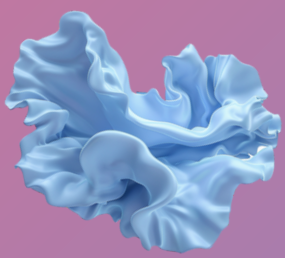
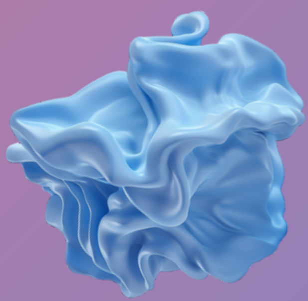
AI for Children

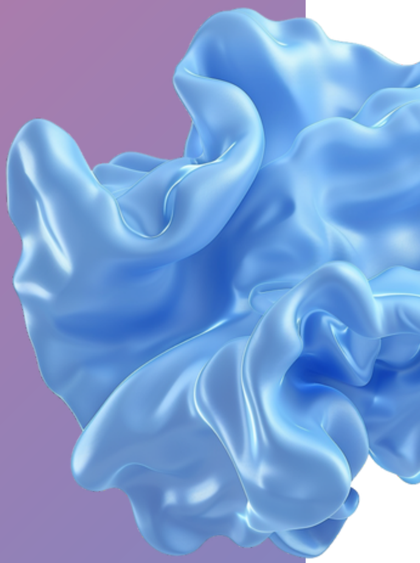
Artificial Intelligence Curriculum for Elementary and Secondary Schools

Physics I

Model – Black Box







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Form for comments

AI for Children's Artificial Intelligence Curriculum Teaching material
for the Development of Digital Competence for Elementary and Secondary Schools

Model – Black Box

A few words to begin

Dear Teacher,
The aim of this lesson is to give students a personal, hands-on experience in creating a model and gaining an understanding of its fundamental properties. As the object of modelling, we will use a didactic tool – a black box – which can be made from commonly available materials or printed using a 3D printer. This exercise is inspired by the work of German physics educator Horst Petrich.

– AI for Children team

Introduction

For this lesson, it is necessary to create a set of similar black boxes in advance, using cardboard or other materials. All the details are explained in the introductory video accompanying the methodology. You can find the link on page 03 in the chapter Preparation for Teachers.

Lesson presentation in PDF

Editable presentation in Canva

Lesson Overview

Prior Knowledge/Recommended Age, Lesson Length
Students are able to explain the term machine learning.
Children aged 13-15, 45 minutes.

Building Blocks
Model.

What Are the Students Learning?
Models are simplifications of complex systems and phenomena and are inherently imprecise.

Why Are They Learning This?
Based on the creation of the model, they will find out how its inaccuracies (distortions) arise.

How Do We Know They Have Learned It?
They apply methods to explore an unknown system, create a model that simplifies reality, and evaluate its accuracy.

Tools
Teacher: Projection equipment, presentation.
Students: Writing supplies, worksheet and black box for each group plus an exploratory tool (e.g. magnet, marble, wire, etc.).

Digital Competence
Facilitating Learners' Digital Competence.

Bloom's Taxonomy
Applying: Students apply various methods (e.g. magnet, wire) to explore the contents of the black box.
Evaluation: They assess the accuracy of their black box model and discuss how it could be improved by incorporating new information or methods.
Creating: They create a model (a drawing of the internal structure) of the black box.

Five Big Ideas
2-A-I Representation (Abstraction).

Note: Gender equality is key for AI for Children, but for brevity, we use masculine formulations in our methodologies.

Glossary of terms

Artificial Intelligence (AI)
There is no single, universally agreed-upon definition of artificial intelligence. However, most definitions agree that AI refers to systems that simulate human thinking and actions.
Artificial Intelligence typically takes the form of a computer program designed to solve tasks that once required significant human intelligence – tasks that were traditionally considered uniquely human.
AI is also a scientific discipline, with roots dating back to the first half of the 20th century. Its goal is not only to understand intelligent systems but, more importantly, to build them.

Machine Learning (ML)
Just as humans can learn from examples and experience, so too can machines created by humans.
The method they use is called machine learning, which enables AI systems to go beyond pre-programmed actions and generate new solutions on their own.
The goal of machine learning methods is to uncover patterns hidden within large volumes of data.

Machine Learning Model
This is the name given to a program that learns how to solve various tasks from many examples or experiences. Learning takes place in two phases – training and testing. For example, in the training phase, we show the model a number of examples (videos, images, texts, etc.) on which it learns by looking for patterns (similarities). In the testing phase, the model is given examples it has never seen before, so we can evaluate how well it performs.

Modeling
To model something means to create a simplified representation of reality that helps us better understand, analyze, or simulate complex processes, systems, or situations.

Examples:
In mathematics: Modelling means creating equations that describe the behavior of a system – such as the weather or an economy.
In art: Modelling refers to shaping materials like clay into specific objects, such as a sculpture.
In computer science and AI: Modelling can mean designing an algorithm that mimics real-world processes – for example, image recognition or predicting future outcomes.
In short, modelling allows us to work with simplified versions of complex things, which is useful for research, analysis, or prediction.

