Author: Georgia Lascaris

Title: When Cardboard Comes to Life: Pollinators, Robotics, and Machine Learning

Purpose of the challenge

- **To raise awareness** of **pollinators** like bees and butterflies, their role in biodiversity, and their specific color vision.
- **To teach the fundamentals** of **Machine Learning (ML)** by having students create, train, and test an image classification model using Google Teachable Machine.
- To introduce the concepts of **Artificial Intelligence** (AI) and **Machine Learning** (ML) through **experiential learning**, enabling students to understand how computers learn from data and patterns.
- To integrate **robotics** with **AI tools** and develop **computational thinking skills** by programming Arduino-based servos to move in response to AI detections.
- **To explore AI ethics and bias** by facilitating discussions on how **subjective** data labeling and unbalanced datasets can lead to incorrect machine decisions.
- **To demonstrate real-world positive impact** by showing how AI and robotics can be applied to **environmental conservation and monitoring**.
- **To foster interdisciplinary creativity** by combining **art and engineering**, allowing students to design and craft their own physical cardboard garden models.

Description of the challenge

Students design and build a cardboard garden. Using Artificial Intelligence, Machine Learning, and robotics, they program bees and butterflies to move in response to flower colors. The challenge also introduces students to pollinators and ethical issues in technology.

Target audience

Upper Primary School students (10 to 12 years) or lower secondary school (12 to 14).

Experience

- Basic familiarity with computers.
- Basic block coding skills (Scratch/PictoBlox) like conditionals, variables, functions.
- Basic knowledge of robotics (Arduino) and servo motors.

Duration

5 to 7 sessions of 45 minutes each.

Recommended tool:

Hardware

- Computer(s) with webcam and internet connection (1 per team, or 1 shared setup).
- Arduino-based board with 2 mini servo motors and jumper wires (1 per team, or 1 shared setup).

Software

- Teacher and pupils' account to Pictoblox - desktop or online version https://pictoblox.ai/ - https://thestempedia.com/product/pictoblox/?srsltid=AfmBOorMpAHJHK0VkfdzuHUg-ns2PwJ8t-wK3Xb37Mcc_WDWck6U2rGV

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- Web based tool Google Teachable MachineGoogle, https://teachablemachine.withgoogle.com/

Crafting Materials

- Cardboard, egg cartons, wooden skewers.
- Colored paper and colored pencils.

Online Materials about pollination and pollinators

- Video – "*What is pollination*": https://youtu.be/xmQmqi5ghjQ
- Video – "*Why Protect Pollinators*?": https://youtu.be/p8uxJnNteNY?si=DlemlWABNNBukqu2
- "*Pollinator Pathmaker*", online simulation- Design and plant gardens for endangered bees, butterflies and other pollinators: https://pollinator.art/
- Video tutorial on how to use the "*Pollinator Pathmaker*" simulator tool: https://mashable.com/video/pollinator-pathmaker-algorithm-garden-art-alexandra-daisy-ginsberg
- Pollinator Color guide : https://ucanr.edu/sites/default/files/2020-04/324875.pdf

Videos and simulations about AI , Machine Learning

- Video – "What *is Machine Learning*": https://youtu.be/OeU5m6vRyCk?si=YzwwphWGvYDCpXB0
- Simulation Game on AI:" *AI for Ocean*": https://code.org/oceans
- Online Kaggle flower dataset for training data: https://www.kaggle.com/datasets/bogdancretu/flower299

Tutorials with examples on how to use "Google Teachable Machine, "Pictoblox" and Arduino

- Video-Tutorial on Google Teachable Machine, "Fruit classifier Google Teachable Machine": create-train-export https://youtu.be/MPyDoDa9-rw?si=qniOU1cl6RJkC66S
- Video- Tutorial on using Pictoblox with and Arduino board and one micro servo motor, "*OpenSessame_ControlServoWithPictoblox*":https://youtu.be/WmdOFnDUDMg?si=T2oM8d_CHZ8DeUQJ
- Video - Tutorial on using Pictoblox with Google Machine Learning "*Machine Learning with Pictoblox What is this fruit*": https://youtu.be/I9JBY11eIA0?si=CCwCMDTjHjVauSL-
- Video- Tutorial Pictoblox with Machine Learning and Arduino board and one micro servo motor here "*OpenSesame-Machine Learning_Arduino_Speech*": https://youtu.be/RsB6kTxjJpM?si=Btc-JzTKRtRWBC2g
- Tinkercad simulation on how to connect Arduino Uno board with two motors: https://www.tinkercad.com/things/4BJoSWreTs4-arduino-2-servosgeorgialascaris?sharecode=JyLwH1Ng793mQGMk82hyGAQDGcKucJb3Y9gC8y1m3u0

Ready-to-Run Materials

- Video of the experiment – "*When Cardboard Comes to Life: Pollinators, Robotics, and Machine Learning*": https://youtu.be/MI2_7aqPLv0?si=5rJW2X9Pi0NcgCyo
- Google Machine Learning Model we trained: https://teachablemachine.withgoogle.com/models/4rV5pm4MR/
- GitHub resources - Code, Data, and ML: https://github.com/glascaris/WhenCardboardComes2Life-/tree/main

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Instructions

Step 1: Understanding Pollination

- Use the videos "*What is Pollination*" (https://youtu.be/xmQmqi5ghjQ) and "*Why Protect Pollinators*" (https://youtu.be/p8uxJnNteNY?si=DlemlWABNNBukqu2) to introduce the importance of pollinators and pollination, focusing on bees and butterflies.

