STEAMCITY CURRICULUM

WASTE SORTING THANKS TO AI

thematic: artificial intelligence and new technologies

sub-theme: environment, well-being and public health

Introduction

Understanding how **artificial intelligence (AI) learns and predicts results** is essential for effective AI training. This protocol guides students through the process of **selecting appropriate training data and understanding cognitive biases**, which are key elements in comprehending AI functionality.

By implementing a waste sorting project that utilizes image recognition technology, we establish a connection between Artificial Intelligence and Education for Sustainable Development. The project demonstrates how AI can **analyze and categorize different types of waste materials** through **computer vision**, making the technology relevant to students. This hands-on approach shows AI's impact on our daily lives and its applications in environmental sustainability. Students will learn about **data collection, model training, and real-world implementation** while developing critical thinking skills about AI's role in solving environmental challenges.

The use of AI in waste sorting has evolved significantly since the early 2010s. In 2016, Finnish company ZenRobotics pioneered the use of AI-powered robotic arms to sort construction waste. By 2018, AMP Robotics developed sophisticated machine learning systems that could identify and sort recyclables at speeds of up to 80 items per minute - far exceeding human capabilities. More recently, in 2022, British company Recycleye has implemented computer vision systems that can recognize over 500 different categories of waste materials with over 99% accuracy.

The protocol combines theoretical understanding with practical experience, allowing students to see how AI can be used as a tool for positive environmental impact.

Interdisciplinarity

technology & engineering

biology

Sustainable Development Goals

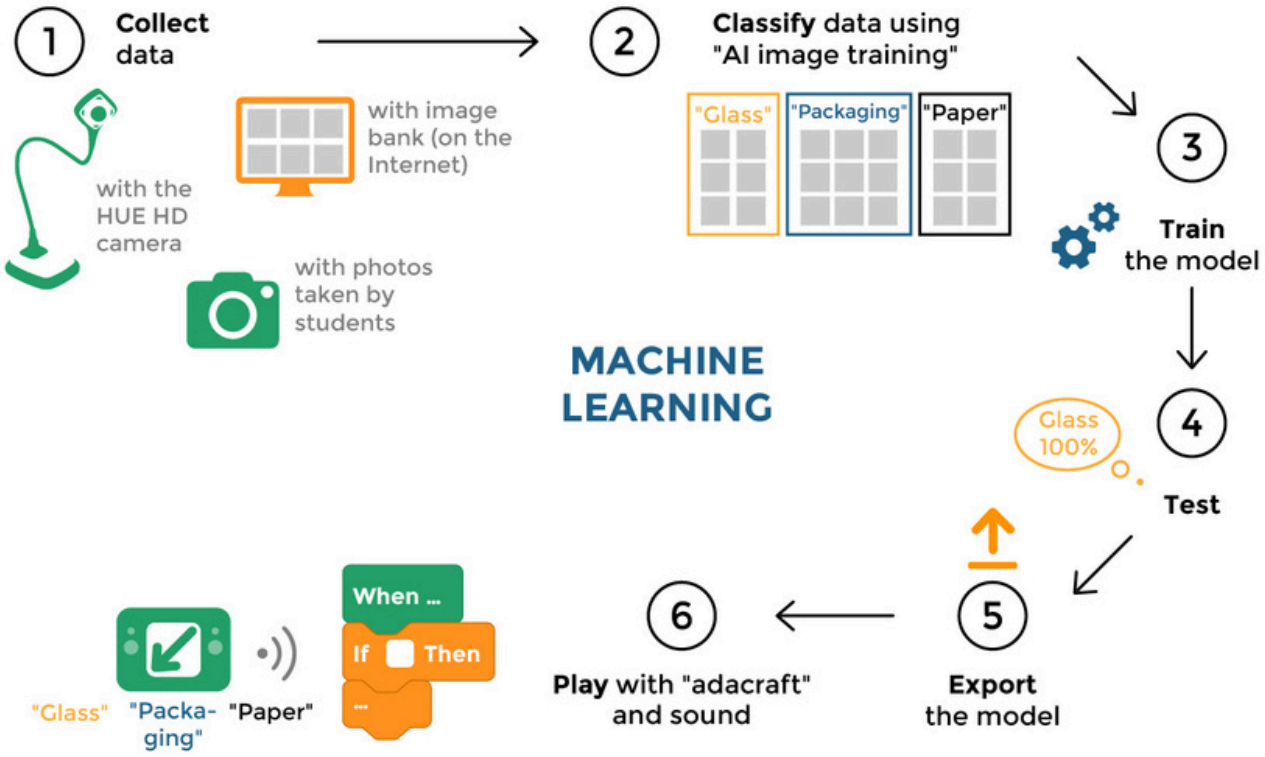
Overview

Protocol Structure

In this protocol, students will develop an **AI-powered waste sorting system** using computer vision. Through experimentation and learning, they will create a program that can **identify different types of recyclable materials** using a camera. The project consists of **four steps**: data collection, model training, testing, and implementation.

