

IoT and AI in STEM Education with Hydroponic



FÁTIMA PAIS | 24.06.2025 | TURKEY

Agenda

- Introduction: AI and hydroponic systems with IoT
- Aligning hydroponics with STEM and other curriculum áreas
- Presentation of the HAI Platfform
- Insights of the HAI KIT



In 2026 how many years
will Artificial Intelligence
celebrate?



1956

Dartmouth Summer Research Project on Artificial Intelligence

John McCarthy: Often credited with coining the term "artificial intelligence"

Marvin Minsky: One of the most influential figures in early AI research.

Claude Shannon: Known as the father of information theory, Shannon played a role in AI and computing through his work on logic and communication.

Nathaniel Rochester: A computer scientist who designed the first programmable computer at IBM.

Alan Turing

- Turing is considered the ***intellectual father of Artificial Intelligence*** (AI), laying the theoretical foundations before the field officially existed.
- In 1950, in the paper “*Computing Machinery and Intelligence*”, where he posed the question: “Can machines think? And introduced the Turing Test
- **He proposed that instead of programming intelligence directly, machines should be built to learn, just like a child does – a visionary idea that underpins modern machine learning.**
- The Dartmouth organizers explicitly acknowledged Turing’s influence, especially his ideas on learning machines and simulating human thought.
- **His legacy remains central to both the philosophy and practice of AI today.**

What is Artificial Intelligence?

“ It is a branch of computer science by which we can create intelligent machines which can behave like a human, think like humans, and able to make decisions.” ”

Source: <https://www.onlogic.com/company/io-hub/what-is-ai/>

What is Artificial Intelligence?

AI is a multi-use technology.

Like electricity and other technologies it can be applied in different ways, to different scenarios.

AI tasks include:

- learning from experiences,
- interpreting complex data,
- making decisions based on the information gathered,
- understanding natural language,
- recognizing patterns or objects, etc.

The essence of AI lies in its ability to mimic cognitive functions associated with the human mind, such as learning and problem-solving.

Traditional program vs Artificial Intelligence

- ‘Traditional programming’ involves encoding human knowledge and experience into a set of precise rules that a computer can follow, step-by-step, which make the computer appear to respond intelligently.
- These rules, called algorithms, tell computers how to perform tasks and in traditional programming are often expressed in an ‘IF-THEN-ELSE’ format, which resembles a decision tree.
- For example to create a ‘digital doctor’, an algorithm might look like

***IF** the patient has a fever*

***THEN** prescribe Drug X*

***ELSE** send the patient home*

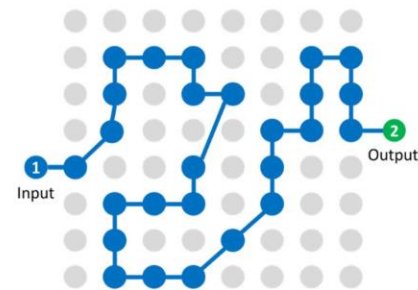
The intelligence in traditional computer systems comes directly from human knowledge and expertise being recorded into a format that a computer can process.

Traditional program vs Artificial Intelligence

- To develop a useful and reliable ‘digital business advisor’, a huge number of rules and exceptions would be required that the system would very quickly become very large, very complicated, and unlikely to capture all of a real doctor’s expertise and experience gained over time.
- Therefore traditional programming of ‘intelligent systems’ is best suited to constrained environments which do not change much over time and where the rules can be strictly defined.



Traditional Programming

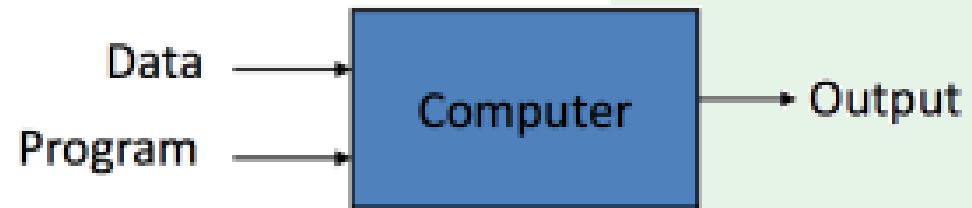


Artificial Intelligence (AI)

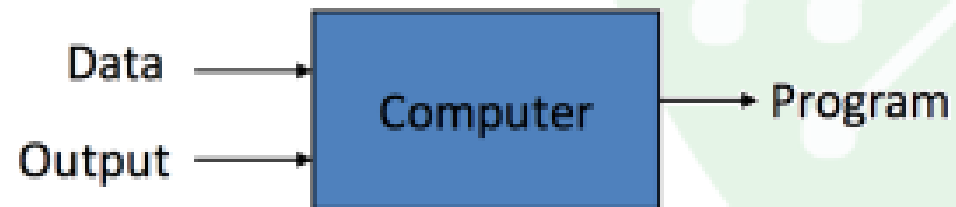
Figure: AI systems can also continuously ‘learn from experience’ and therefore not possible to program that logic by a series of defined steps.