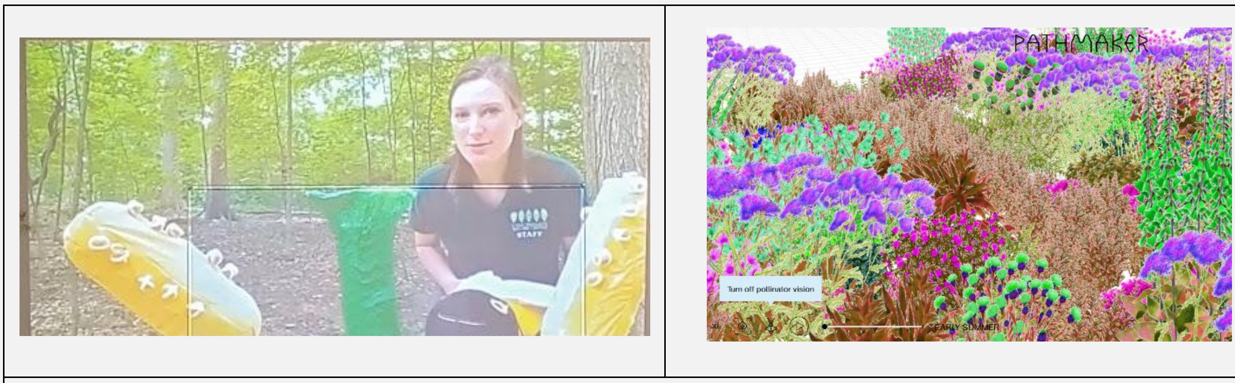


Figure 1 - the role of bees and pollinators' vision

- Discuss how pollinators see colors:
  - the "*Pollinator Pathmaker*"simulator game (https://pollinator.art/) to design a pollinator-friendly garden and see how insects see colors or
  - the "Pollinator Color guide" (https://ucanr.edu/sites/default/files/2020-04/324875.pdf).
- Conclude that:
  - Bees see purple and yellow very well.
  - Butterflies see yellow and red very well.

Recommendation : If needed, help student to use the "*Pollinator Pathmaker*" tool (https://mashable.com/video/pollinator-pathmaker-algorithm-garden-art-alexandra-daisy-ginsberg)

Step 2: Learn About Artificial Intelligence (AI) and Machine Learning (ML)

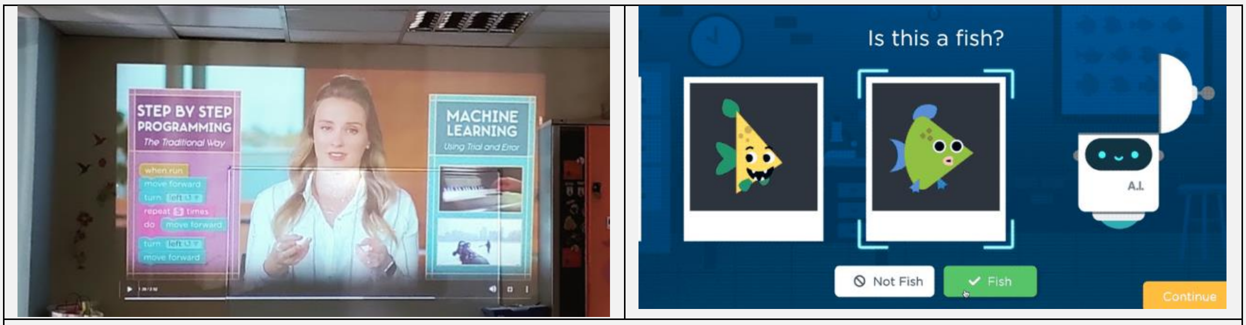


Figure 2 – Learn about Machine Learning

- Watch an introductory video on Machine Learning: https://youtu.be/OeU5m6vRyCk?si=YzwwphWGvYDCpXB0
- Play "AI for Ocean": code.org/oceans: https://code.org/oceans

Recommendation: Those activities can also be implemented in a flipped classroom format.

Step 3: Data Collection

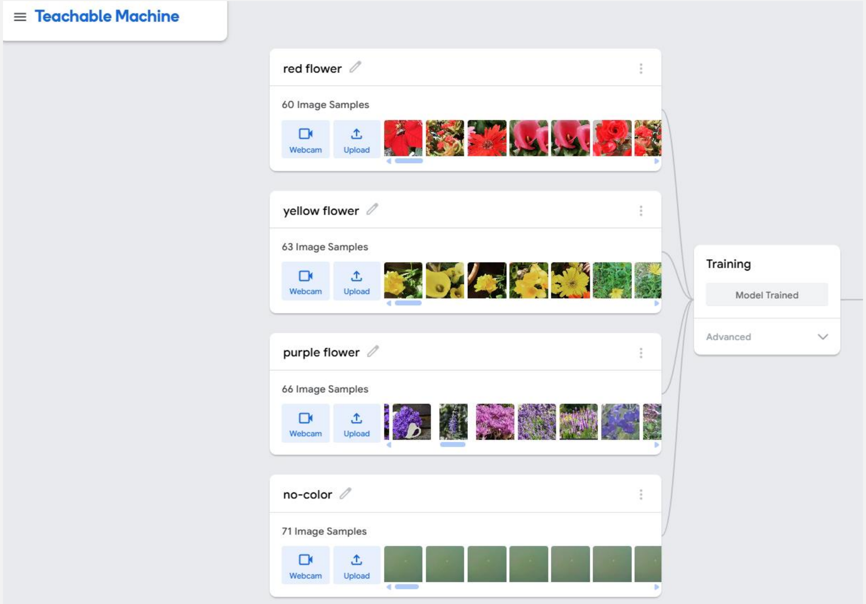
- Students gather photos of purple, red and yellow flowers from their homes, gardens, or neighborhoods. They need at least 30 flowers for each category.
- Alternatively, they can use the online sources provided by the teacher (Kaggle flower dataset https://www.kaggle.com/datasets/bogdancretu/flower299 or the ready to use materials in the GitHub repository).

Recommendation:

- Encourage diversity: Different types of flowers, various lighting conditions, multiple angles, different backgrounds, different species within each color group. This helps build a more accurate and less biased model.
- This activity can be implemented in natural science lesson or as homework.

Step 4: Build the Machine Learning Model in Google Teachable Machine (See details in Annex1)

- Open the Image Project in Teachable Machine https://teachablemachine.withgoogle.com/train/image .
- Create **four categories**: three categories for each color (yellow flower, red flower, purple flower) and one more category (**no-color**) for the background (the table, desk, or neutral background used while taking photos. This helps the model distinguish flowers from non-flower images).
- **Upload** your images into each category.



Teachable Machine

red flower
60 Image Samples

yellow flower
63 Image Samples

purple flower
66 Image Samples

no-color
71 Image Samples

Training
Model Trained

Figure 3 – The Google Machine Learning Model

- **Train** the model and test it with new photos or create 3D paper flowers.
- **Export** the model as TensorFlow.js and **save** the shareable link for PictoBlox (step 7).

Recommendation:

- Discuss **bias and perception** while categorizing images. For example, the colors purple, violet or blue may may divide students. This kind of debate helps them understand that labeling can be subjective (people may interpret colors differently) and that ambiguous data can affect how fairly and accurately the model learns.