During these steps, students will **gather and organize waste images**, **train an AI model** to recognize different materials, **test the model's accuracy**, and finally **connect it to physical hardware**. This progression allows them to understand both the theoretical foundations and practical applications of AI systems. This practical approach helps students develop key understanding in two crucial areas:

- Aware that **AI systems use statistics and algorithms** to process (analyse) data and generate outcomes (e.g. predict what video the user might like to watch).
- Aware that what is usually meant by AI today is **Machine Learning**, which is only one type of AI. What distinguishes Machine Learning from other types of AI (e.g. rule-based AI and Bayesian networks) is that it requires **huge amounts of data**.



Getting started

Duration: 180 minutes or 3 lessons (first for : step 1 and step 2 with introduction and activity 1, second for : step 2 with activity 2 and 3 and step 3, third for : step 4)

Level of difficulty: *Easy (from primary to high school)*

Material needed: Computer with webcam (or HUE HD camera); Micro:bit; Grove Shield for micro:bit; Servo motor

Glossary

Keywords & Concepts	Definitions
Artificial Intelligence (AI)	A set of theories and techniques used to create machines capable of simulating human intelligence.
Machine Learning (ML)	A branch of AI where computers learn from data to make predictions or decisions without explicit programming.
Neural Network	A computational model with layers of interconnected nodes that processes information similar to biological neural networks.
Natural Language Processing (NLP)	A field of AI focused on enabling machines to understand, interpret, and generate human language.
Image Recognition	A technology that enables machines to identify objects, places, and people in digital images.
Dataset	A collection of data used to train AI models, such as labeled images or text examples.
Training	The process where an AI model learns patterns from input data to perform specific tasks.
Supervised Learning	A learning method where AI models are trained using labeled data to recognize patterns.
Big Data	Large volumes of data used to train AI systems and improve their accuracy.
Bias	Systematic errors in AI systems caused by limitations or imbalances in training data.
Pixel	The basic unit of a digital image, containing color and brightness information.
AI-Powered Solutions	Systems that use AI capabilities to address practical challenges and improve processes.
Microcontroller	A small computer on a chip that controls physical components in AI applications.
Arduino	An open-source hardware platform that connects AI systems to physical components.
Servo Motor	A motor that enables precise position control based on AI system outputs.
Recycling	The process of converting waste materials into reusable resources.
Sustainability	The practice of using resources in ways that preserve their availability for future needs.

Protocol

Step 1 - Building an Image Database for Waste Classification

Background and description of the problem to be solved in this step: This first step introduces students to key concepts of AI image recognition, including data collection, model training, and bias awareness and can be completed either in class or at home. Students will create a database suitable for training artificial intelligence.

Learning Objectives: Understanding AI fundamentals: students explore how image recognition AI works, its core principles, and its methods for processing visual data. Developing data collection skills: students learn to gather high-quality, relevant data while understanding fundamental principles and optimal data collection requirements.

Conceptualisation

Before getting started, you need to assess the students' level of knowledge and get them to think about key concepts. To help you do this, here are some questions to work on with them, which will help them find answers for future activities.

What is Artificial Intelligence or AI?

Defining artificial intelligence is challenging due to the concept's controversial nature and rapid recent evolution.

Several prominent researchers have offered different definitions.

Arthur Samuel (1959) described it as "science that gives our computer the elements to learn without being explicitly programmed."