Traditional program vs Artificial Intelligence

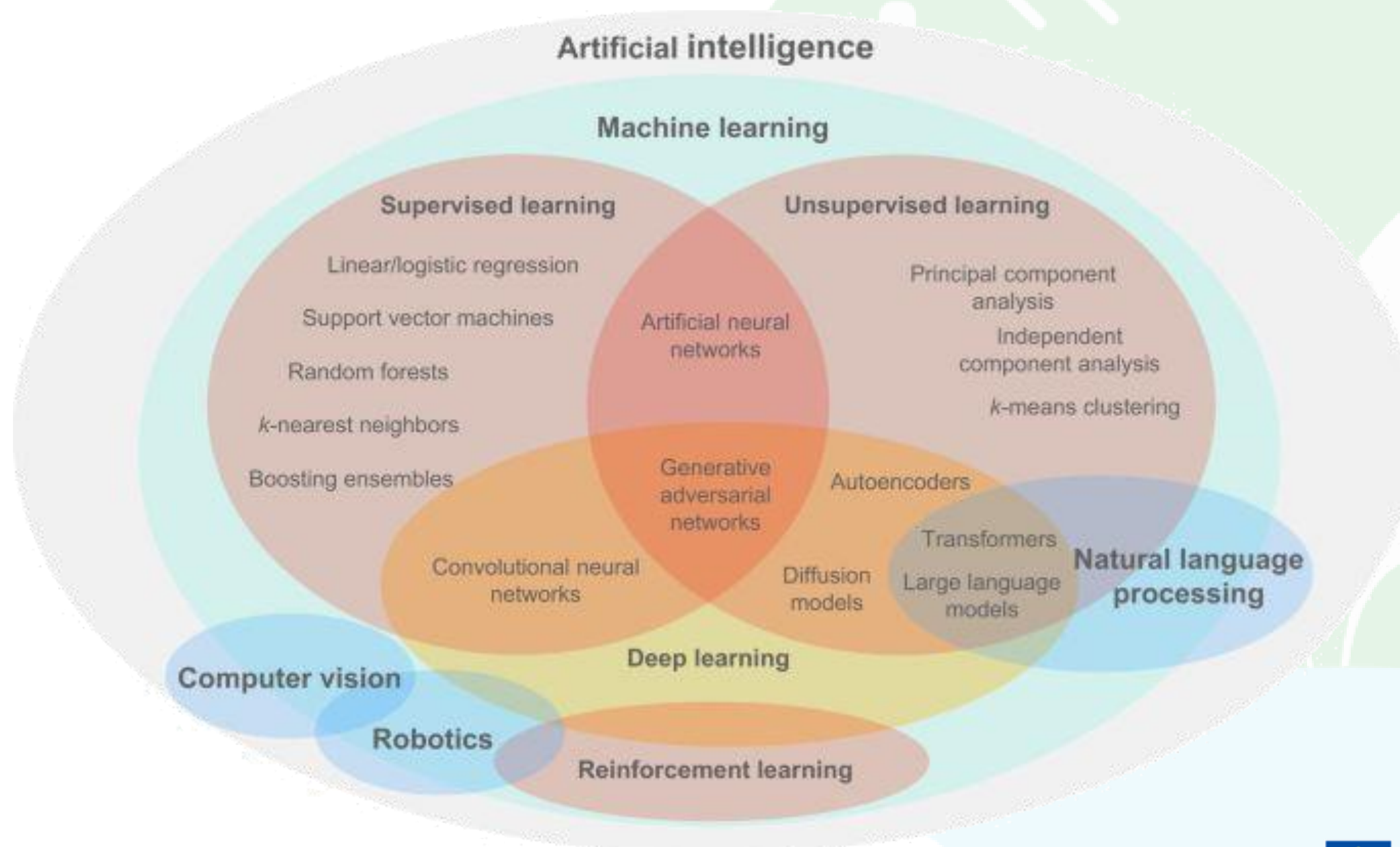
Traditional Programming



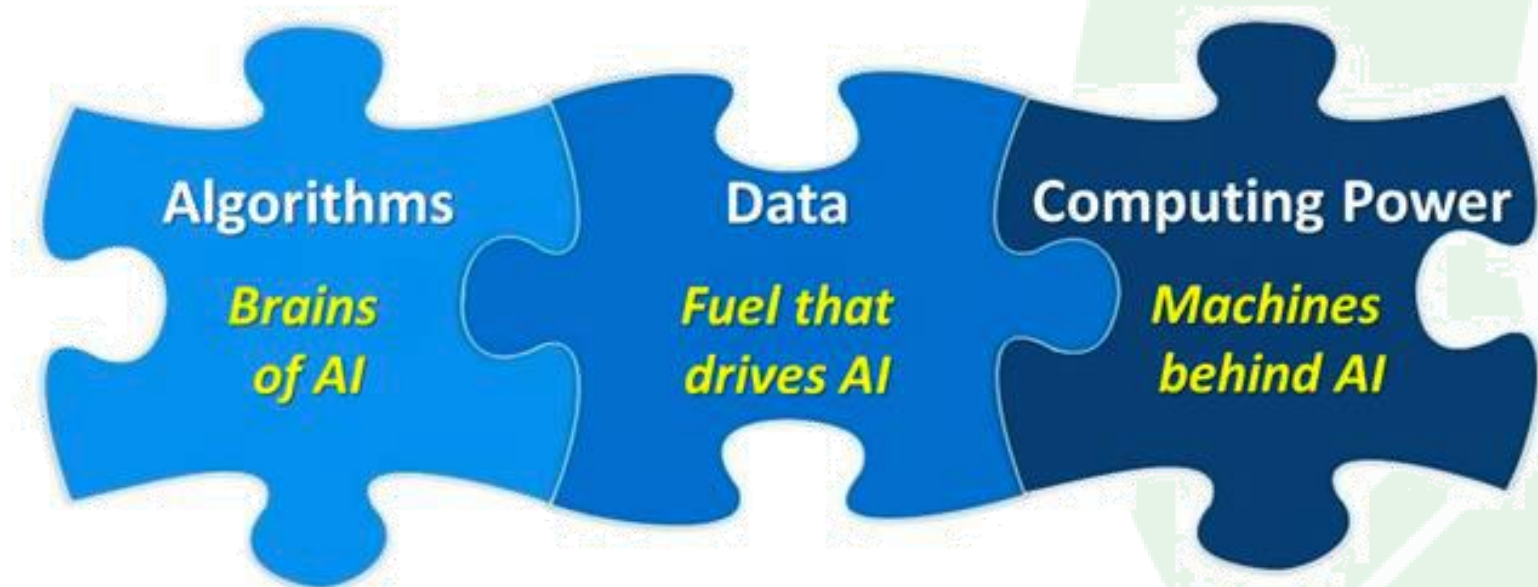
Machine Learning



Source: <https://renjithnano.medium.com/basic-concepts-used-in-ai-4027720e9503>



Core Components of AI



Algorithms tell computers
what to do.

Data tells computers
what to learn.

Computing power gives
machines the power to **learn**
and **make decisions.**

Data

Data is the fuel” behind modern computing and AI algorithms, allowing them to learn, find relationships in data and make informed predictions and decisions.

Data	Bytes	Size
1 Kilobyte (KB)	1,000	10^3
1 Megabyte (MB)	1,000,000	10^6
1 Gigabyte (GB)	1,000,000,000	10^9
1 Terabyte (TB)	1,000,000,000,000	10^{12}
1 Petabyte (PB)	1,000,000,000,000,000	10^{15}
1 Exabyte (EB)	1,000,000,000,000,000,000	10^{18}
1 Zettabyte (ZB)	1,000,000,000,000,000,000,000	10^{21}

- Figure: Paper ‘Artificial Intelligence Threats & Opportunities’ (EU Parliament, 2023) estimated that by 2025 the volume of data produced in the world each year could be 175 zettabytes

Data	Bytes	Size
1 Ronnabyte (RB)	1,000,000,000,000,000,000,000,000,000	10^{27}
1 Quettabyte (QB)	1,000,000,000,000,000,000,000,000,000,000	10^{30}

- Figure: The volume of digital data in the world is rising so fast, that in 2022 scientists formally agreed two new units of measurement for the first time in 31 years: Ronnabyte (RB) and Quettabyte (QB)

Data

This data explosion is largely driven by three factors:

- Increasing numbers of smartphones and internet devices: the number of devices connected to the internet grows every year.
- Growth of social media: social media platforms generate many terabytes of text, video and audio data every day.
- New data collection and storage technologies: new technologies, such as sensors placed throughout our cities, energy grids and transport infrastructure, are generating huge amounts of data on human usage patterns. Similarly the 'Internet of Things (IoT)', which are the networked everyday items (such as fitness trackers and Smart TV's) are growing in popularity and producing new streams of data.

Data

This increasing volume of data is also leading to a significant rise in cloud computing and data storage centres.

Companies have been working towards becoming more data-driven for many years, with some now using cloud computing to store and manage their vast quantities of data on remote cloud-based servers (rather than on premises computers), in either 'data lakes' or 'data warehouses' (or both).



Data

In particular 'big data' supports the rise of AI in the following ways :

1. **Training Data:** AI systems require substantial amounts of training data to learn patterns. This makes their predictions and decisions more accurate.
2. **Feature Extraction:** large and diverse datasets help AI algorithms to accurately identify and extract features from within data.
3. **Model Performance:** big data enhances the performance and robustness of AI models, allowing them to handle a wide range of situations and inputs.
4. **Predictive Analytics:** large datasets and AI can be used by businesses to forecast trends, regime shifts, reasons of changes, etc.

Data

5. Personalisation: when AI systems can access large volumes of data on human behaviours, preferences, and interactions they can provide tailored suggestions and experiences for users.
6. Natural Language Processing (NLP): NLP models, such as AI powered chatbots, virtual assistants and language translation systems, benefit from diverse and extensive language data, such as books, articles and social media posts.
7. Real-Time Decision Making: as the 'velocity' of big data accelerates AI systems can process and analyse this data in (near) real time to provide instant recommendations, or decisions that require extra warnings.

Computer Power

- Training AI systems typically requires a lot of data. This data can be very large and very complex and needs to be processed very quickly, which requires a lot of computing power.

For example, sophisticated AI chatbots (such as Google Bard, Microsoft Copilot) were trained on datasets that included hundreds of billions of words (for comparison the Bible contains fewer than one million words).

To download this volume data on a typical home internet connection and then process it for AI training could take **40 years on a standard computer!**

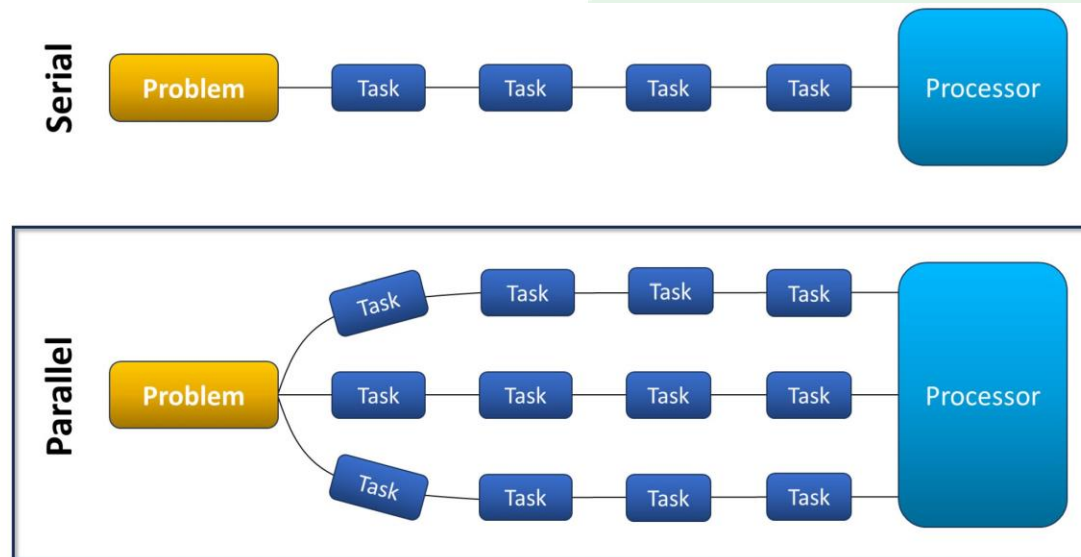
Computing power is crucial for training and deploying AI models. The complexity and size of modern AI models require significant computational resources to process large datasets and perform complex calculations.