Step 5: Crafting the Cardboard Garden

The students work in teams of 3-4 to create their gardens using cardboard, egg cartons, colored pencils, and wooden skewers to create flowers, bees, butterflies and attach them on the egg cartons. They explore photos online to learn about the anatomy of bees and butterflies and made their models more accurate. Each student contributed a unique design. One of the bee and butterfly will later be connected to servo motors.

Recommendation: implement this activity during the Art, STEM lessons or as homework. Make the bee and butterfly that will be attached to the servo motors light weight otherwise the motors may not work properly.

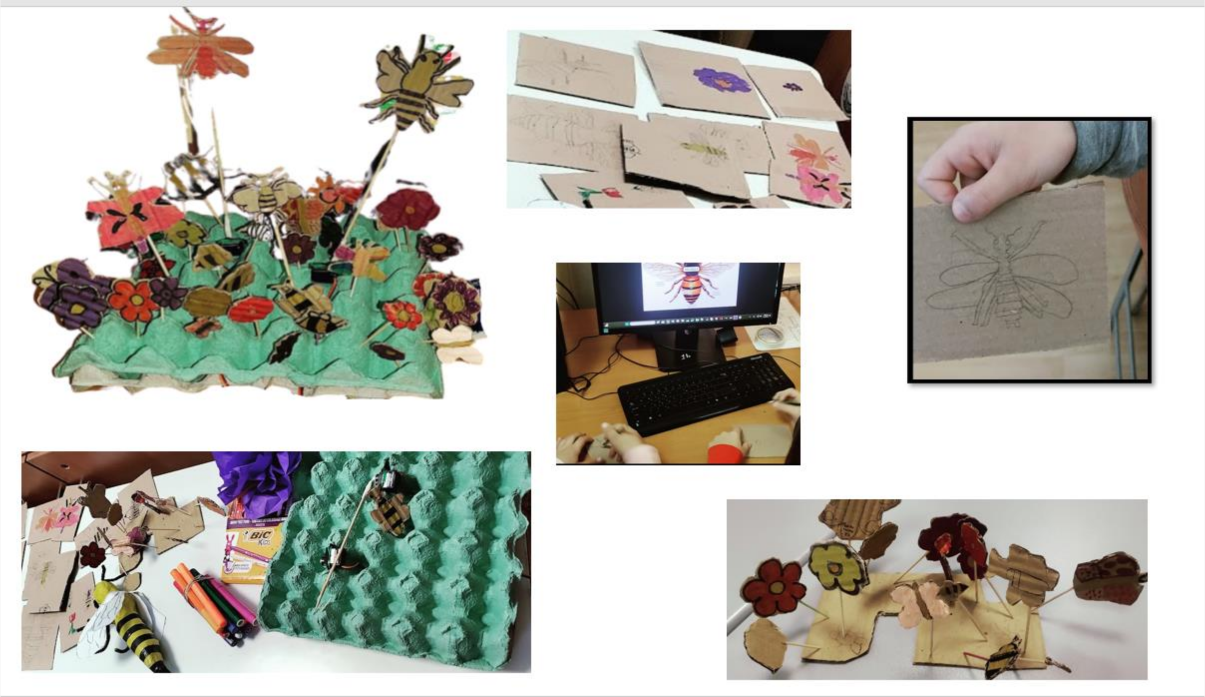


Figure 4 – Crafting the garden and pollinators

Step 6: Robotic Setup

- Use an Arduino-Uno based board, with two servo motors. Breadboard and jumper wires may be required depending on the Arduino model.
- Connect one motor to pin 5 (it will be used to move the butterfly) and the other to pin 9 (it will be use to move the bee).

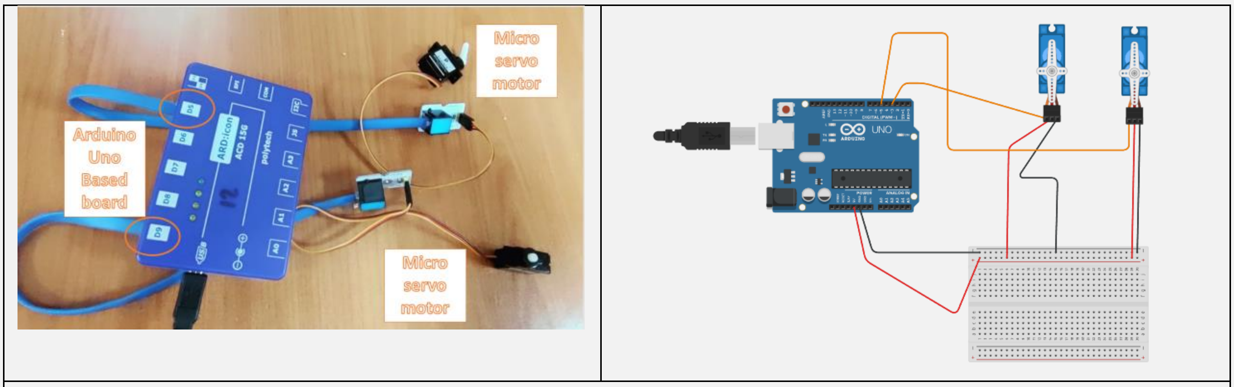


Figure 5 – Examples of implementation: using 2 micro servo motors to an Arduino based board (ARD:icon board on the left) and an Arduino Uno board on the right

Recommendation: Tinkercad simulation on how to connect Arduino Uno board with two motors: https://tinyurl.com/y4m3djap

Step 7: PictoBlox Coding (see details in Annex 2)

- Open PictoBlox (desktop or online https://pictoblox.ai).
- Sign in with team account. (**1**)
- Connect Arduino board: from the Menu click on "Board' (**2**) and then click in "Connect" (**3**)
- Click on Extensions (**4**) and add the "ML with Teachable Machine" extension.
- Choose the "Machine Learning" library (**5**) and load the Google Machine Learning exported model (**6**) in step 4.