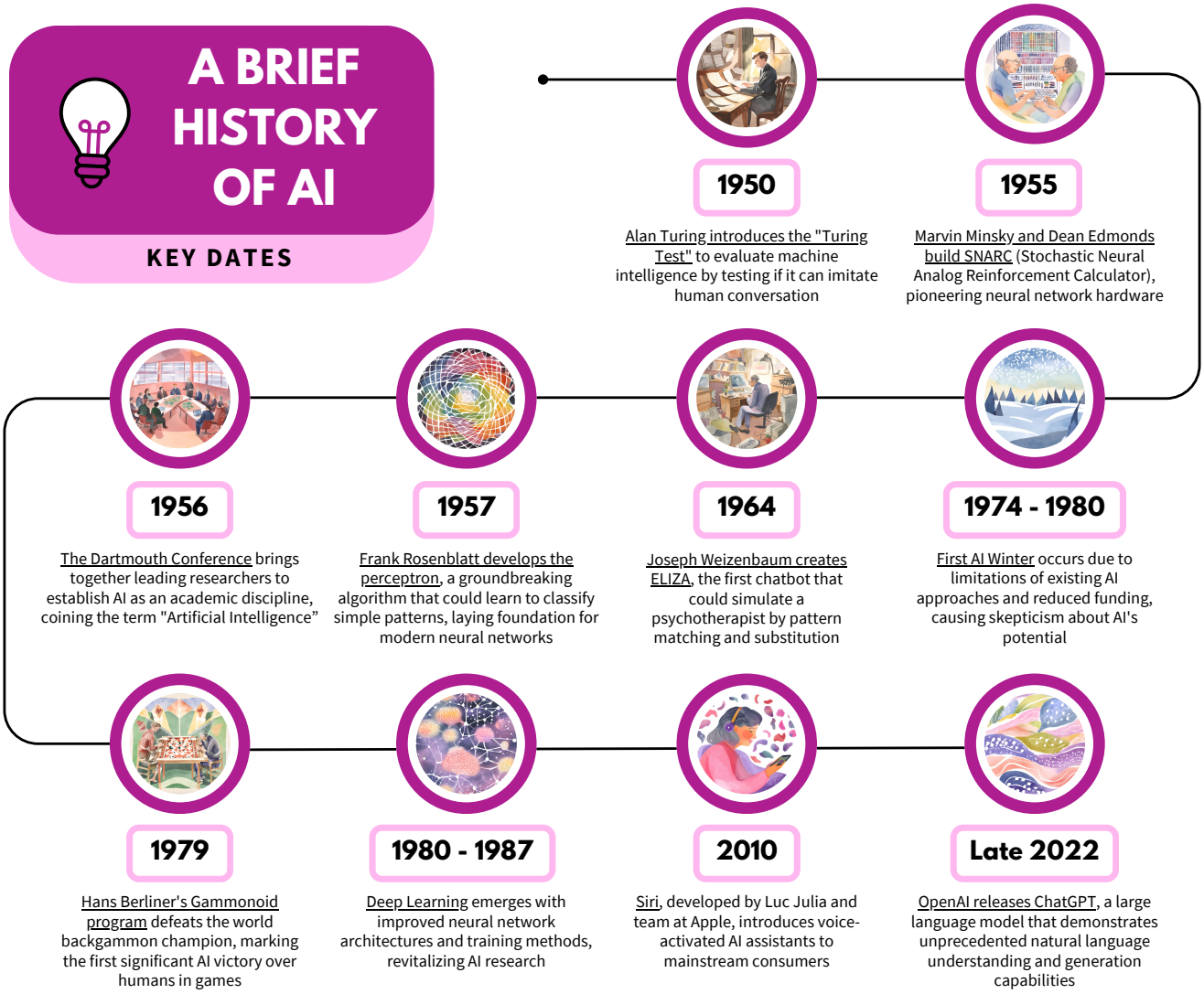
Marvin Lee Minsky (1956) defined it as "the construction of computer programs that engage in tasks that are, for the time being, performed more satisfactorily by human beings, because they require high-level mental processes.".

Yann LeCun (Alan Turing Award, 2019) called it "a set of techniques enabling machines to perform tasks normally reserved for humans."

Luc Julia, the creator of Siri, even challenges the term "Artificial Intelligence" itself. He advocates for "Augmented Intelligence" instead, arguing that "AI should help intelligent beings enhance their capabilities and excel at specific tasks."

We recommend using the Larousse dictionary's clear definition: "A set of theories and techniques used to create machines capable of simulating human intelligence."

This definition effectively highlights the concept of simulation. It's crucial to remember that humans program these machines to simulate human capabilities. While they excel at specific, programmed tasks—often surpassing human performance—they remain tools designed for particular purposes.



How do AIs learn to recognize images? What does an AI see?
The machine uses sensors to decipher its environment and collect data.

For a computer, an image is made up of a set of **small squares called pixels**. Each pixel is made up of 3 channels (Red/Green/Blue). The value of these channels is encoded by a byte. A byte is a sequence of 8 bits. A bit is a binary number: 0 or 1. Example: 10010001 is a byte. There are 256 possibilities in all (2 exponent 8). A pixel is thus coded by a triplet of values, which can vary from 0 to 255, depending on its luminous intensity in red, green and blue.

Students Investigation

The activity is launched by the teacher with the support of the Vittascience interfaces and a camera. It can be carried out in groups or with the whole class. *Duration: 20 minutes*

Instructions for the students: The first step involves creating a photo database of the waste you want the students to sort. You have two options :

- Find the corresponding images in a royalty-free image bank.
- Take photos of waste to be recycled. This option is greater educational interest.

You therefore need to create 3 folders : "**Glass**", "**Packaging**" and "**Paper**" in which to place the images you are going to capture.

Good to know

- You could ask the students to take photos of the rubbish they recycle at home and share them with a digital working environnement or via a USB key.
- We also suggest that you tell the students to place a blank sheet of paper on a table, put the waste on it and then take the photo. This ploy will "pollute" the model as little as possible.
- For the "glass" class, we also recommend avoiding transparent glass. It's better to choose brown beer bottles or green wine bottles, for example. Transparent glass is difficult to detect, as it most often resembles a plastic bottle. However, it may be worth reworking the concepts of bias and big data on the basis of this observation.