Preparation for teachers

Model

In education, abstract concepts are often used with the assumption that everyone understands them. In reality, however, students frequently lack a clear idea of what these concepts actually mean. One such frequently used and important concept across both the humanities and sciences is the notion of a model. We talk about AI models (computer science), Bohr's model of the atom (physics), the structural model of personality (psychology), statistical models (mathematics), and many others. But what exactly is a model? How is it created, and what are its defining characteristics?

While the term model does not have a single, unified definition across disciplines—and its meaning can shift depending on the context—it consistently shares several core characteristics:

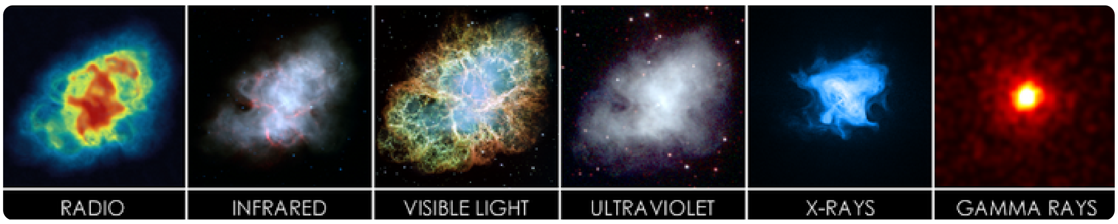
+ A model serves as a generalized or simplified representation of a phenomenon or idea.
+ Models are constructed using reasoning, observation, and data.
+ Because a model is a simplification, it inherently includes inaccuracies.
+ We use models to form hypotheses, but due to their imprecise nature, these hypotheses must be tested and validated through further investigation.
+ The accuracy of a model can often be improved by incorporating additional reasoning or data.
+ Models can be combined, refined, or simplified.

The analogy of real scientific research to exploring a black box

The work of scientists can be incredibly diverse, but they all share a common goal: to understand how the world works. To achieve this, they create—or verify—models that help them announce new discoveries, many of which later find real-world applications in the form of innovations.
Models are especially useful when dealing with complex phenomena or processes that are difficult to observe directly with our senses. These models need to be examined and validated using a variety of approaches. As such, their development often involves collaboration among numerous highly specialized experts. While there are many fascinating real-world examples of model creation, not all of them are suitable for classroom use—either because they are not easy to illustrate clearly or because of time constraints.

Let's take an example from astronomy.

Can we learn anything from data about the supernova explosion in the Crab Nebula, located in the constellation Taurus? Thanks to observations made with different telescopes—each capturing the nebula in a different part of the light spectrum—we are gaining a more complete picture of the energies, velocities, and distances involved. This allows us not only to better understand the Crab Nebula itself, but also to refine our models of supernovae based on data from other similar phenomena.



One example we can look at is the Carina Nebula – a massive complex of gas, dust, and stars located approximately 8,500 light-years from Earth. Due to its great distance and the thick, opaque dust it contains, astronomers cannot observe its structure directly. Instead, they rely on various imaging technologies, such as telescopes and instruments that capture different wavelengths of light. Each of these reveals a different facet of the nebula, and only by combining them can scientists form a complete picture of its structure and the physical processes taking place within it.

A simplified explanation of how different imaging techniques are used to study space objects – specifically the Carina Nebula – is illustrated in this two-minute video: youtube.com/watch?v=lW9qrVeZ6z8.

Similarities between a black box, the Carina Nebula, and an artificial intelligence model

All three systems – a black box, the Carina Nebula, and an artificial intelligence model – share a common characteristic: they are complex, and their internal structures or mechanisms are not directly accessible or visible. Understanding how they function requires the use of indirect methods of analysis and modeling.

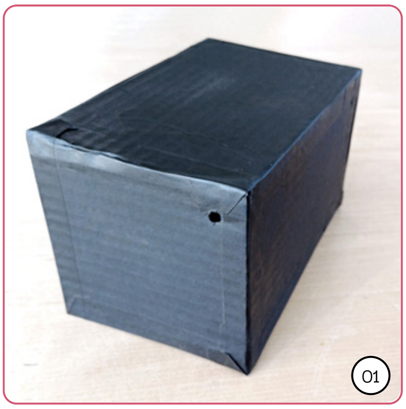
To make the analogy easier to grasp, the following table provides a comparison:

Aspect	Black box	Carina Nebula	AI model
Unknown structure or content	The internal structure is not accessible.	The interior is obscured by dust and distance.	The processes inside the AI model are not fully understood.
Indirect methods of analysis & visualization	Experiments using sounds, movements, and magnets.	Light analysis across different wavelengths.	Visualization and analysis of internal attributes.
Hypothesis and modeling	Students infer the internal structure based on observation.	Astronomers model its structure based on data.	Researchers hypothesize about the model's decisions.
Limits of observation or data	Reliant on simple tools.	Constrained by technology and available data.	Limited by tools and model interpretability.