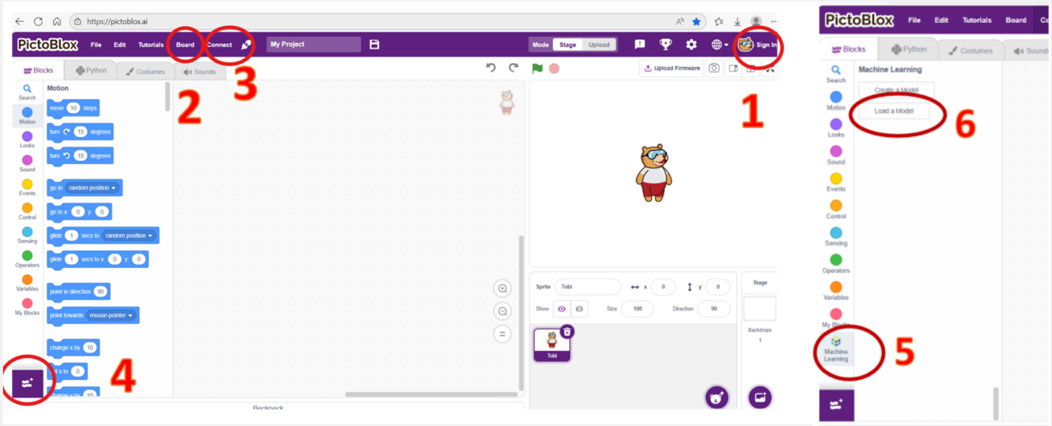


Figure 6 – Pictoblox Interface

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- Use the ML blocks to: (**see details in Annex 2**)
    - Open the recognition window
    - Capture webcam input
    - Identify flower colors in real time
    - Set recognition confidence threshold ≥80% for reliable movement.
    - Optionally, use the Text-to-Speech extension to speak the category aloud.
    - Trigger servo motor actions:
        - When a yellow flower is recognized: Both the bee and the butterfly move.
        - When a red flower is recognized: Only the butterfly moves.
        - When a purple flower is recognized →Only the bee moves.

Students test the robotic setup with real or paper flowers and make adjustments.

Step 8. Discussion and Dissemination

At the conclusion of the project, the teacher facilitates a guided discussion focusing on:

- Model misclassifications and limitations.
- Bias in the training data.
- Strategies for improving dataset quality.
- Connections between artificial intelligence, robotics, and environmental awareness.

Photos and videos documenting the project are shared with the school community. Students are encouraged to present and demonstrate their AI-powered robotic systems to their peers.

Assessment (See details in Annex 3)

Formative Assessment:

Teacher observation is used throughout the project to check student participation, teamwork, and understanding. Students are also encouraged to reflect on their progress using self-assessment and team-assessment rubrics, which help them think about their knowledge of AI, collaboration, responsible use of technology and the role of flowers' color on pollinators.

Summative Assessment:

The final products (robotic bees and butterflies, presentations) are evaluated based on how well they work, the accuracy of the coding, and how clearly, they raise awareness about pollinators. In the final presentation, students explain the Machine Learning process and describe the decisions they made during the project. This final evaluation helps students demonstrate their learning, justify their choices, and share their ideas with confidence.

Replicability

The project is easily adaptable to other AI classification themes (e.g., sorting waste, recognize fruits, identifying emotions, recognizing plants).

Teachers can scale the difficulty to match their students' level and curriculum time availability:

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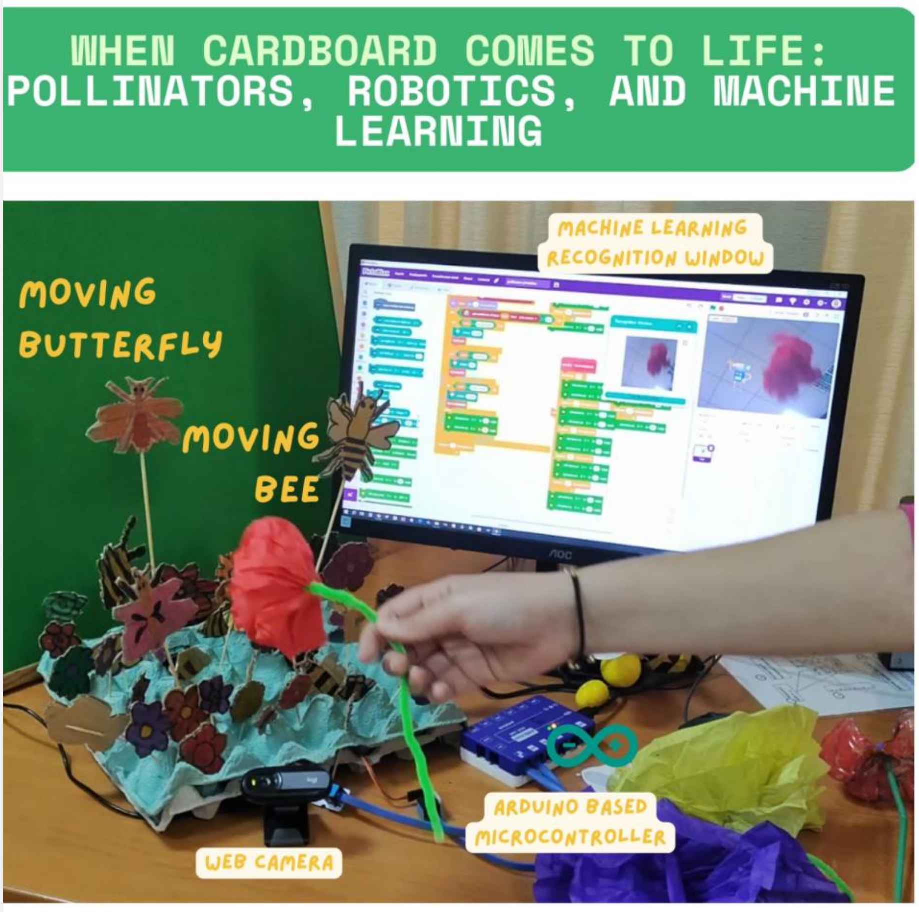
- **Younger students / simpler version**: Use only AI recognition with Google Teachable Machine, without coding. Students learn about Machine Learning, pollinators, and pollination while building a color-based flower recognition model.
- **Intermediate version**: Combine AI recognition (Google Teachable Machine) with Block Coding (Pictoblox) to create animations. The bee and butterfly sprites move only when the correct flower color is recognized.
- **Arduino version**: Use Arduino with a single motor. Students can program the motor and attach either a bee or a butterfly, simplifying the hardware setup.
- **Advanced version**: Older students can use Pictoblox with Python instead of block coding.
- **Alternative hardware**: Other boards, such as BBC Micro:bit, can be used instead of Arduino.