Conclusion & Further Reflexion

- **Knowledge Mobilized:** Understanding basic AI concepts, image recognition, and data collection. Recognizing the need for structured and labeled data in AI.
- **Classroom Implementation Reflection:** Students collect images of waste, either at home or in class, and organize them into categories. Teachers facilitate discussions about image quality and data organization.
- **General Learning Outcomes:** Students learn the importance of data in AI training and understand how machines interpret images differently from humans.

Having explored the fundamentals of AI, students can now make meaningful connections between artificial and human vision systems. This understanding forms a crucial bridge to deeper learning about AI capabilities and limitations.

To reinforce this learning, teachers can guide students through three key questions:

1. **How does AI interpret the images captured?** This question helps students understand the technical aspects of computer vision, comparing how machines process pixels and patterns versus how humans perceive images holistically. It demonstrates that AI "vision" is fundamentally different from human vision, despite achieving similar results.
2. **What are the similarities and differences between AI and human vision?** By exploring this question, students can grasp how AI uses pattern recognition and statistical analysis to "see," while humans rely on complex neural networks developed through evolution. This comparison helps demystify AI while highlighting its unique capabilities and limitations.
3. **How does AI's approach to learning differ from human intelligence?** This final question encourages students to think critically about the nature of intelligence itself. They can explore how AI learns through structured data and algorithms, while human learning involves creativity, intuition, and complex reasoning - abilities that current AI systems cannot truly replicate.

Step 2 - Creating a Waste Recognition Model

Background and description of the problem to be solved in this step: This second step allows students to learn how to train an artificial intelligence using the data they have collected. The teacher guides the students in class through the Vittascience AI interface.

Learning Objectives: The aim of this step is to familiarize students with training an artificial intelligence, creating it and better understanding how it learns.

Conceptualisation

Before getting started, you need to assess the students' level of knowledge and get them to think about key concepts. To help you do this, here are an activity to work on with them.

Let's explore the concept of data bias and diversity in AI training by having students analyze different datasets. This exercise will help understand why varied, representative data is crucial for creating unbiased AI models.

Students will examine and compare their collected data with their classmates', noting any differences in what data is present or missing.

This comparison helps them understand how individual perspectives and biases influence data collection. Since AI should strive to be unbiased, careful consideration must be given to the training data provided.

The AI's output may reflect the programmer's unconscious biases or assumptions. For example, if an AI is trained exclusively on images of blank paper, how would it interpret a magazine filled with diverse images? This highlights why data quality and diversity are crucial in AI development. To minimize bias and improve performance, AI systems require large amounts of varied training data—what we call "Big Data".

Students Investigation

Activity 1: Waste Recognition Training (20 minutes)
This hands-on activity, facilitated by the teacher using Vittascience interface, introduces students to practical AI training. Using everyday objects like glass bottles, cardboard boxes, and paper, students will:

- Learn the fundamentals of AI training through direct experience
- Develop critical thinking about data collection and classification
- Understand how AI systems learn from examples
- Practice collaborative problem-solving in groups

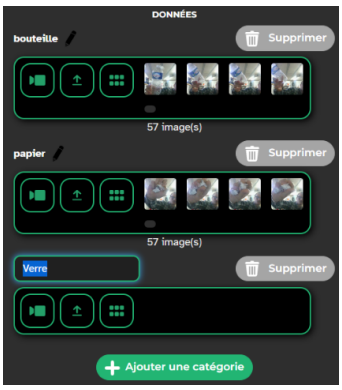
The activity can be conducted either in small groups or as a whole class exercise, promoting both independent learning and collective discussion. This approach helps students grasp abstract AI concepts through concrete, relatable examples.

Instructions for the students:

1. On the Vittascience interface, go to "**AI training**".
2. Create 3 categories in the "**data**" section: " **Glass**", "**Packaging**" and "**Paper**".
3. Drag and drop the **collected images**.
4. Once the dataset has been created, click on "**Training**".
5. **Test the model** with different objects (a plastic bottle, a glass beer bottle, an old newspaper, etc.). You can test it either by dragging and dropping a file or by switching on the webcam. The test phase is important in AI, so take the time to check that the model is well trained. The model needs to be tested with objects supplied as input data and other objects for which the model has not been trained.

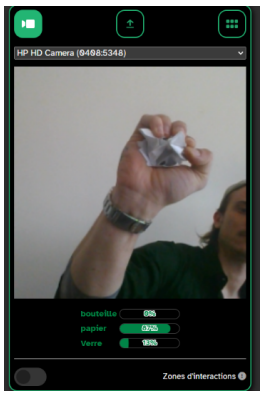
6. Think about activating the **interaction zones** to understand on which element your model is based to predict a result. By clicking on "Interaction zones" you can view the most relevant areas of the image that have enabled the "machine" to provide its prediction. Activating this zone can help you make the results provided by the "machine" more explicable.
   - Test with transparent glass known and unknown
   - Test with paper known and unknown
   - Test with a PET bottle known and unknown
7. **Question your model**: Did the AI recognize all objects 100% of the time? What accounts for the errors? What characterizes glass? packaging? paper? Does the sample represent the majority of waste?

