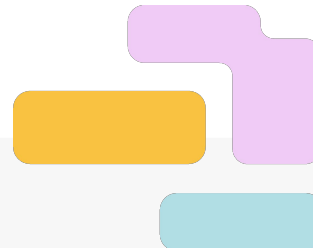




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Developing unplugged resources to teach about neural networks

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RASPBERRY PI
COMPUTING EDUCATION
RESEARCH CENTRE



What we're talking about today

- ★ AI Education in Ghana
- ★ Unplugged & Unplugged AI
- ★ Background to study
- ★ Description of role play and board game
- ★ Evaluation with teachers
- ★ Summary
- ★ What else we do & how to stay in touch with us!



Rationale - learning about AI in school

Integrating AI learning objectives into official school curricula is crucial for students globally to engage safely and meaningfully with AI. (UNESCO, 2024)

AI literacy represents the technical knowledge, durable skills, and future-ready attitudes required to thrive in a world influenced by AI. It enables learners to engage, create with, manage, and design AI, while critically evaluating its benefits, risks, and ethical implications. (OECD, 2025)

AI is currently nationally implemented in school in:
China, Finland, Hong Kong, Singapore, South Korea, Thailand, UAE. **And Ghana!**



AI Education in Ghana

Educational Context

- Basic education is compulsory in Ghana.
- JHS education is designed to equip learners between the ages of 13 and 16 with academic skills in reading, writing, arithmetic, problem-solving and creativity.
- In 2021, the National Council for Curriculum and Assessment (NaCCA) introduced a new computing curriculum into basic schools.



AI Education in Ghana

- This new curriculum features modern computing topics such as programming, algorithms, **artificial intelligence** and robotics.
- AI as a substrand in the curriculum includes topics such as applications of AI in society, neural networks, comparison of intelligence in humans and machines, classical AI and machine learning.



What is included in the curriculum

Basic 7

- Discuss the applications of various areas of AI.
- Discuss the uses and importance of AI to society.

Basic 8

- Discuss artificial neural networks and compare intelligence in humans and machines.
- Discuss the difference between strong and weak AI.

Basic 9

- Describe the knowledge-based systems (expert systems) as classical AI.
- Demonstrate how to use Google's Teachable Machine demo to get a basic understanding of how machine learning works.



Teaching Unplugged

What is unplugged?

- Unplugged involves teaching computing away from the computers. Physical objects are used to illustrate abstract concepts.
- Variations include role-playing computation, puzzles, games and magic.
- Abstract concepts are made physical (Curzon et al, 2023).
- Started as a means of outreach (Bell et al, 2009)
- Unplugged activities generally involve some kind of challenge that students try to solve themselves. (Bell, 2009)



The AI learning levels framework (SEAME)

Social, Ethical considerations SE level	e.g. knows about the idea of bias in Machine Learning (ML) and how this impacts their lives
Application A level	e.g. identify some ML applications, can design an application that includes ML image recognition
Model M level	e.g. can explore an ML model that was created by someone else, understands the process for selecting and cleaning data needed to train a simple ML model
Engine E level	e.g. can explain how a decision tree can be used to classify items, can explain in simple terms how a neuron works with relationship to learning about ML

rule-based
easier to explain
e.g. decision trees



data-driven
less easy to explain
e.g. neural networks, deep learning

Waite, J., Tshukudu, E., Cucuiat, V., Whyte, R., & Sentance, S. (2023). Towards a framework for learning content analysis in K-12 AI/ML education. In *2023 IEEE Frontiers in Education Conference (FIE)* (pp. 1-5). IEEE.

AI in a Box



Using AI systems to predict and prevent crimes.



Is it an AI application or not?

These unplugged activities focus on societal and application level aspects of AI



Developed using AI (fake) or not?