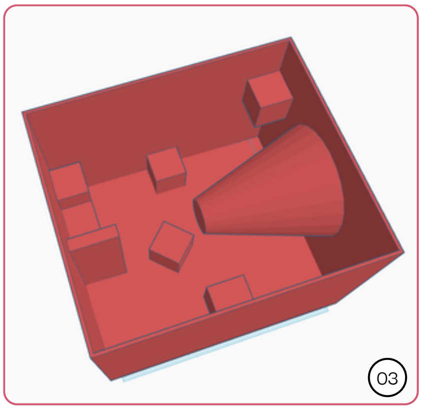
Black box demonstration

investigative methods. For example, you can examine the black box (images 01 and 02) using a magnet with a metal ball or a piece of wire. Your students will likely come up with their own creative approaches to exploration as well.

If you'd like to 3D print the black box, a 3D model has been prepared for you by Stanislav Jakoubek (image 03). You can download it from Tinkercad.com.


01


02


03

The student's work in understanding the black box is an analogy to creating an artificial intelligence model. Machine learning builds models based on data, which are then used to make predictions and decisions. Much like when students explore a black box–an unknown system they must investigate using various methods–they construct a model through observation and experimentation, uncovering hidden relationships that aren't directly visible. In doing so, students come to understand that the inaccuracy of the research method is an inherent aspect of any model.

Engage

5 min

Think about it. 5 min

Show your students a black box that you've prepared and ask them what they think it might be.
Make sure to mention the term black box.

Sticky note method (or alternatively, use Mentimeter or a similar app)
Students write their answers on sticky notes (individually or in pairs), and then the notes are grouped together based on similarities.

Pass the black box around, and then have the students come up with and write down on sticky notes different ways they could figure out what's inside (without opening the black box).
We have prepared two suggested methods for the students to explore the box – from the outside using a magnet and a metal ball inside, and also by using a wire that can be inserted into the box through a small hole.

There are things we cannot look at directly, yet we still form ideas about them. Can you think of any specific examples?
Possible answers: People have an idea of what the Earth's core looks like, even though they can't see it. Other examples include nebulae in space, black holes, electrons...

Understand

25 min

Activity 1 25 min

Presentation slide 02 or 03

Students work in groups to explore the internal structure of black boxes (presentation slide 02 or 03)
Divide the students into groups based on the number of black boxes you've prepared. Hand out the black boxes and worksheets.
(Choose the drawing in the worksheet that most closely matches the shape of the black box you created.)
Students explore the internal structure of the black box using pre-prepared tools:

Magnet: They move the metal ball inside and draw its internal structure based on that.
Ball: They listen to the sound the ball makes as it moves inside the box.
Wire: They use a wire inserted through a small hole to map the inner structure of the box.

Each group writes down their observations and draws a hypothesis about the internal structure of the box.

TIP
You can either give each group access to all the investigation tools, or assign each group just one method and then have them compare their results with one another.

Students compare their findings. You can guide the discussion with questions such as:
Did the findings differ depending on the investigation method? If yes, how? Why do you think that is?
Which method do you think gave the most accurate results? Why?
How would you improve your black box investigation process if you had more time or a different tool?

Explain to the students:
Machine learning builds models based on data, and then uses those models to make predictions and decisions. Just like in the black box activity – where we explored an unknown environment using different methods – machine learning also works by observing patterns and inferring relationships that are not directly visible.

Explain:
Just like we explored the black box using different methods, scientists also investigate distant nebulae – such as the Carina Nebula – using indirect methods. They use telescopes and other instruments that detect different wavelengths of light to create models of these objects.

Presentation slide 04

Play the students this video.
In a simplified way, it shows the various ways in which the Carina Nebula can be visualised: youtube.com/watch?v=lW9qrVeZ6z8.

Even in this case, we cannot directly see the structure of the nebula. But by combining data from different observation methods, scientists can build a more accurate model.

Reflect

15 min

Discuss, evaluate

Do you think models are always accurate?
Models are not always accurate because they are simplified representations of reality and may contain errors or inaccuracies. In practice, we deal with this by continuously updating and improving models using new data and observations. We can also reduce inaccuracies by combining different methods of investigation.

How is creating a model (drawing what it looks like inside a black box) similar to working with machine learning models?
Model building involves defining a goal, collecting data, testing, and adjusting the model based on results – similar to how scientists and engineers create models for complex systems, including machine learning (ML) models. In both cases, we try to understand complex phenomena by simplifying them into a form that allows for prediction or classification.

What are some other examples of models in real life where we have to estimate or investigate something we can't directly see?
Examples include weather forecasting models, economic models to estimate GDP growth, medical models for disease spread, or Bohr's model of the atom – which helps us understand atomic structure, even though we can't see atoms directly.