> **Good to know**
> Once you've tested your model, if the results are rough, add more images and train it again to improve.

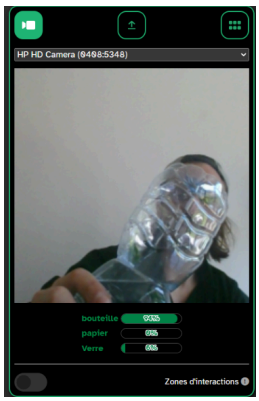


Create 3 classes: " Glass", "Packaging" and "Paper".

Test with transparent glass



Test with paper



Test with a PET bottle

We have a model capable of recognising different types of waste, and now we want to take action based on the detection result.

<u>Activity 2: Connecting AI to Hardware (20 minutes)</u>

This hands-on activity integrates technical skills with pedagogical objectives, helping students:

- Understand the connection between AI software and physical hardware components
- Develop problem-solving skills through practical experimentation
- Learn basic principles of robotics and automation
- Practice collaborative learning in a project-based environment

The activity is facilitated by the teacher using the Vittascience interface and a microcontroller. It can be carried out in groups or with the whole class, promoting both technical understanding and teamwork skills.

Instructions for the students: Use **Adacraft** to connect the output of our model to the input of a microcontroller such as an **Arduino** or a **micro:bit** programming board.

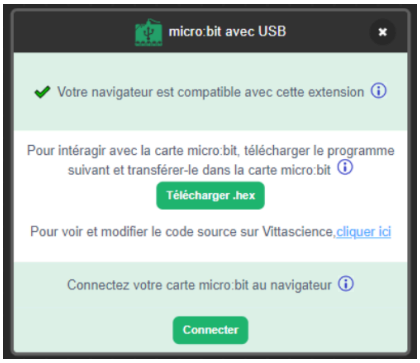
The board will be able to **perform actions** (move a servo motor, switch a LED on/off) each time a new detection is made.

To do this, we click on the **Adacraft icon** at the top right-hand corner of the interface. You will need to choose whether you want to save the model locally or on the browser. To create a program, you need to add the blocks enabling us to communicate with a board, click on "**Extensions**" at the bottom right of the screen from which you can select the board you want to use:

A popup window will appear allowing you to download a program that you can drag and drop onto your board, allowing it to 'talk' to Adacraft.

Once this has been done, press "Connect" to create the serial connection with the board

You now have a recognition model ready to detect objects, and blocks enabling you to talk to a physical board.



<u>Activity 3: Creating Interactive AI Feedback (20 minutes)</u>

This hands-on activity aims to bridge the gap between AI concepts and real-world applications. Through guided exploration with the Vittascience interface and microcontroller programming, students will:

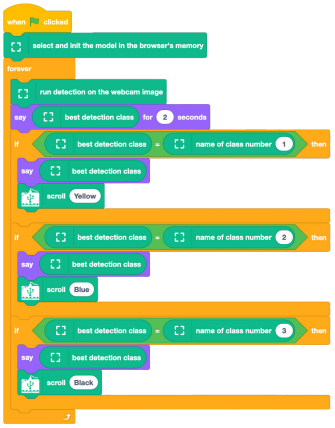
- Develop practical skills in connecting AI systems to hardware components
- Understand how AI can be integrated into physical devices for real-world applications
- Learn the principles of input/output relationships in AI-powered systems
- Practice problem-solving in a collaborative environment

The activity can be carried out in groups or with the whole class, promoting both technical understanding and teamwork skills while ensuring hands-on experience for all participants.

Instructions for the students: Create a program on Adacraft to make the Vittabot character say the detected class. Initialise the model. Run detection. Choose to launch a detection on a file available on the Internet via a URL or directly via the webcam. Useful blocks are available in "IA Image". Then show a text on the micro:bit led matrix according to the detection.

Good to know

- The detection response is recorded in the block: "best detection class".
- The order in which the dataset is labeled during training is important and will be available in the "name of class number (1)" block. You need to be vigilant and remember the order of the class names assigned in "AI Training".
- It is important to note that waste sorting vary from country to country and even locally. For example, in Germany and Switzerland, sorting bins come in different colors (yellow, blue and red) and each color corresponds to a specific type of waste. It is therefore advisable to check the sorting instructions applicable in your region before carrying out the proposed activity.



To go further, imagine an arrow controlled by a servo motor which would indicate which bin to use depending on the waste captured by the webcam.