Examples of AI unplugged resources

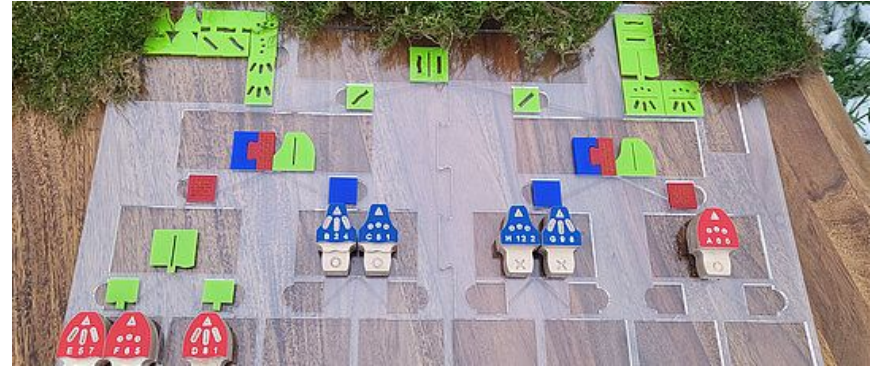
University of Würzburg

Professor Silvia Joachim



Learning k-nearest neighbours algorithm



These unplugged activities focus primarily on the Engine level of SEAME



Learning about decision trees

<https://www.informatik.uni-wuerzburg.de/didaktik/aktivitaeten/ki/>

Resources from Prodabi

Apfel		Popcorn	
			
Nährwerte pro 100g		Nährwerte pro 100g	
Energie	52 kcal	Energie	499 kcal
Fett	0,2 g	Fett	23,0 g
davon gesättigte		davon gesättigte	
Fettsäuren	0,0 g	Fettsäuren	13,8 g
Kohlenhydrate	13,8 g	Kohlenhydrate	57,0 g
davon Zucker	11,0 g	davon Zucker	3,8 g
Eiweiß	0,3 g	Eiweiß	10,7 g
Salz	0,0 g	Salz	1,8 g

Decision trees with data cards

Apfel oder Popcorn? Eine enaktive Einführung in KI, maschinelles Lernen und Entscheidungsbäume mit Datenkarten

[MORE >](#)

Learning about decision trees

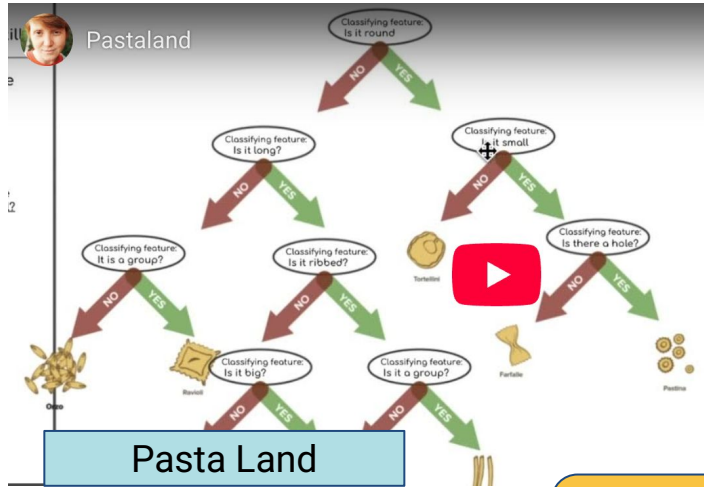
These unplugged activities combine the Application and Engine levels of SEAME



Learning about reinforcement learning

Podworny, S., Fleischer, Y., Hüsing, S., Biehler, R., Frischemeier, D., Höper, L., & Schulte, C. (2021, November). Using data cards for teaching data based decision trees in middle school. In *Proceedings of the 21st Koli Calling International Conference on Computing Education Research* (pp. 1-3).

MIT's DAILY (Developing AI Literacy) curriculum



These unplugged activities focus on the Engine level of SEAME (but DAILY has other activities too)

1.2 Neural Networks Lesson

DID YOUR NETWORK LEARN?

<https://raise.mit.edu/resources/curricula/daily/>


Learning about neural networks

Summary of the benefits of learning unplugged


- ★ Abstract concepts made concrete
- ★ Tangibility (touch) supports learning
- ★ Learning can be presented in real contexts
- ★ Helpful in low-resource environments
- ★ Engaging and fun

Some unplugged activities are more tangible than others





**Developing unplugged resources to teach about
neural networks in the Ghanaian context**



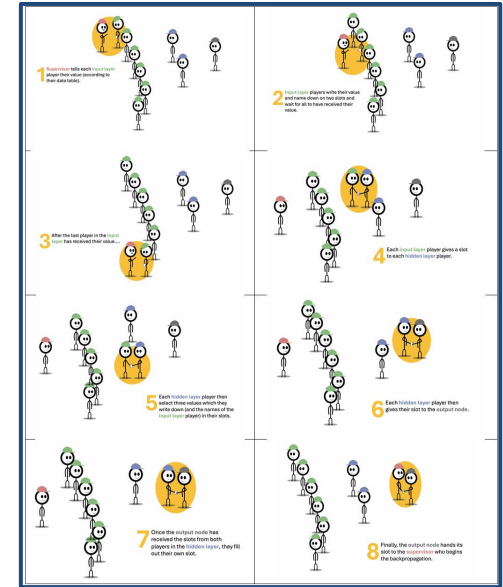
Background to the study (1)