Computer Power

Types of Computing Resources:

- Central Processing Units (CPUs): General-purpose processors that handle various computing tasks. While essential, they are often not sufficient for high-performance AI tasks.
- Graphics Processing Units (GPUs): Specialized processors designed for parallel processing are ideal for training deep learning models. GPUs can efficiently handle the massive computations required for training neural networks.
- Tensor Processing Units (TPUs): Custom-designed processors by Google specifically for AI tasks, offering optimized performance for training and inference of machine learning models.
- FPGAs (Field-Programmable Gate Arrays): Used in edge AI or low-latency environments.
- AI Supercomputers/Clusters: Combine thousands of GPUs/TPUs in data centers to train models like GPT-4 or Gemini.

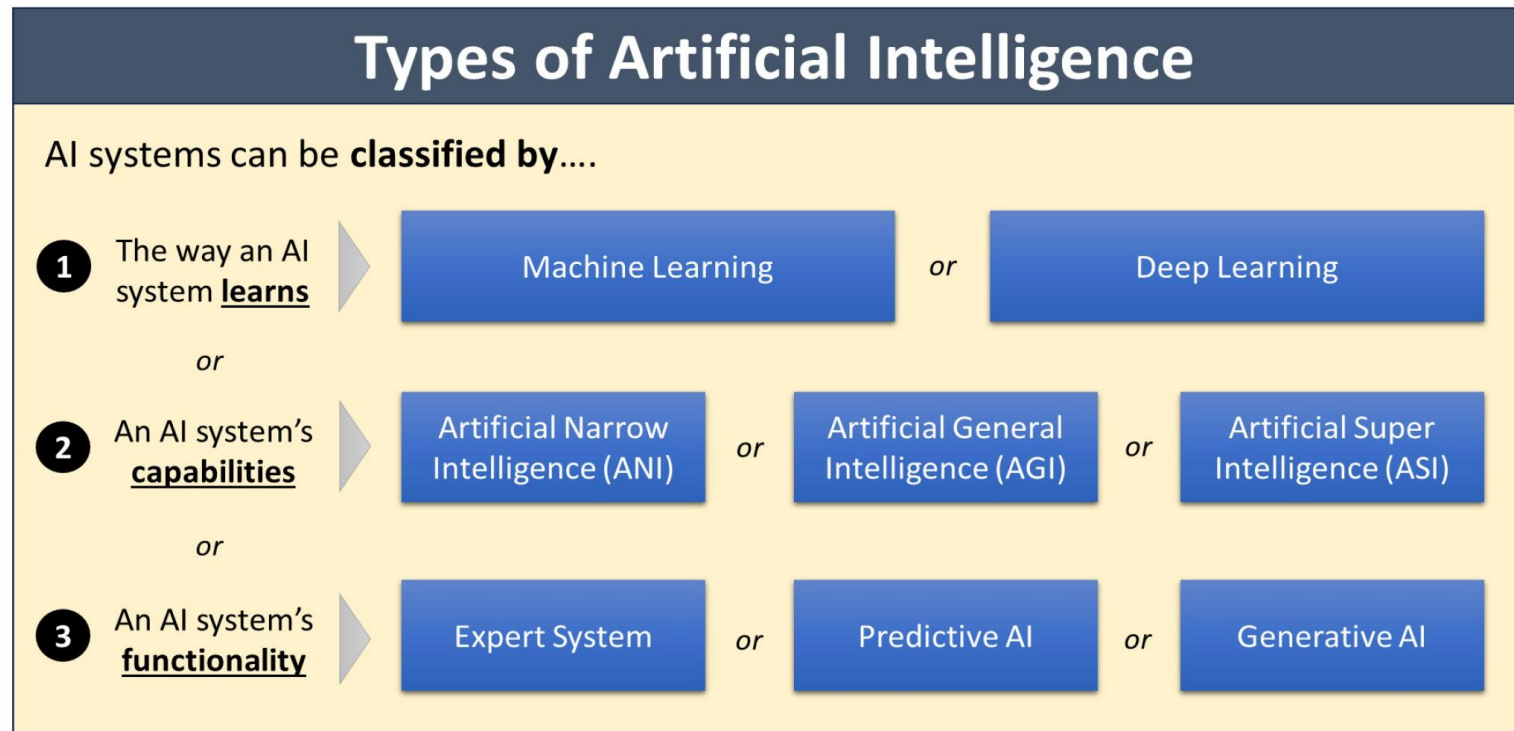
Computer Power



A key innovation is to process tasks in parallel (rather than sequentially as in normal computers), which turns out the accelerated parallel processing required to create lifelike graphics in computer games and movies is ideal for powering AI applications and especially deep learning systems, such as sophisticated computer vision aided assistants.

Types of AI

AI is a multi-use technology, with many different applications. There are therefore different ways that AI systems can be categorised, but they are normally segmented into one of three categories - either by the way they learn, by their capabilities or by their functionality.



Types of AI

Artificial Narrow Intelligence (ANI)

Also called **Narrow AI**, or **Weak AI**.
These are AI systems that are designed to perform one specific task (or a narrowly defined set of tasks)

Example ANI systems include a (simple) AI powered email spam filter, or a (complex) self-driving car

ANI systems cannot apply their knowledge to multiple areas (e.g. an AI spam filter cannot also operate a self-driving car)

ANI systems are the most common type of AI in use today

or

Artificial General Intelligence (AGI)

Also called **General AI**, or **Strong AI**. These are AI systems that can perform a range of tasks with human like performance and can also apply their knowledge to several areas (including topics they may not have been specifically trained on)

AGI systems do not yet exist, but are a major goal of AI research and can involve the integration of AI with robotics, so a system can 'think' and perform physical tasks

Several AI and robotics companies have a stated goal to develop AGI solutions

or

Artificial Super Intelligence (ASI)