The project can be implemented in different subjects and lessons as it supports cross-curricular teaching by integrating Science, Art, Computer Science, and Ethics. Some activities can be implemented at home in a flipped classroom approach or as homework.



WHEN CARDBOARD COMES TO LIFE: POLLINATORS, ROBOTICS, AND MACHINE LEARNING

MACHINE LEARNING RECOGNITION WINDOW
MOVING BUTTERFLY
MOVING BEE
ARDUINO BASED MICROCONTROLLER
WEB CAMERA

Video: https://youtu.be/MI2_7aqPLv0

ANNEX 1 – Use Google Teachable Machine

Watch the video tutorial Watch the Video-Tutorial on Google Teachable Machine, "Fruit classifier Google Teachable Machine": create-train-export https://youtu.be/MPyDoDa9-rw?si=qniOU1cl6RJkC66S .

Follow the instructions:

- Open Google Teachable Machine https://teachablemachine.withgoogle.com/train/image
- Create four classes: click on Add Class (1). Use the pencil icon (2) to rename each class and then upload the training data.
  - **Yellow flower**: upload (3) the pictures of the yellow flowers – at least 30
  - **Red flower**: upload (3) the pictures of the yellow flowers – at least 30
  - **Purple flower**: upload (3) the pictures of the yellow flowers – at least 30
  - **No-color**: use the web camera (4) to take pictures of the background where the experiment is taking place.

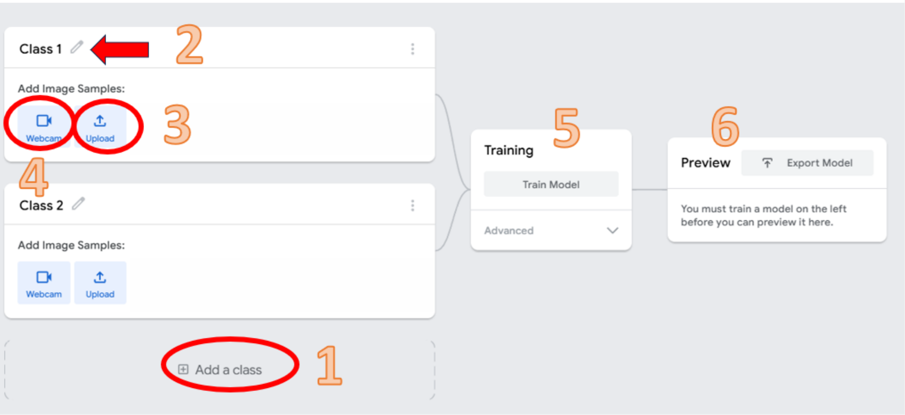


Figure 7 – Google Teachable Machine Interface

- **Train the model (5)**
- **Test the model (6)** using photos of flowers (real flowers or paper flowers) which were not included in the training data. If the result is not satisfying and the model does not recognize the colors with accuracy, then check again your testing data, add more photos or remove photos that are ambiguous. Retrain your model.
- **Export your model** (**7**), (**8**), and save the provided link (**9**). You will use it later in the Pictoblox platform.

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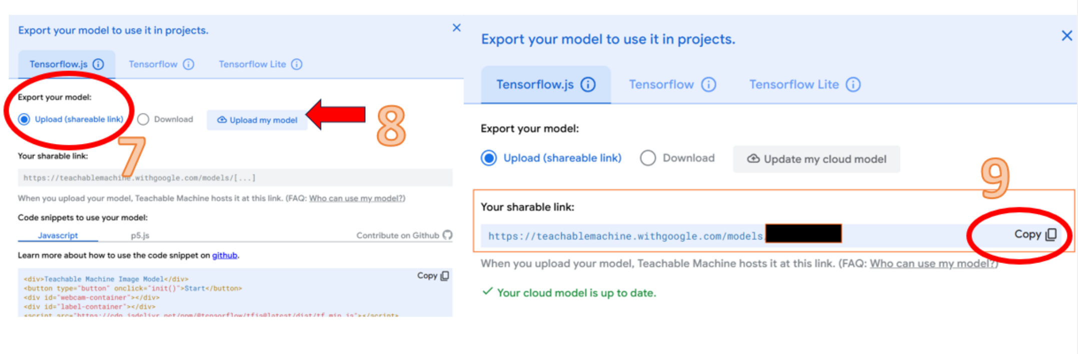

Export your model to use it in projects.

Tensorflow.js | Tensorflow | Tensorflow Lite

Export your model:

● Upload (shareable link) ○ Download | Upload my model

Your sharable link:

`https://teachablemachine.withgoogle.com/models/[...]`

When you upload your model, Teachable Machine hosts it at this link. (FAQ: Who can use my model?)

Code snippets to use your model:

Javascript | p5.js | Contribute on Github

Learn more about how to use the code snippet on github.

```
<div>Teachable Machine Image Model</div>
<button type="button" onclick="init()">Start</button>
<div id="webcam-container"></div>
<div id="label-container"></div>
```

Export your model to use it in projects.

Tensorflow.js | Tensorflow | Tensorflow Lite

Export your model:

● Upload (shareable link) ○ Download | Update my cloud model

Your sharable link:

`https://teachablemachine.withgoogle.com/models`[redacted] Copy

When you upload your model, Teachable Machine hosts it at this link. (FAQ: Who can use my model?)

✓ Your cloud model is up to date.