- In 2024 I conducted a case study on AI education in Junior High Schools (JHS) within the Tema district in Ghana.
- Teachers interviewed reported a lack of PD relating to AI.
- One teacher reported that teaching about neural networks was particularly challenging.
- Rather than use existing online resources relating to neural networks, I wanted to develop resources that were contextualised to Ghana.



Background to the study (2)

- In 2025, I developed a role play and board game as a tool for explaining how neural networks are trained for students in JHS.
- These resources were developed through an iterative process with many rounds of feedback.
- I piloted the resources in the UK with education researchers, AI experts and two computing teachers in Ghana online.
- In June 2025, I further piloted the resources with 43 computing teachers at a teachers' workshop in Tema.
- Ten of these teachers were observed in the classroom while they implemented these resources followed by a teacher interview.



Resources for neural networks: the learning objectives

- The primary learning objective was to help students identify and distinguish the processes of **forward propagation**, **evaluation**, and **backward propagation** involved in training a **neural network**.
- The resources represent an effort to demystify the opaque nature of neural networks without relying on mathematics or programming.
- The focus is on developing teaching materials that are contextually and culturally relevant without dependencies on ICT infrastructure.





The role play

- The role play is an activity within the context of **farming and crop disease**, an accessible context for Ghanaian teachers and students.
- The purpose of the role play is for players to **identify features that are relevant for detecting diseases on a cocoa tree**. Students take on the roles of supervisor (one), input layer (six), hidden layer (two) and the output layer (one).
- Ropes and cards are used to note what is passed between players are used to facilitate movement between layer.
- By the 3rd training iteration, students are able to see **how neurons from the input, hidden and output layers are connected**, with each weight of the connection pointing to the trust the preceding neuron builds with the subsequent neurons.
- Identifying these connections helps students identify which input neurons represent the **relevant features for predicting crop disease**.

The role play

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The role play (the data set)

- We ensured data was in numerical format; hence not entirely a qualitative feel of neural networks.
- The features of the data are easy for the students to understand, e.g. Is the temperature suitable? (0=No, 1=Yes)

Supervisor data table: Farms								
Give to	A	B	C	D	E	F		
Farm (round)	Temp 0=No 1=Yes	Spots 0=No 1=Yes	Fertilizer 0=No 1=Yes	Leaf colour 0=Green 1=Otherwise	Distance 0=Near 1=Far	Family farm 0=No 1=Yes	Disease present	Predict- ion
1	0	0	1	0	1	1	0	
2	1	1	0	1	0	0	1	
3	1	0	1	1	0	0	1	
4	0	0	1	0	1	1	0	
5	0	0	1	0	1	1	0	

Progression of the activity (Feed forward)

Present the data set to the supervisor with the following instructions for both the supervisor and input neurons

Supervisor

Forward propagation

You start

- 1 Show each player in **input layer** their value from your data table.
- 2 Make sure players in **hidden layer** and output node aren't watching.

Round ends

- 3 When the output node has selected a prediction begin back propagation (backside)

Input Layer

Forward propagation

A
name

After **supervisor**

- 1 You will receive a value from **supervisor**. Remember it. Wait until all have received one.
- 2 Write down the value received and your name in the slot provided, and pass it to players in the **hidden layer**.

Progression of activity (feed forward)

In a typical feedforward neural network, each neuron first computes a weighted sum of the input values and then applies an activation function to that result.

However, to keep this activity simple without advanced mathematics for the students, we used random selection of inputs. This randomness reflects training neural networks in the real world, where weights are often initialised with random values at the start.

Students were also instructed to choose only three of the six input values, which represents the idea that some weights may initially be set to zero.

Hidden Layer

Forward propagation

name

After all **input layer** players

- 1** You will receive a value from each player in **input layer**. Write all 6 down.
- 2** Select 3 of the 6 values. During first round select randomly. Afterwards choose based on trust (rope).
- 3** Pass on the 3 selected values to the output node.