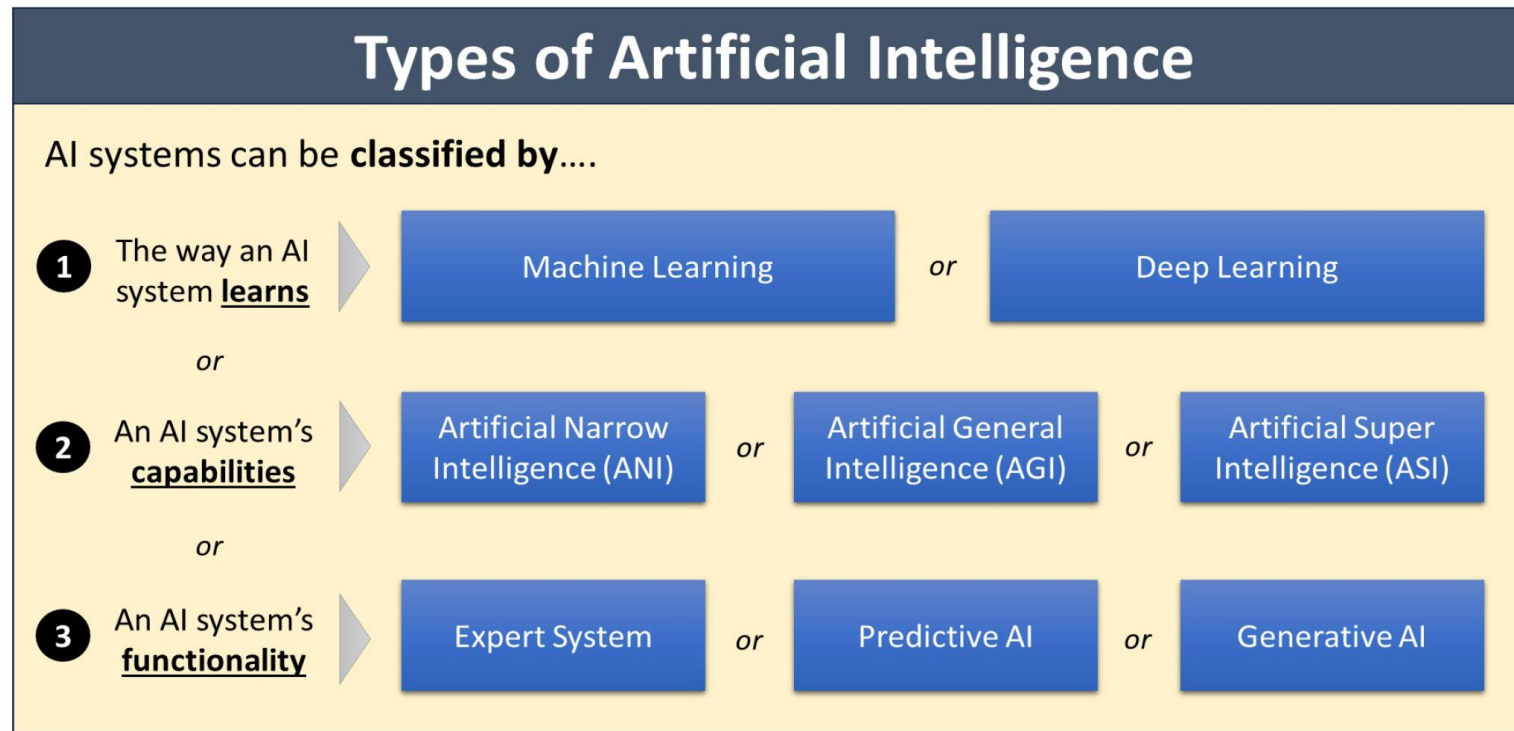
These are hypothetical AI systems that are more capable and intelligent than humans

They are often associated with a point in time known as the 'Singularity', which is a hypothetical point at which the growth of AI becomes uncontrollable and irreversible.

ASI raises many ethical and philosophical questions for the future of humanity

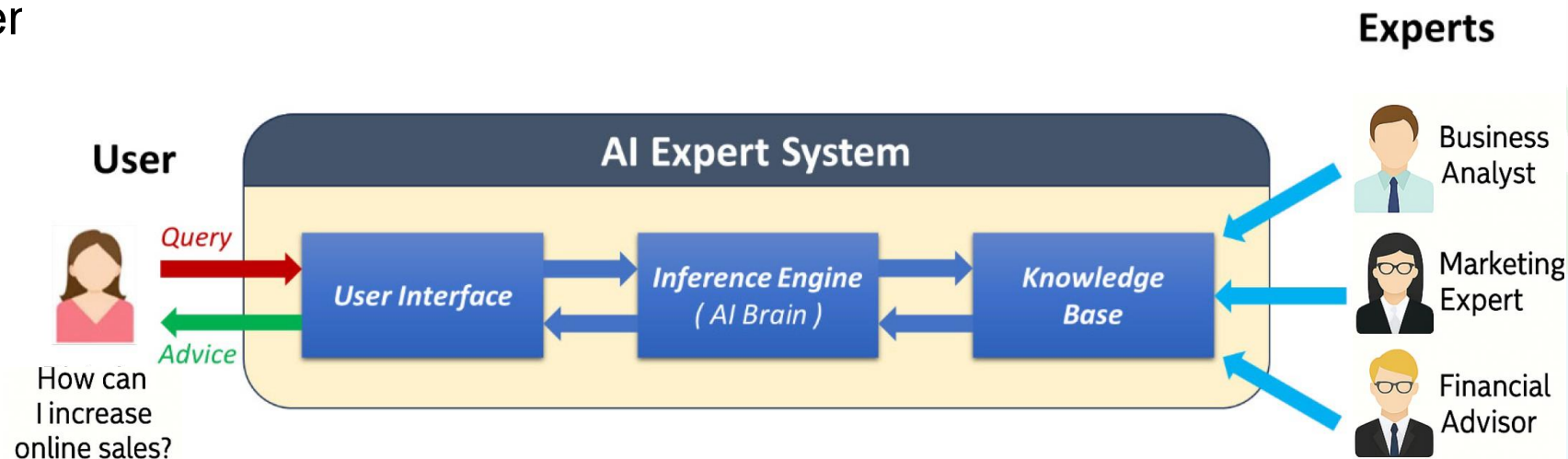
Types of AI

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Types of AI – Expert System

- An AI Expert System is a smart computer program that uses AI to simulate the expertise of humans in a specific area, such as for medical diagnosis, health monitoring or financial advice.
- Expert systems contain a knowledge base of rules and facts about a specific domain, which are combined with AI (in a system called an ‘inference engine’) to reason through problem



Types of AI – Predictive AI

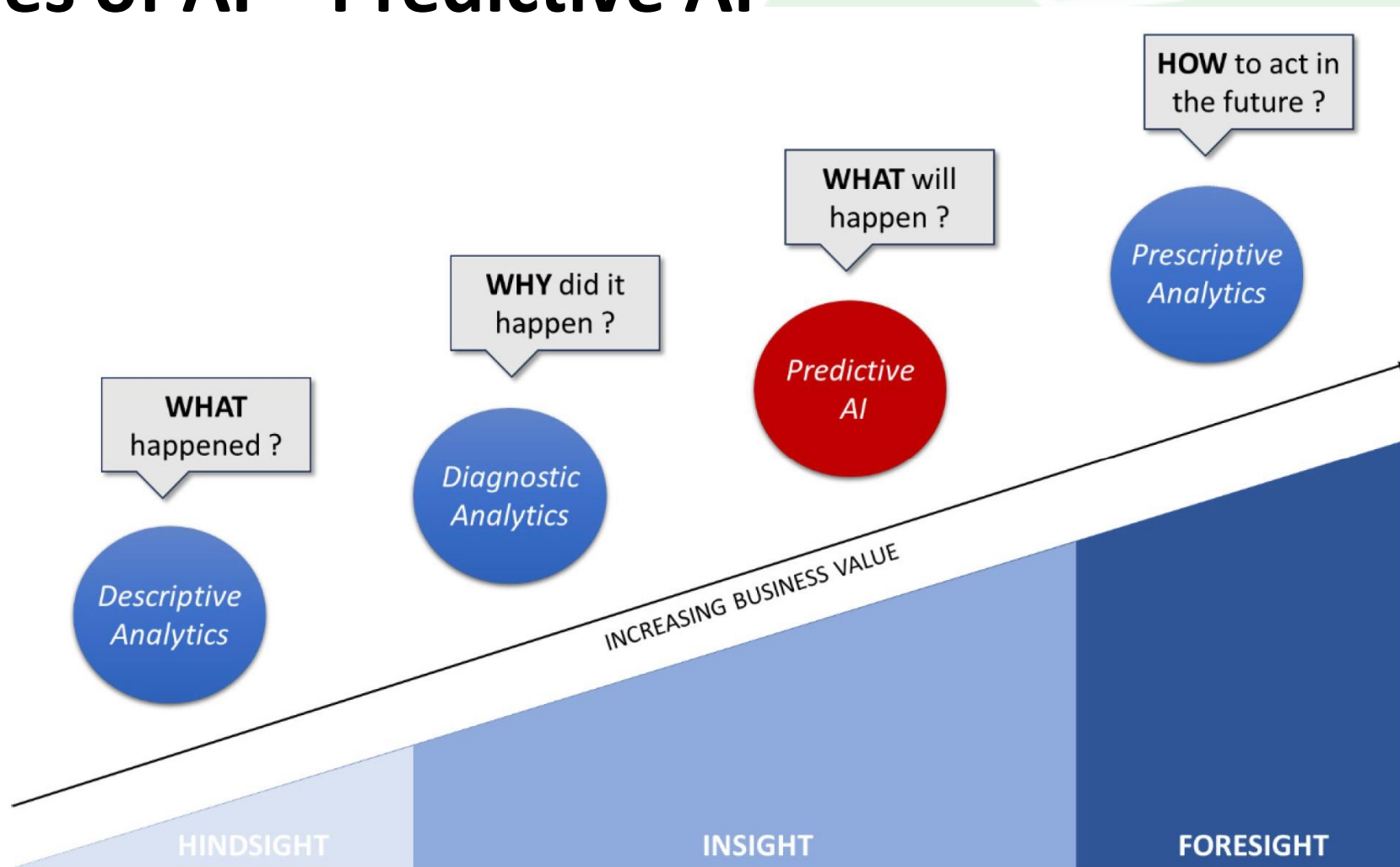
- Predictive AI is another way to classify an AI system's functionality and refers to AI that uses current and historical data to make predictions about future events, outcomes, or behaviours.
- They do this by analysing large amounts of data to identify patterns, trends and relationships that can help to anticipate the future.
- Predictive AI can also be combined with other forms of data analytics to create more comprehensive and powerful approaches to solving complex problems and gaining valuable business insights.