Figure 8 – Google Teachable- Export your ML model

ANNEX 2- Code with Pictoblox and ML blocks

1. Open **Pictoblox** (online version https://pictoblox.ai/ or desktop version) and choose "**Blocks**" (Figure 10)

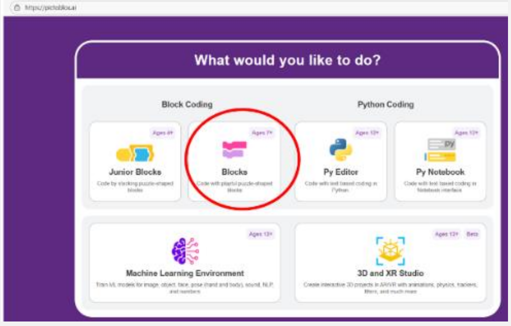

figure 10 – Pictoblox Blocks version

2. Sign in with the **team account** and password the teacher has created, Figure 11 – (**1**).

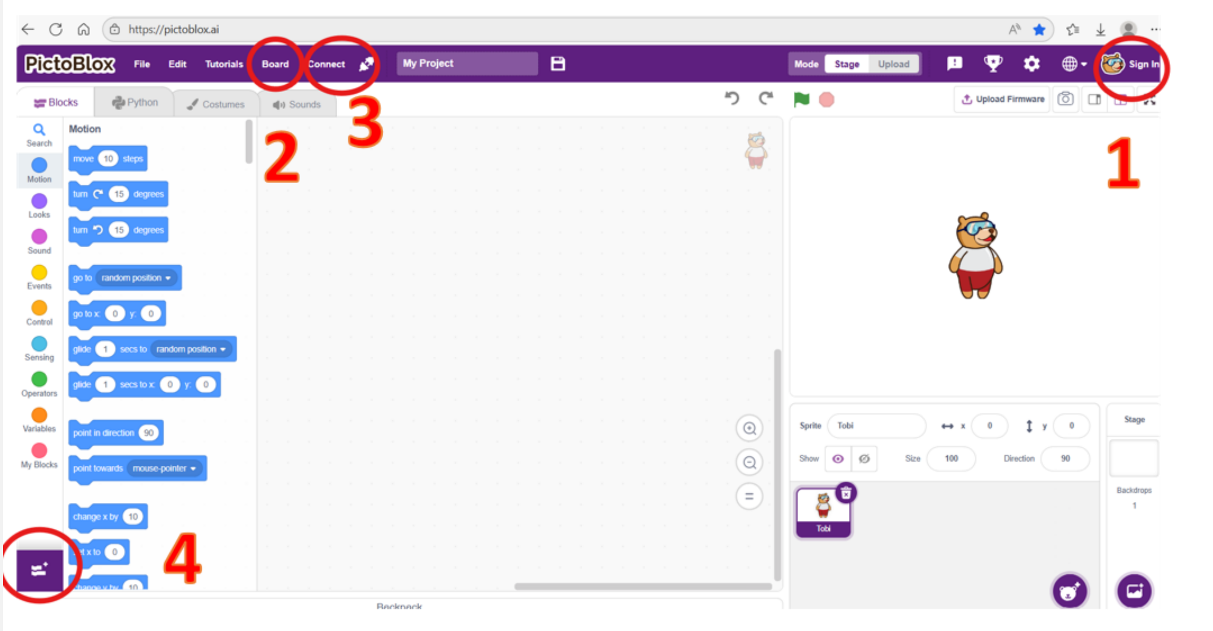

Figure 11- Pictoblox Interface

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3. Connect your **Arduino board** on the computer and click "**Board**" (2) from the menu. (figure 11)
4. Select your Arduino board. (figure 12), Click on "**Connect" (3**) from the Pictoblox menu. (figure 11)
5. Select your Arduino port and click "Connect". (figure 13)

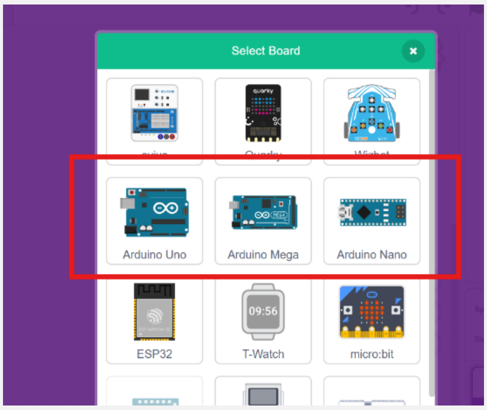
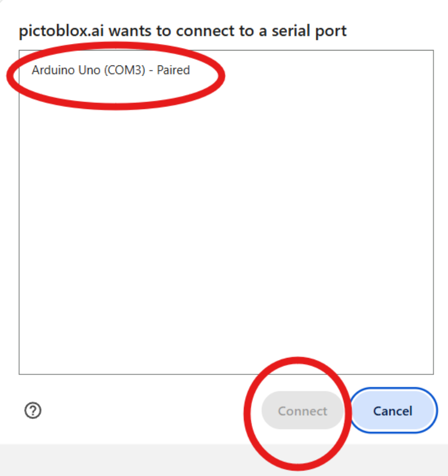


Figure 12 – Select your Arduino board


pictoblox.ai wants to connect to a serial port

Arduino Uno (COM3) - Paired

Figure 13- Select the Arduino Port

6. **Add extensions**. Click on the extensions button (**4** on figure 11) and select the :
   a. "Machine Learning Model with Teachable Machine" extension (figure 14) and
   b. "Text to speech" extension (optional) (figure 14)

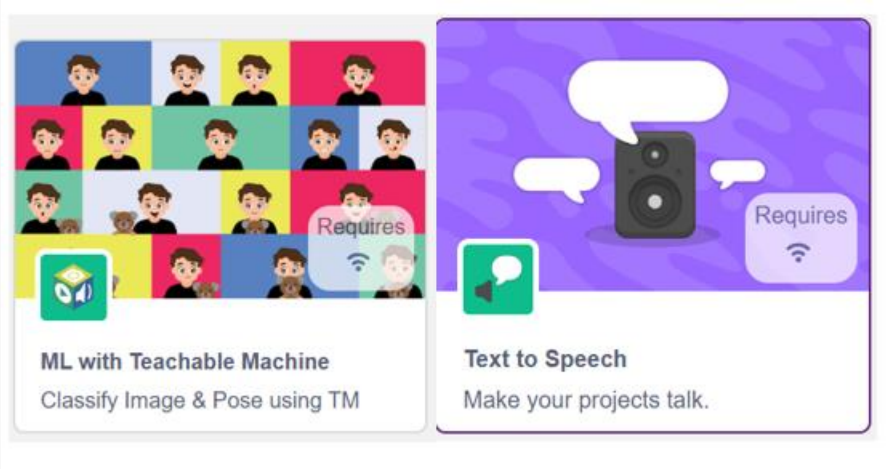


Figure 14 – Pictoblox extensions

7. **Upload your Machine Learning model**: Click on the ML extension library and click "Load a Model". (figure **15**)

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8. **Copy the link of your flowers ML model**. Click "Paste" and "Load Model". Wait for the model to load. (figure 16)