Conclusion & Further Reflexion

- **Knowledge Mobilized:** Basics of AI model training and testing. Awareness of how biases in data affect AI performance.
- **Classroom Implementation Reflection:** Using an AI interface, students train a model with their images and test its recognition ability. Teachers encourage students to discuss errors and refine the dataset.
- **General Learning Outcomes:** Students understand how AI learns, the role of data quality, and how to test and improve AI models.

Through these activities, students have developed critical analytical skills by examining each phase of AI training. Let's explore the key learning outcomes:

1. **Data Collection Analysis**: Students learn to critically evaluate the data they gather and select for AI training. This helps them understand how initial data quality and diversity directly impact AI performance. By questioning their data collection methods, students develop awareness of potential sampling biases.
2. **Training Process Evaluation**: Students examine how their choices in training data affect the AI's learning process. This deepens their understanding of how AI systems learn patterns and make predictions, while highlighting the importance of representative training datasets.
3. **Results Interpretation**: By analyzing the AI's outputs, students learn to identify and correct potential biases in the results. This develops their critical thinking skills and helps them understand the relationship between input data quality and output accuracy.

The analogy between AI learning and human brain development proves particularly effective. Just as a child learns from exposure to various experiences, an AI system requires diverse, quality data to develop accurate recognition capabilities. This parallel helps students grasp both the potential and limitations of AI systems, preparing them for more advanced concepts in the next step.

Step 3 - Analysing the Data and Learning from them

Background and description of the problem to be solved in this step: Once the students have learned how to train an AI and use it, the teacher guides the students into the classroom to visualize the AI algorithm resulting from the training phase. The “AI Training” interface is used to visualize the neural network.

Learning Objectives: Is to open the “black box” and understand how a neural network works.

Conceptualisation

Before getting started, you need to assess the students' level of knowledge and get them to think about key concepts. To help you do this, here are a question to work on with them, which will help them find answers for future activities.

What is supervised learning?

By providing the computer with several images and the name of the associated class, the AI perfects its learning process. This is known as a dataset. The algorithm built beforehand will determine the various parameters (weights and biases) in each layer of neurons so that, at the end of the process, the output neuron corresponds to the class in the dataset presented. The way in which these changes take place is sometimes difficult to explain and interpret, and is referred to as a "black box".

With each new image, the neural network becomes more efficient. Weights and biases are refined, and we speak of training. This learning phase, call machine learning, creates an image recognition model. We can have several layers of neurons, known as deep learning.

Students Investigation

This hands-on investigation activity (around 15 minutes) aims to develop students' understanding of AI systems while building practical skills. Through guided exploration with Vittascience interfaces, students will:

- Learn to analyze and interpret AI model behavior
- Develop critical thinking about neural networks
- Build confidence in working with AI tools

The activity can be carried out in small groups or as a whole class discussion, promoting both collaborative learning and individual engagement with the concepts. Teachers can facilitate using the Vittascience interfaces while encouraging students to make their own discoveries and observations.

Instructions for the students: Observe the various interactions between neurons in the various layers when testing with an image from a file or a screenshot via the camera.

1. Click on the following button, "**View neural network**".
2. Ask students "**what do you see**?"
3. Based on their answers, **provide additional explanations** :
    - The "**Simplified View**" shows the neural network schematically, with each shape representing a layer, and the size of the layers evolving. At first the images are large and few in number, then they become small and very numerous.
    - Click on "**Detailed view**”. The "Detailed view" lets you see all the neurons in the network - there are over a million of them! The first layer consists of applying a Red, Blue and Green color filter. This retains only the red, green or blue value of the pixels in the test image.
    - You can **navigate the neural network** by zooming in with the mouse or using the buttons on the bottom right. By clicking on the **"i"** information button, you can display the size and number of neurons on each

layer. By hovering the cursor over the neurons, you can view the links with the previous layer, which become frozen if you click on the neuron. The "**Open information**" button displays the number of images and their pixel size within each layer. By clicking on pixels, you can obtain explanations of the **calculations performed by the AI on the layers**.

- In the **convolution layers**, a 9-pixel square (3x3) is scanned over the filter images. Several layers follow one another to identify "patterns", i.e. the characteristics of the object to be identified in the image. Neurons are activated if certain characteristics are identified (alignment of pixels giving rise to shapes, etc.) in correlation with training data. The information is then propagated to the output layer, which provides a prediction.

Conclusion & Further Reflexion

- **Knowledge Mobilized:** How neural networks work, including layers, weights, and biases. Critical thinking about the "black box" nature of AI systems.
- **Classroom Implementation Reflection:** Students visualize the trained neural network, exploring how it processes input. Teachers guide discussions on observed patterns and decision-making in AI.
- **General Learning Outcomes:** Students gain insights into how AI systems process information and make predictions, connecting these processes to real-world applications.

