick is that Student A is walking with their eyes closed, and it is up to Student B to give directions like "getting hotter", "getting colder", "watch out, there's someone there", "there's a tree in front of you", "wrong way", etc. as they try searching for the item. For a twist and if the ball is placed in a place such that it is

possible, have them avoid going on grass and only be able to go on concrete/asphalt.

5. The first pair to get to the location of the ball wins.
6. Repeat steps 2-5 with the pairings swapped (now, Student B will walk with their eyes closed and Student A will give directions). If there is no time, skip to step 7 after one round.
7. Once both students in each pair have been the "car," ask the students if they can relate this activity to how a self-driving car works.
8. The objective is to understand that this is exactly how a car and it's sensors work. Cars alone have no idea where they are, but they use receptors such as GPS, blind spot monitors, and lidar sensors to detect objects around them. The student with their eyes closed relies on the other student just as cars rely on these sensors to move and identify objects (trees or other students in our case).

Procedure - Virtual

1. Show mentees a video on how cars dynamically classify objects and act instantaneously.
2. Then, show them images of intersections, crosswalks, highways, etc. and ask them to identify what and how a car would recognize different objects around it.

Classroom Notes

It's extremely important to make sure nothing is in the way of the students as they walk around. Also, it might be useful if the mentors briefly demonstrate the activity to show how it works.

Conclusion

Conclude by talking about how production lines increase how fast cars are made. They rely on robotics (which also deal with Artificial Intelligence) to ensure the high quality and quantity of these machines. Also, efficiency is highly important to reduce pollution, and it can be traced to sources of energy and specific physics, such as drag, that affect the car. Finally, self-driving cars will ensure the safety of passengers and rely on a ton of data to act perfectly and notice everything in their surroundings. However, it is also important to discuss the ethics not only of the machines and what they do, but also how engineers program them to decide on moral dilemmas.

References

- None

Summary Materials Table

Material	Amount per Site	Expected $$	Vendor (or online link)
Extremely Specific Item Name	1 per student		Amazon