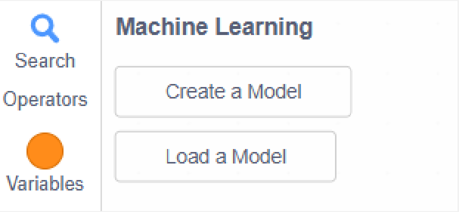
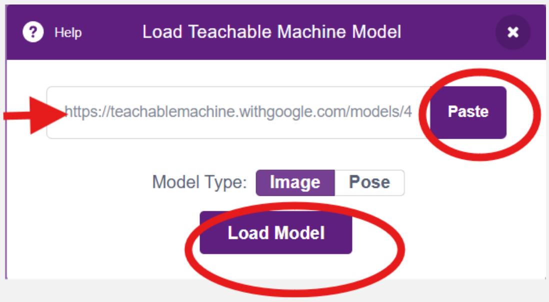


Figure 15

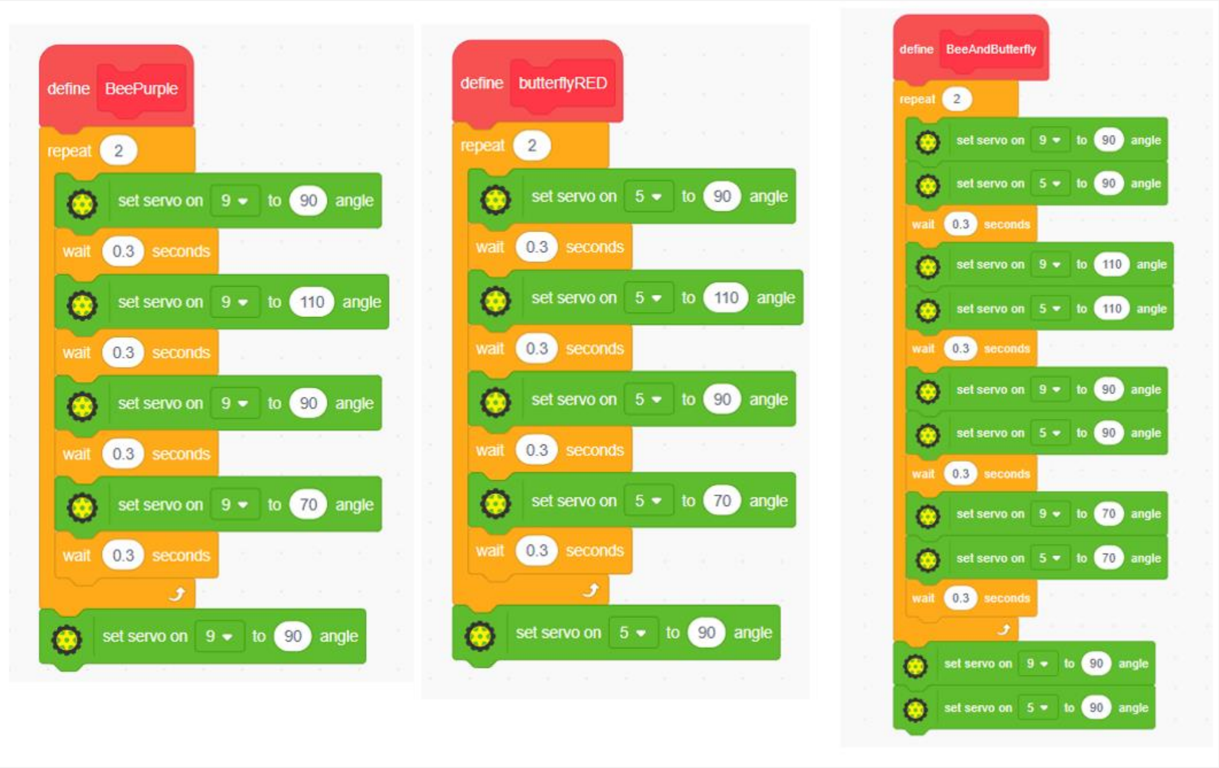


https://teachablemachine.withgoogle.com/models/4

Model Type: Image Pose

Figure 16

9. Using the libraries Actuators , My Blocks and Control create three **functions** to move the bee and butterfly servo motors (figure **17**):
   a. The **BeePurple** function moves only the bee on motor **9**
   b. The **ButterflyRed** function moves only the butterfly on motor **5**
   c. The **BeeAndButterfly** function moves the bee and the butterfly



```
define BeePurple
repeat 2
    set servo on 9 to 90 angle
    wait 0.3 seconds
    set servo on 9 to 110 angle
    wait 0.3 seconds
    set servo on 9 to 90 angle
    wait 0.3 seconds
    set servo on 9 to 70 angle
    wait 0.3 seconds
set servo on 9 to 90 angle
```

```
define butterflyRED
repeat 2
    set servo on 5 to 90 angle
    wait 0.3 seconds
    set servo on 5 to 110 angle
    wait 0.3 seconds
    set servo on 5 to 90 angle
    wait 0.3 seconds
    set servo on 5 to 70 angle
    wait 0.3 seconds
set servo on 5 to 90 angle
```

```
define BeeAndButterfly
repeat 2
    set servo on 9 to 90 angle
    set servo on 5 to 90 angle
    wait 0.3 seconds
    set servo on 9 to 110 angle
    set servo on 5 to 110 angle
    wait 0.3 seconds
    set servo on 9 to 90 angle
    set servo on 5 to 90 angle
    wait 0.3 seconds
    set servo on 9 to 70 angle
    set servo on 5 to 70 angle
    wait 0.3 seconds
set servo on 9 to 90 angle
set servo on 5 to 90 angle
```

Figure 17

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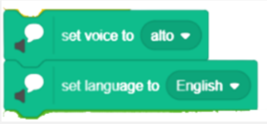
10. Using the coding blocks from the libraries Events , Control , Actuators , Text to Speech , Machine Learning , Variables , and My Blocks make the bee and the butterfly move in response to the color identified from the camera. When a specific color is recognized, the computer will speak the color aloud and trigger the corresponding functions BeePurple, Butterfly Red and BeeAndButterfly. (Figure **18**).

a. **Initialize the program**.

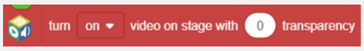
a.1) Use the "Set Voice "and "Language" blocks to prepare the text-to-speech engine.



set voice to alto ▾
set language to English ▾

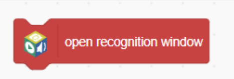
a.2) Set servos 5 and 9 to 90°. This ensures your bee and butterfly start in a neutral position.

a.3) Use the "Video Stage" blocks to turn on the camera. This allows the AI to capture real-time frames.



turn on ▾ video on stage with 0 transparency

a.4) Use the "Open the recognition window" block to see the AI's detections in real time, with labels and confidence scores shown on the camera feed so you can easily check what the computer is seeing.