Through this hands-on experience, students have developed a fundamental understanding of how AI systems learn and operate. To deepen their comprehension, the teacher can guide a reflective discussion with the following key questions:

1. "**What have we learned?**" - This question encourages students to articulate their understanding of AI's learning process, helping them consolidate their knowledge and identify any gaps in their comprehension.

2. "**How intelligent is AI?**" - This critical thinking question prompts students to consider the nature of artificial versus human intelligence, leading to discussions about AI's capabilities and limitations, and helping them develop a more nuanced understanding of what "intelligence" means in different contexts.

3. "**How do input data affect AI's results?**" - This analytical question helps students understand the crucial relationship between training data quality and AI performance, emphasizing the importance of diverse, unbiased datasets in developing effective AI systems.

Step 4 - Using IA to improve the Environmental Footprint

Background and description of the problem to be solved in this step: The last step allows students to take their programming skills a step further with tools (interfaces and hardware). It can be done in the classroom. Create a program that performs an action every time the trained AI model makes a prediction.

Learning Objectives: The aims of this step is to learn how to use artificial intelligence in relation to an everyday need. Students learn to recognize the usefulness of these tools by improving their environmental footprint and know when they are facing one of them.

Conceptualisation

Before getting started, you need to assess the students' level of knowledge and get them to think about key concepts. To help you do this, here are a question to work on with them, which will help them find answers for future activities.

Understanding AI in Daily Life

Artificial Intelligence has become deeply integrated into our daily routines, manifesting in various forms that we interact with constantly. From the moment we wake up, we encounter AI through **facial recognition systems** on our phones, **personalized content recommendations** on social media platforms, and **intelligent navigation systems** that optimize our travel routes. Digital assistants like **Siri, Google Home, and Alexa** demonstrate advanced natural language processing capabilities, while streaming services employ sophisticated algorithms to analyze and predict our entertainment preferences.

Create a collective mind map with students, documenting all AI interactions they experience in a typical day. This visual representation helps students realize the prevalence of AI in their lives.

Environmental Impact of AI Systems

When examining the environmental implications of these AI systems, we can identify several ways they contribute to sustainability efforts. Smart navigation systems help reduce carbon emissions by optimizing travel routes and reducing traffic congestion. AI-powered smart home systems can significantly improve energy efficiency through intelligent temperature control and resource management. These applications demonstrate how AI technology can be leveraged to support environmental conservation efforts while providing practical daily benefits.

Let's analyze: Which of these AI technologies in your daily life helps reduce your environmental impact? Think about navigation apps optimizing routes, smart home systems managing energy, or AI-powered recycling solutions.

Extending Learning Through AI Odyssey - Datawalk

To deepen understanding of AI's presence in our environment, consider undertaking the SteamCity protocol called "**AI Odyssey - Datawalk in the city**". This complementary activity takes learning outside the classroom, allowing students to physically identify and document AI and data collection systems in their urban environment. By observing and photographing various sensors, cameras, and smart devices throughout their city, students develop a concrete understanding of how AI systems gather and process data in real-world contexts.

Students Investigation

Activity 1: AI Waste Detection Field Test (20 minutes)

This hands-on activity encourages students to apply their AI knowledge in a real-world environmental context. By combining waste collection with AI validation, students will develop practical experience while critically evaluating AI performance in actual field conditions. The activity promotes environmental awareness while demonstrating how technology can be used to address everyday sustainability challenges.

The activity is launched by the teacher with the support of the Vittascience interface and a microcontroller. It can be carried out in groups.

Instructions for the students: For this activity you will be using the AI model you created in the previous steps to apply it in real-world conditions. Follow the steps below:

1. **Gather materials**: garbage bag, gloves, and a phone.
2. **Divide students into small groups** and assign them an **area to explore** (school grounds, building, or public square).
3. Collect information:
   a. **One student collects any waste they find.**
   b. **One student uses the phone with the class-created AI model to verify correct waste sorting for each collected item.**
   c. **One student records data**: types and quantities of waste bins encountered (general waste, paper, glass, etc.), specific types of waste collected (paper items, food waste, etc.), and any errors in AI detection.

Activity 2: Smart Waste Classification Challenge (25 minutes)

This final activity aims to strengthen students' understanding of AI applications while developing their environmental awareness and collaborative skills. It helps students understand how AI works in real situations while learning about the environment. The teacher guides groups of students through hands-on exercises that make learning both fun and meaningful.

Instructions for the students: For this activity you will be using the AI model you created in the previous steps to apply it in real-world conditions and the results of activity 1. Back in the classroom, the teacher asks students to consider the following questions:

- Can AI sort all waste?
- What would it take to sort them all?
- Are all the garbage cans needed to recycle the waste found at the site studied?

If not, report back to the town hall or school principal on the activity and the possibility of improving waste sorting at the site studied.