Types of AI – Predictive AI

Examples of other data analytical techniques that can be combined with predictive AI include:

- **Descriptive Analytics:** this summarises the past using historical data and helps to answer questions such as **WHAT**, **WHERE** and **WHEN** something happened by using methods such as dashboards, reports and other visual imagery to see and analyse patterns.
- **Diagnostic Analytics:** this aims to understand **WHY** something happened by investigating its root cause. These important insights from diagnostic analytics can also improve the accuracy of predictive AI models.
- **Prescriptive Analytics:** this suggests **HOW** to act in the future based on the data insights. It combines predictive AI forecasts with prescriptive recommendations it enables better planning and responses to potential future events.

Types of AI – Predictive AI



Types of AI – Predictive AI

- Supermarket data showed men buying diapers often also bought beer.
- Rule: {Diapers} → {Beer} with high support and confidence.
- This pattern was discovered through transactional analysis and used to optimize shelf layout
- Though partly anecdotal, it illustrates the value of unexpected insights.



Types of AI – Predictive AI

Apply association rule mining (Apriori algorithm) to automatically adjust nutrient levels in a smart hydroponic system powered by IoT and solar energy.

- Solar-powered smart hydroponic setup
- Real-time monitoring using IoT sensors:
 - TDS (nutrient concentration)
 - Water temperature
 - Air humidity
 - Sunlight intensity
 - Rain detection
- Data processed using Fuzzy Association Rule Mining (FARM) - extension of the Apriori algorithm



Source: Wedashwara, W., Jatmika, A. H., Zubaidi, A., & Arimbawa, I. W. A. (2021). Solar-powered IoT based smart hydroponic nutrition management system using FARM. IOP Conference Series: Earth and Environmental Science, 913 (1), 12010.

Types of AI – Predictive AI

Discovered Rule (example)

{TDS = low, temperature = high} → {Adjust nutrients}

Support: 0.40 and Confidence: 0.83

Results

- The system automatically adjusted nutrients 7 times in 1 week
- Improved growth consistency
- Reduced manual intervention and waste
- Showed that Apriori-based rule mining can support automation with basic sensors



Types of AI – Predictive AI

This is **Unsupervised Learning** because:

- No labeled outcomes (e.g., no "ideal nutrient adjustment" labels)
- Discovers patterns and associations in sensor data
- System learns which environmental conditions tend to occur together

Since the system works without pre-labeled targets and focuses on finding structure in the data, this is a clear example of unsupervised learning.



Problem: Predicting Waste Bin Overflow

In this scenario, we have data about bins such as bin location, historical data on waste accumulation, collection schedule, and weather conditions. The goal is to predict when a bin will overflow to optimize collection routes.

Approach:

Input: Features like waste volume measurements, time of last collection, location data, and weather information.

Output: The system will output a binary classification (overflow or not overflow) or a regression output (number of hours/days until overflow).

Example: Train a supervised model on labeled data (e.g., past collection logs) to predict when and where bins will be full, allowing waste management companies to schedule pickups efficiently and prevent overflow.

This is Supervised Learning because...

- Uses labeled historical data (e.g., past bin overflow events)
- Learns a relationship between input features and known outcomes
- Goal is to predict a target variable
- Since the model is trained on examples with known results, this is clearly supervised learning.

Problem: Real-World Challenge in Smart Hydroponics

A hydroponic system collects continuous sensor data like:

- Temperature
- pH
- TDS
- Humidity
- Light
- (...)

Students manually measure plant growth (e.g., height, leaf count).

But these measurements are infrequent and only available for a few plants...

Semi-supervised learning

is a machine learning method that uses a small amount of labeled data and a large amount of unlabeled data.

Key idea:

- The model learns structure from unlabeled data
- Refines its understanding using the labeled portion

In our exemple we have:

- Lots of unlabeled data: continuous sensor readings with no known plant outcome
- Few labeled data points: plant height or growth measured by students, only occasionally

- The model can combine both types of data to learn patterns
- It can generalize better than with labeled data alone
- This fits the **semi-supervised learning paradigm**

Problem: Optimizing Waste Collection Routes

The waste management system needs to determine the most efficient routes for garbage trucks, considering factors like fuel consumption, traffic patterns, bin fullness, and legal restrictions.

Approach:

Agent: A waste collection truck or fleet management system.

Environment: The city, with bins in different locations, and dynamic conditions like traffic and bin fullness.

Action: Choosing the next bin to visit or determining the sequence of bins to service.

Reward: Minimizing fuel consumption, time spent, and number of overflowing bins, while maximizing the number of bins emptied.

Example: Use **Reinforcement Learning (RL)** to dynamically learn the most efficient route for waste collection. The system receives feedback (reward or penalty) based on fuel used, traffic conditions, and number of bins emptied. Over time, the RL agent learns optimal routes, even as conditions change.

Problem: Automated Waste Sorting Using Computer Vision

A waste management facility might want to automate the sorting of recyclables from non-recyclable waste using deep learning techniques.

Approach:

Input: Camera images or videos of the waste items on a conveyor belt.

Output: Classifying items as plastic, metal, glass, paper, or non-recyclable.

Model: A **Convolutional Neural Network (CNN)** can be trained on large datasets of labeled images of waste to accurately classify waste into different categories. Model like **YOLO (You Only Look Once)** could be used to detect and classify multiple items in a single image.

Example: A deep learning-based system that processes real-time images of waste on a conveyor belt to accurately classify and sort materials like paper, plastic, or metal for recycling. Over time, the system improves its sorting accuracy by training on more labeled data.

Types of AI – Generative AI

Generative AI is a relatively new form of AI that burst onto the global scene in late 2022 with the release of a sophisticated AI chatbot called ChatGPT.

- AI chatbots are powered by generative AI, which is a type of AI technology that can produce new and creative content such as text, imagery, video and audio, from a user 'prompt'.
- It creates this new content based on the prompt and what it has learned from very large quantities of training data (sometimes many millions of internet pages) to produce a generative AI model.
- Generative AI has its origins in a 2017 Google research paper entitled “**Attention Is All You Need**”, which introduced a new type of AI architecture for language understanding called 'Transformers'.

From Generative AI to Large Language Models (LLMs)

Generative AI

- A class of AI systems that can create new content: text, images, code, audio, etc.
- Powered by deep learning, especially neural networks trained on vast data.
- Used in applications like image generation (e.g., DALL·E), music composition, and text synthesis.