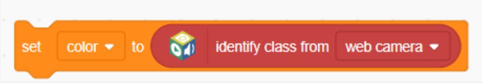


open recognition window

b. For Ever Loop

Use the "Forever" Block to constantly:

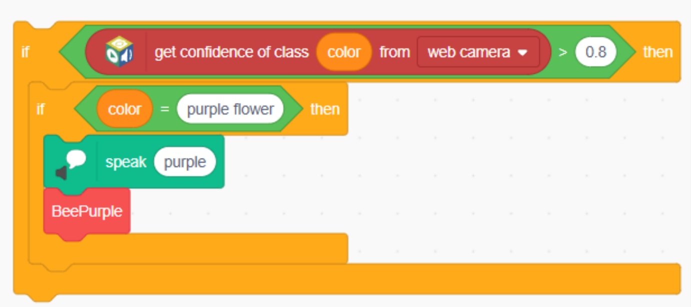
b.1) check the camera feed to determine the flower color and stores it in a variable: create a variable "color" and use the "set color" block command to store the recognized class live from the camera:



set color ▾ to identify class from web camera ▾

b.2) if the AI is 80% or more confident that it has recognized one color then

- announce the detected color aloud.
- trigger the specific bee or butterfly function that matches the identified color.



```
if get confidence of class color from web camera ▾ > 0.8 then
    if color = purple flower then
        speak purple
        BeePurple
```

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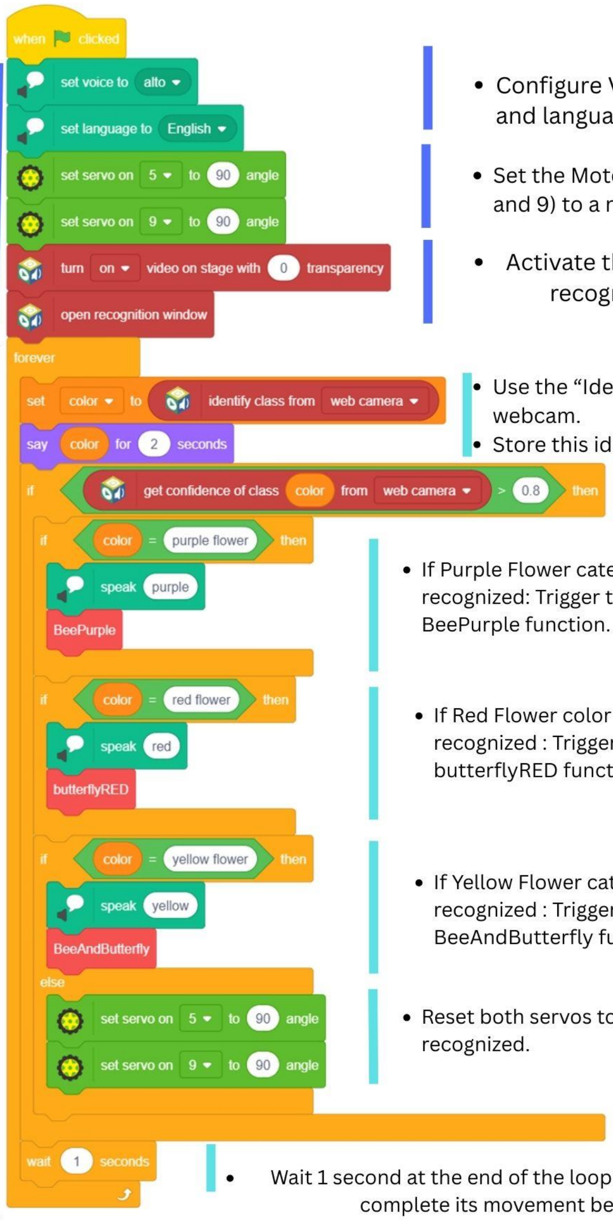
b.3) Returns the servos to their home position if no flower is recognized.



```
when 🏴 clicked
set voice to alto ▾
set language to English ▾
set servo on 5 ▾ to 90 angle
set servo on 9 ▾ to 90 angle
turn on ▾ video on stage with 0 transparency
open recognition window
forever
    set color ▾ to identify class from web camera ▾
    say color for 2 seconds
    if get confidence of class color from web camera ▾ > 0.8 then
        if color = purple flower then
            speak purple
            BeePurple
        if color = red flower then
            speak red
            butterflyRED
        if color = yellow flower then
            speak yellow
            BeeAndButterfly
        else
            set servo on 5 ▾ to 90 angle
            set servo on 9 ▾ to 90 angle
    wait 1 seconds
```

Initialization

- Configure Voice: Set the voice type and language for the AI.
- Set the Motors: Set both servos (Pins 5 and 9) to a neutral 90°.
- Activate the camera and the recognition window.

For Ever Loop:
see, recognize, speak,move

- Use the “Identify Class block” to scan the webcam.
- Store this identification in a variable called color.
- If the ML is at least 80% sure to recognize the correct color.
- If Purple Flower category is recognized: Trigger the BeePurple function.
- If Red Flower color category is recognized : Trigger the butterflyRED function.
- If Yellow Flower category is recognized : Trigger the BeeAndButterfly function.
- Reset both servos to 90° if no flower is recognized.
- Wait 1 second at the end of the loop to give the hardware time to complete its movement before the next scan.

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ANNEX 3 – Assessment

Student Self-Assessment Rubric.

Criteria	😟	😐	😊	😁
I can name different applications I'm using in my life that are AI driven.				
I can explain what Machine Learning is.				
I understand how Machine Learning was used in this project.				
I can explain how the ML model makes predictions.				
I understand how pollinators react to colors.				
I can check that my code or robot works correctly.				
I contributed actively to discussions and decisions.				
I supported my team and communicated respectfully.				
I understand AI ethics and bias issues.				
I contributed confidently to the final presentation.				
I feel confident explaining the project to others.				

Team Assessment Rubric.

Criteria	😟	😐	😊	😁	😟
We collaborated all together and involved all members					
All tasks (ML, coding, crafting, presenting) were shared					
We solved technical/AI challenges together					
Our model and robot worked according to the logic (purple/yellow = bee, red/yellow = butterfly)					
We listen to each other					
We explained how AI/ML helps environmental awareness					
We discussed model bias, accuracy, and improvements					

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