Conclusion & Further Reflexion

- **Knowledge Mobilized:** Practical application of AI models in real-life scenarios. Awareness of sustainability and waste management practices.
- **Classroom Implementation Reflection:** Students use the trained AI model to sort waste in their surroundings and analyze results. Teachers prompt discussions on AI's role in solving environmental issues.
- **General Learning Outcomes:** Students learn how AI can address practical problems, fostering critical thinking about technology's impact on the environment and society.

To conclude this protocol, engage students in a final reflective discussion that synthesizes their learning experience. Here are key discussion points to explore:

- **"How has your understanding of AI evolved?"** This question helps students reflect on their learning journey, from initial perceptions to their current understanding of AI's capabilities and limitations in real-world applications.

- **"What role can AI play in environmental sustainability?"** Through this discussion, students can connect their hands-on experience with broader environmental challenges, understanding how AI tools can contribute to solving real-world problems.

- **"What are the practical applications and limitations of AI in daily life?"** This reflection helps students develop a balanced perspective on AI technology, recognizing both its potential and constraints in addressing everyday challenges.

The protocol demonstrates how AI can be a powerful tool for environmental improvement when properly understood and applied. Students leave with practical experience in AI implementation, a deeper understanding of environmental responsibility, and critical thinking skills about technology's role in solving real-world problems.

Exploring the protocol further

Educational Adaptation

This protocol offers flexibility in its implementation across different educational levels. From kindergarten to high school, teachers can adapt the complexity to match their students' capabilities. At the elementary level, students can focus on basic waste identification and sorting using simple visual tools. Middle school students can begin working with block-based programming, while high school students can dive into Python programming and create sophisticated data analysis tools. This progression allows students to not only understand AI concepts but also develop practical skills in environmental data management and visualization.

Data Science Career Pathways

To introduce students to data science careers, they can explore the day-to-day work of data scientists through virtual job shadowing, interviews with professionals, and hands-on data analysis exercises. Students can learn about the essential skills required, such as statistical analysis, programming, and data visualization. They can work on various AI projects involving image recognition, pattern detection, and predictive modeling. This practical approach helps students understand both the technical aspects of data science and its applications across different fields, with potential applications in environmental protection and sustainable development being just one of many possible career paths.

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- **Advanced Machine Learning for Recycling: AMP Robotics' Vision**
  Source: *AMP Robotics*
  URL: https://www.amprobotics.com/
  Developing AI systems that sort recyclables at high speeds, far exceeding human capabilities.
- **AI and Computer Vision in Recycling: Recycleye's Breakthrough**
  Source: *Recycleye*
  URL: https://recycleye.com/
  AI-driven systems capable of recognizing over 500 waste categories with near-perfect accuracy, advancing the future of recycling.

AI Fundamentals and Machine Learning

- **Machine Learning Mastery**
  URL: https://machinelearningmastery.com/
  A popular website for practical machine learning tutorials, offering hands-on guides for both beginners and advanced practitioners.
- **Towards Data Science**
  URL: https://towardsdatascience.com/
  An online publication with numerous articles on machine learning, artificial intelligence, and data science, catering to both newcomers and experts.
- **Kaggle**
  URL: https://www.kaggle.com/
  A platform for data science competitions and datasets, providing valuable resources for learning machine learning through real-world challenges.
- **Google AI Blog**
  URL: https://ai.googleblog.com
  Google's AI blog provides the latest research, breakthroughs, and news in the field of AI and machine learning, from one of the leading companies in the sector.
- **Coursera: Machine Learning by Andrew Ng**
  URL: https://www.coursera.org/learn/machine-learning
  A foundational online course by Andrew Ng that introduces the basics of machine learning, widely regarded as one of the best resources for beginners.

AI Tools and Platforms for Secondary Schools Teachers and Students

- **User Guide on Artificial Intelligence: Micro:bit Version (only in French)**
  Source: *Vittascience*
  URL: https://fr.vittascience.com/learn/tutorial.php?id=403/guide-d-utilisation-intelligence-artificielle-version-micro-bit
  Offers a guide to implementing AI with the Micro:bit platform, enabling students to explore AI applications in environmental projects like waste sorting.
- **Teachable Machine by Google**
  URL: https://teachablemachine.withgoogle.com/
  A user-friendly tool that helps students learn how machine learning works by creating models that can recognize images, sounds, and poses without any coding. Perfect for introducing AI concepts to secondary school students.
- **TensorFlow for Kids**
  URL: https://www.tensorflow.org/learn

Interest: TensorFlow provides beginner-friendly AI and machine learning tools for students, with tutorials tailored to younger audiences, introducing machine learning concepts in a fun and interactive way.

- **ML4K- Machine Learning for Kids**
  URL: https://machinelearningforkids.co.uk/
  Interest: An AI platform designed for young students to learn about machine learning through fun projects. They can create AI models to do things like recognize objects or play games. It integrates well with Scratch and Python, helping students build their own models without prior experience.