A Specialized Branch: Large Language Models (LLMs)

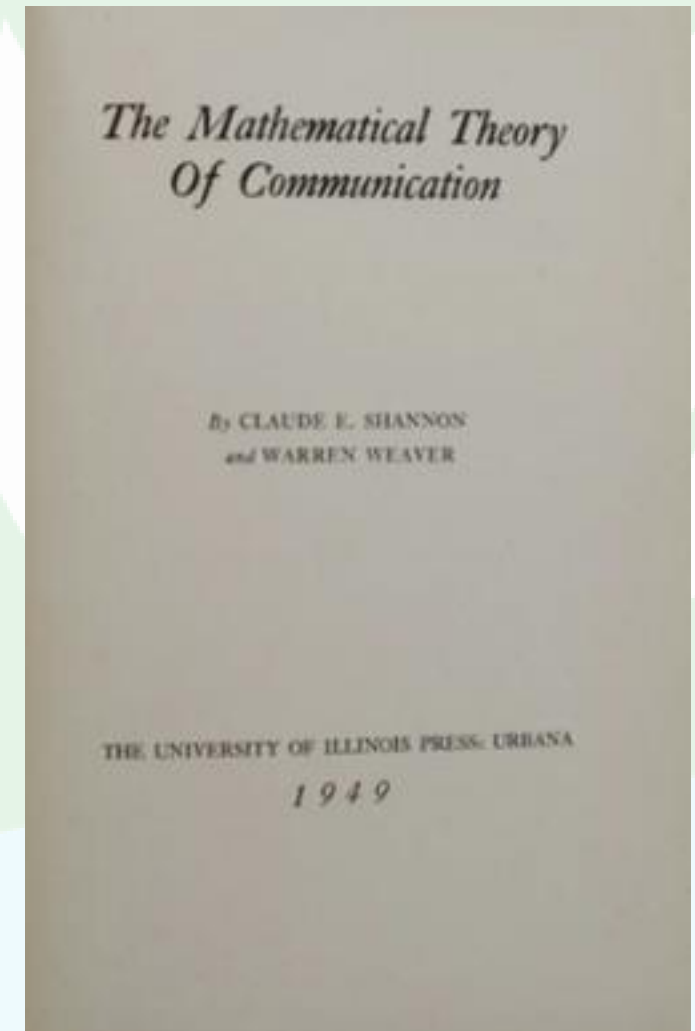
- A type of generative AI focused on natural language understanding and generation.
- Trained on massive text corpora to predict and produce coherent, human-like language.

Examples: ChatGPT, Claude, Gemini, LLaMA

LLMs

Despite the enormous popularity achieved by ChatGPT — whose rise began on November 30, 2022 — artificial intelligence, and in particular language models, have roots that trace back, in a way, to 1948, with the work of the well-known Claude Shannon, in the famous book ***A Mathematical Theory of Communication.***

In this book, Shannon proposes a mathematical model influenced by **Markov processes**, assuming the existence of a finite number of possible states and a set of probabilities associated with transitions between those states.



LLMs – What are they?

(using his own words)

- **Understand and generate human-like text**

LLMs are built to interpret natural language inputs and produce fluent, coherent, and context-aware responses, closely mimicking how humans communicate.

- **Predict the next word or token in a sequence**

At their core, LLMs operate by **predicting** what comes next in a text, enabling them to complete sentences, answer questions, or follow instructions based on prior context.

LLMs – What are they?

- **Model language through probabilities**

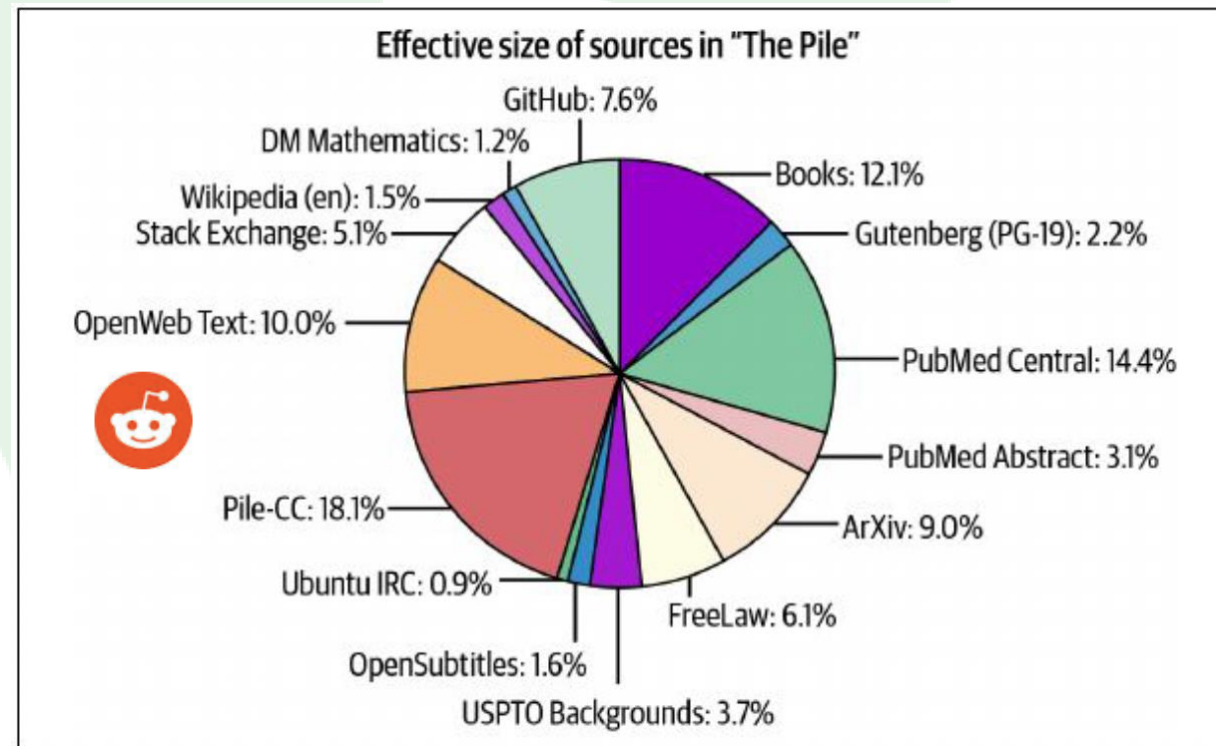
LLMs assign probabilities to every possible next word in a sequence, choosing the most likely one based on learned patterns — a process that underpins their ability to produce meaningful and relevant output.

- **Adapt to a wide range of language tasks without retraining**

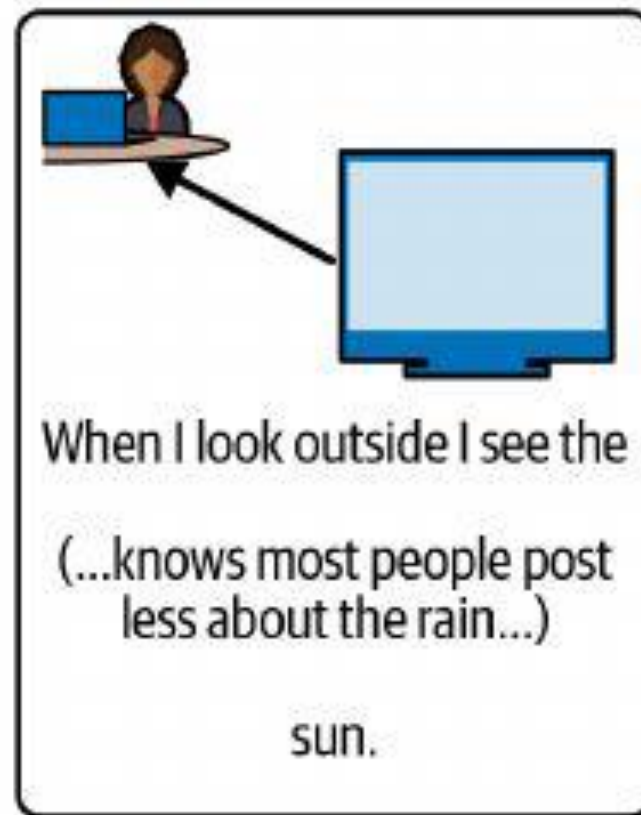
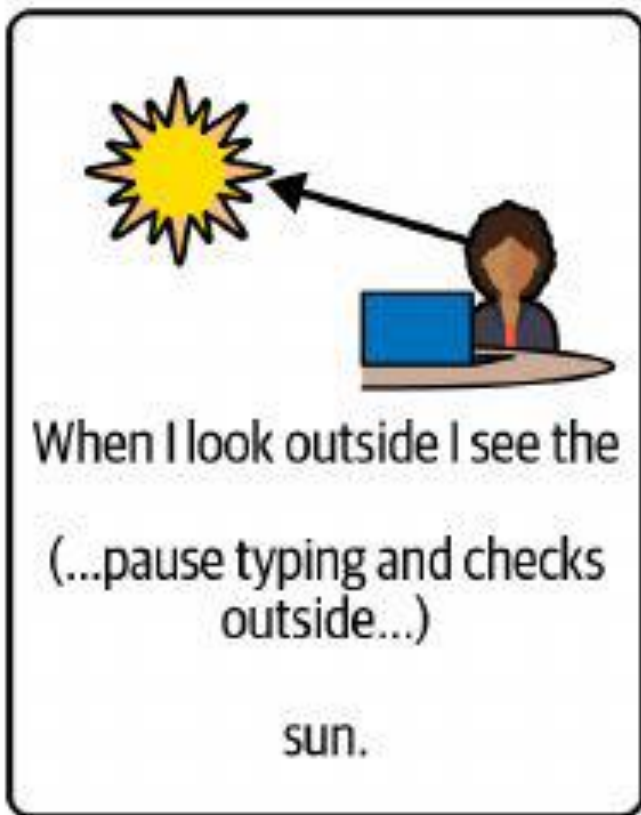
Once trained on diverse datasets, LLMs can perform a variety of language-based tasks (e.g., translation, summarization, coding) through prompting alone, without needing to be retrained for each new task.

LLMs – What are they?

- The image shows the types and proportions of text used to train LLMs — "The Pile" contains over **800GB** of varied content.
- If training includes sources like **PubMed Central**, the model tends to respond using **scientific language and reasoning**.
- LLMs don't just repeat — they learn **patterns of logic and expression** from their training data.
- The goal is to apply learned patterns **flexibly and intelligently**, adapting to different prompts and contexts.



LLMs vs Human



LLMs vs Human

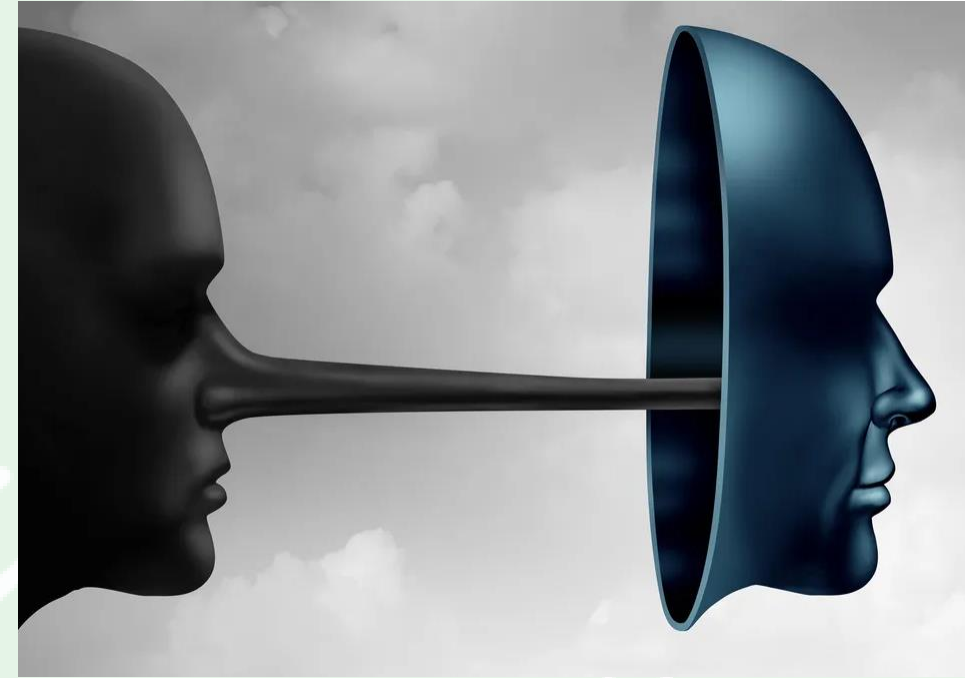
A human can express uncertainty, consult sources (books, the internet, LLMs 😊), and adapt to context or a fluid situation.

An LLM, in its most basic form and without the use of tools cannot:

- search for information — it only guesses;
 - express doubt;
 - admit that its answer is just a guess (since everything it generates is, in fact, the most probable next token/word... meaning everything is essentially a guess).
-
- This brings us to **hallucinations**

AI Hallucination

- Don't forget that AI can be wrong: "garbage in, garbage out"
- Model responses can be wrong, incomplete or simply made-up, a phenomenon often termed **hallucination**.
- Check AI output for inaccurate, misleading, biased, or plausible yet incorrect information



AI Hallucination

Factually incorrect information (such as non-existent links, among others) that appears plausible and, to the LLM, does not differ from other responses

Hallucinations can be induced, for example, by questioning the models and including false or non-existent information in the prompt, which the model will assume to be true.

This happens because the model tends to assume that the prompt is accurate — a phenomenon known as **truth bias**.

(With web-search capabilities, models are more resistant to this.)

The most cautious approach is to always verify everything, ask the model to explain its reasoning, or request data/links/values that we can independently check.

LLMs are powerful — but not magical!

They don't "understand" like humans, but respond based on patterns learned during training.

Their output depends heavily on how you ask...

This is where “prompt engineering” comes in.

Prompt Engineering – what it is?

“*prompt*” is a command given to elicit a response

“*engineer*” is someone who builds things

Prompt Engineering – what it is?

Prompt engineering is the practice of crafting inputs—called prompts—to get the best possible results from a large language model (LLM). It's the difference between a vague request and a sharp, goal-oriented instruction that delivers exactly what you need.

In simple terms, prompt engineering means telling the model what to do in a way it truly understands.

But unlike traditional programming, where code controls behavior, prompt engineering works through natural language. It's a soft skill with hard consequences: the quality of your prompts directly affects the usefulness, safety, and reliability of AI outputs.

Prompt Engineering – AI Literacy

Many AI non-experts do not know how LLMs generate their output

- There is a lack of understanding about which information is crucial to be included in effective prompts for LLMs
- Educating non-experts about the workings and best practices in crafting prompts can improve the utility and safety of these AI systems

AI and Sustainability – The dark side

- A typical ChatGPT user session (~10–50 prompts) uses around 0.5 L of water
- Training a GPT-3–sized model evaporates roughly 700,000 L of fresh water
- Projections estimate AI systems could consume up to 6.6 billion cubic meters annually by 2027 — more than all of Denmark.

AI and Sustainability – The dark side

Training and running AI models relies on massive data centers — and those need water.

A large data center can use up to **2.1 million liters of water per day** to cool servers, often in water-stressed regions.

Even smaller centers can consume 68,000 liters per day, equivalent to the daily use of 1,000 homes.

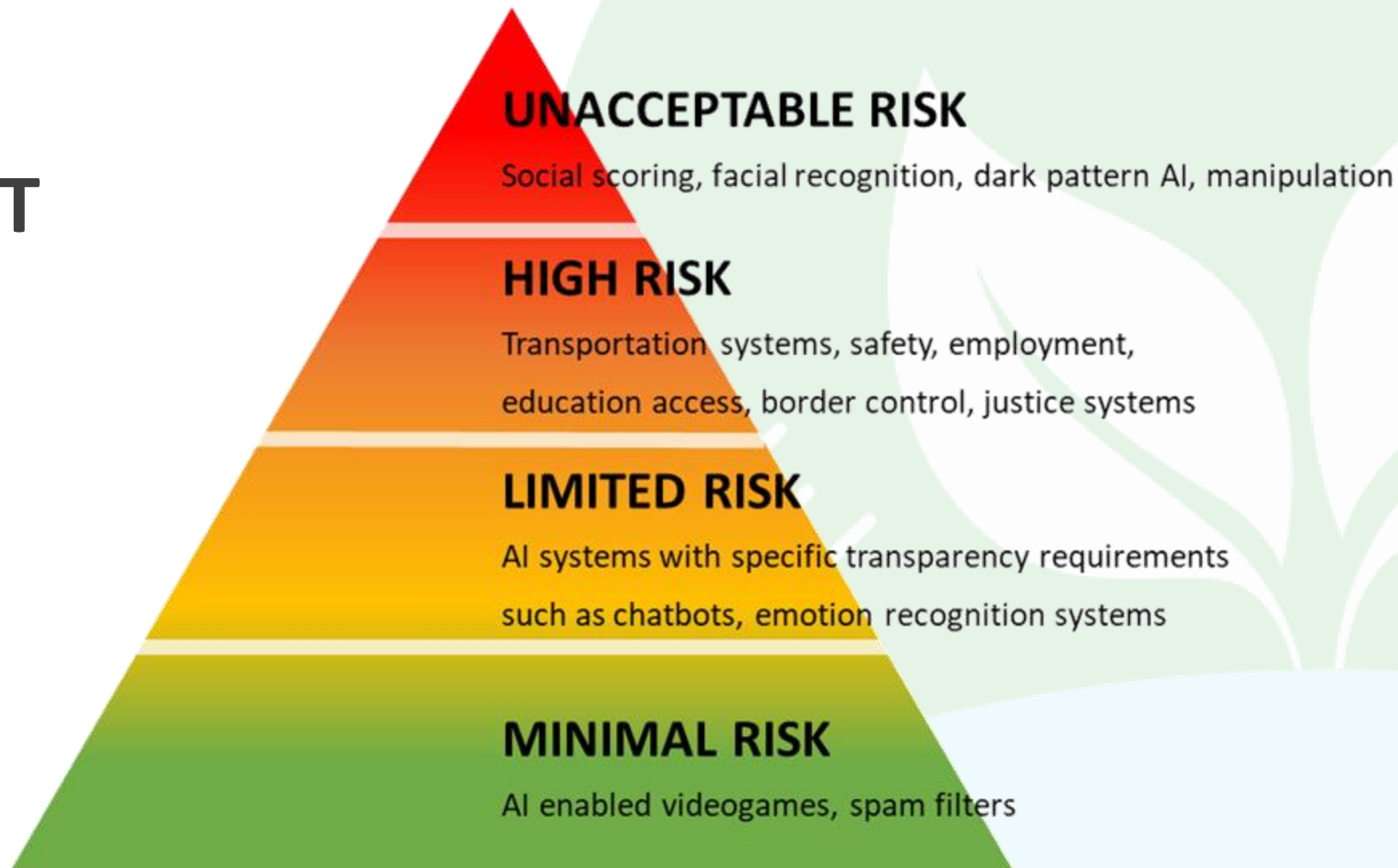
Ethics - AI ACT

As part of its digital strategy, the EU wants to regulate artificial intelligence (AI) to ensure better conditions for the development and use of this innovative technology.

AI can create many benefits, such as better healthcare; safer and cleaner transport; more efficient manufacturing; and cheaper and more sustainable energy.

On **March 13, 2024**, the European Parliament adopted the Artificial Intelligence Act (AI Act). It is considered to be the world's first comprehensive horizontal legal framework for AI. It provides for EU-wide rules on data quality, transparency, human oversight and accountability.

AI ACT



Use Case

A network of schools adopts a smart hydroponic system powered by AI and IoT to monitor student-led plant growth projects. Sensors collect data on: Nutrient levels (TDS, pH), Water usage, Light exposure and Plant growth rate (student input)

The system evaluates how well each student or group manages their hydroponic unit. It uses models to calculate a “growth performance score” based on:

- Sensor data quality and consistency
- Plant health and growth rate
- Adherence to care schedules
- Comparison with peers’ results

Students with low scores may receive lower grades, lose access to lab privileges, or be publicly ranked on a class leaderboard. Students with high scores may earn extra credit, scholarships, or public recognition. The AI model is treated as an objective evaluator, even though data can be noisy or context-dependent



UNACCEPTABLE RISK

Social scoring, facial recognition, dark pattern AI, manipulation

According to the AI Act (Article 6 & Annex III):

- Education domain: The AI system affects students' academic progression
- Automated scoring: Influences grading and public ranking
- Vulnerable group: Involves minors and classroom settings
- Lack of transparency: Students may not understand or challenge the system
- Social consequences: Creates pressure, inequity, and psychological risk

Under the AI Act, this scenario qualifies as **high-risk AI** and must comply with strict safeguards to protect learners' rights and well-being.

Agenda

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- Aligning hydroponics with STEM and other curriculum áreas
- Presentation of the HAI Platfform
- Insights of the HAI KIT

Why Hydroponics in Education?

Hydroponics = soilless plant cultivation using nutrient-rich water

- Offers experiential, interdisciplinary learning
- Supports STEM + sustainability + food systems
- Boosts student engagement, critical thinking, and career readiness

Why Hydroponics in Education?

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Pedagogical Shift: From Passive to Active

- Shift from passive content delivery to project-based learning (PBL)
- Encourages inquiry, creativity, and systems thinking
- Enhances equity in science access and climate resilience
- Students grow plants and ecological literacy

Interdisciplinary Applications

- Biology: plant growth, nutrient cycles
- Environmental science: sustainability, water use
- Engineering: system design, automation
- Data science: measurement, trends, analysis
- Real-world issues: climate change, food insecurity

Examples & Research

From the Ground Up (*Loizzo et al., 2024, USA*)

This project integrates hydroponics into secondary school STEM education through a structured curriculum supported by hands-on kits and virtual simulations. The goal is to foster inquiry-based learning around plant growth, water usage, and sustainability concepts. Students participate in real-time monitoring and engage with scientific reasoning.

Participants: urban high school students

Examples & Research

Rural Inclusion (*Tillett et al., 2024, USA – Midwest*)

Implemented in Winifred, Montana, this initiative introduced low-cost indoor hydroponic systems to a PreK–12 school. Supported by university students and faculty, the program aimed to expand STEM access in rural communities. It provided hands-on learning for K–12 students while also offering horticultural training to university seniors.

Participants: ~150 students (Winifred School, estimated)

Examples & Research

Aquaponics & Food Justice

Fasoli (2025, Sweden): Introduced aquaponics (integrating fish and plants) in primary schools as a tool for teaching environmental systems thinking and sustainability. Students managed real aquaponic systems, learning about nutrient cycles, ecology, and food production.

Participants: ~90–100 primary students (aged 9–12)

Examples & Research

Catalonia STEAM Project (*Llanas Parra et al., 2024, Spain*)

This STEAM initiative integrated aeroponics into both primary and secondary education in the Garraf region of Catalonia. Students co-designed sustainable food systems using aeroponics and IoT technologies. Younger students explored plant basics, while older students engaged in data collection, system programming, and ecological reflection.

Participants: 35 primary students (6–7 yrs) + 24 secondary students (12–13 yrs)

Agenda

- Introduction: AI in hydroponic systems with IoT
- Aligning hydroponics with STEM and other curriculum áreas
- Presentation of the HAI Plattform
- Insights of the HAI KIT

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- Introduction: AI in hydroponic systems with IoT
- Aligning hydroponics with STEM and other curriculum áreas
- Presentation of the HAI Platform
- Insights of the HAI KIT

HAI KIT – first draft

- Structure - 2 units
- Allows you to grow around 40 plants (25 growth + 15 nursery) and includes:
 - 1 nursery profile + 3 growth profiles
 - Accessories: plugs, injectors, tubes, hoses, brackets
 - Anti-rust Galvanized Iron Structure
 - Nutrient Solution Reservoir
 - Submersible pump
 - Timer (15 min on / 15 min off)
 - Nutrient kit for all plants
 - 25 mesh baskets for production profiles
 - Measurements:
 - Height: 1.0 m
 - Length: 1.1 m
 - Width: 0.50 m



HAI KIT – first draft

Component	Category	Function
pH Sensor (DFRobot SEN0161-V2)	Submerged	Measures acidity/alkalinity of nutrient solution
ORP Sensor (Seeed 501Z)	Submerged	Measures oxidation-reduction potential (water quality)
Analog TDS Sensor	Submerged	Measures total dissolved solids (nutrient concentration)
Turbidity Sensor (Seeed)	Submerged	Measures water clarity/transparency
Throw-in Liquid Level Sensor (5m) + Converter	-	Measures reservoir water level
Peristaltic Pump (NKP-DE-S10)	Submerged	Injects nutrients into the system
ESP32 Dev Board	-	Main controller (reads sensors, sends data)
LED Grow Light Strip 12V (1.1m)	-	Provides artificial light for plant growth
Relay Module (2-channel, 5V or 12V)	-	Controls high-power devices (lights/pump)
ADS1115 Analog-to-Digital Converter (ADC) for ESP32	If needed	Expands analog inputs for sensors
Waterproof Power Supply 12V/5A (for LEDs and pump)	If needed	Powers LEDs and pump safely

Thank you for your attention!