Progression of activity (feed forward)

Unlike in a typical output layer when threshold functions are used to determine the prediction of the model, in our activity we used the following heuristic: *the output is 0 if both majority values are 0; otherwise, the output is 1.*

This design decision was used because it avoids the mathematical notion of threshold functions and students find easier to understand.


Output Node

Forward propagation

After all **hidden layer** players

1 Receive 3 values from each player in **hidden layer**, making a total of 6.

2 Write them down while also writing down the majority value.

 If player G in the hidden layer gave you 0,0,1 the majority value would be 0 (it occurred most times)

3 Make a prediction using the following rules:

Round 1: Pick 0 if both majority values are 0; otherwise, pick 1.

Later Rounds: Pick the majority value from the more trusted player (rope). If trust scores tie, use the Round 1 rule.

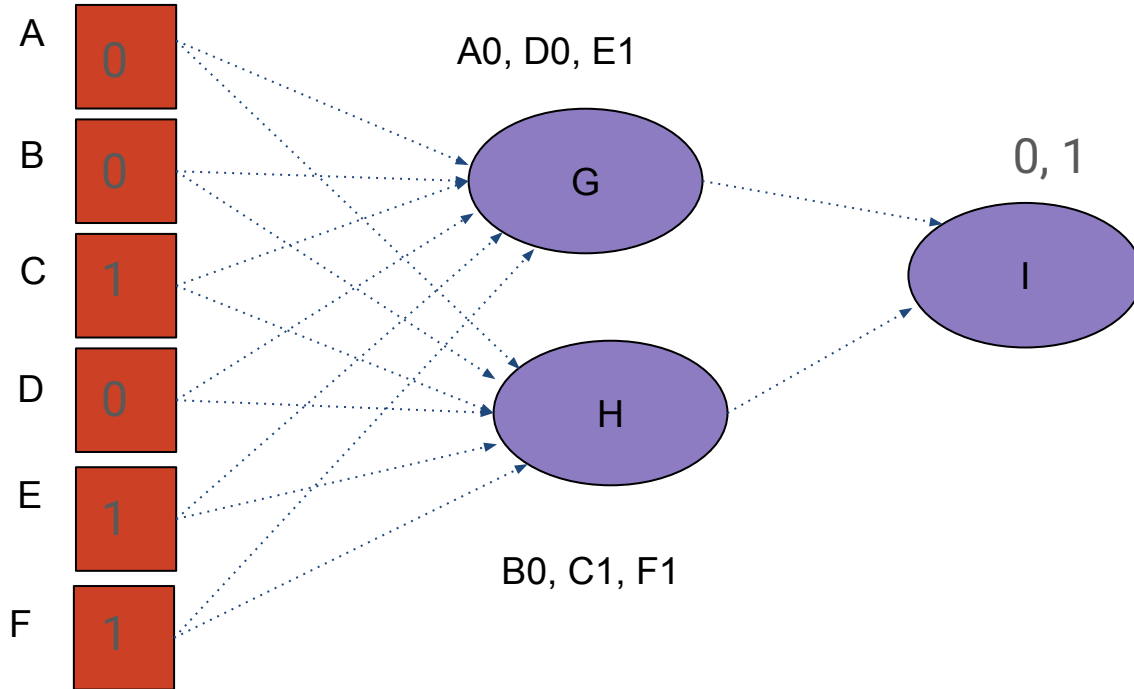
Progression of activity (evaluation)

At the end of the feedforward stage, the output layer evaluates how well the network performed by comparing the predicted output (output generated by the forward propagation process) to the actual value.

This is analogous to using the loss function to calculate or assess the error of the network.

Output Node slots							
	G		H				
Round	Values	Majority Value	Values	Majority Value	Prediction	Actual	✓
2							
3							
4							
5							

Feedforward (Summary)



Iteration	Actual	Prediction
1	0	1
2		
3		
4		

Progression of activity (backpropagation)

After the error of the network has been calculated, the error is shared back through the network on a layer-by-layer basis until it reaches the input layer.



As a researcher, backpropagation which involves calculus was challenging to model.

Thus, we drew inspiration from MIT's RAISE (Responsible AI for Social Empowerment and Education) depiction of backpropagation in their role play activity (establishment of trust).

Supervisor

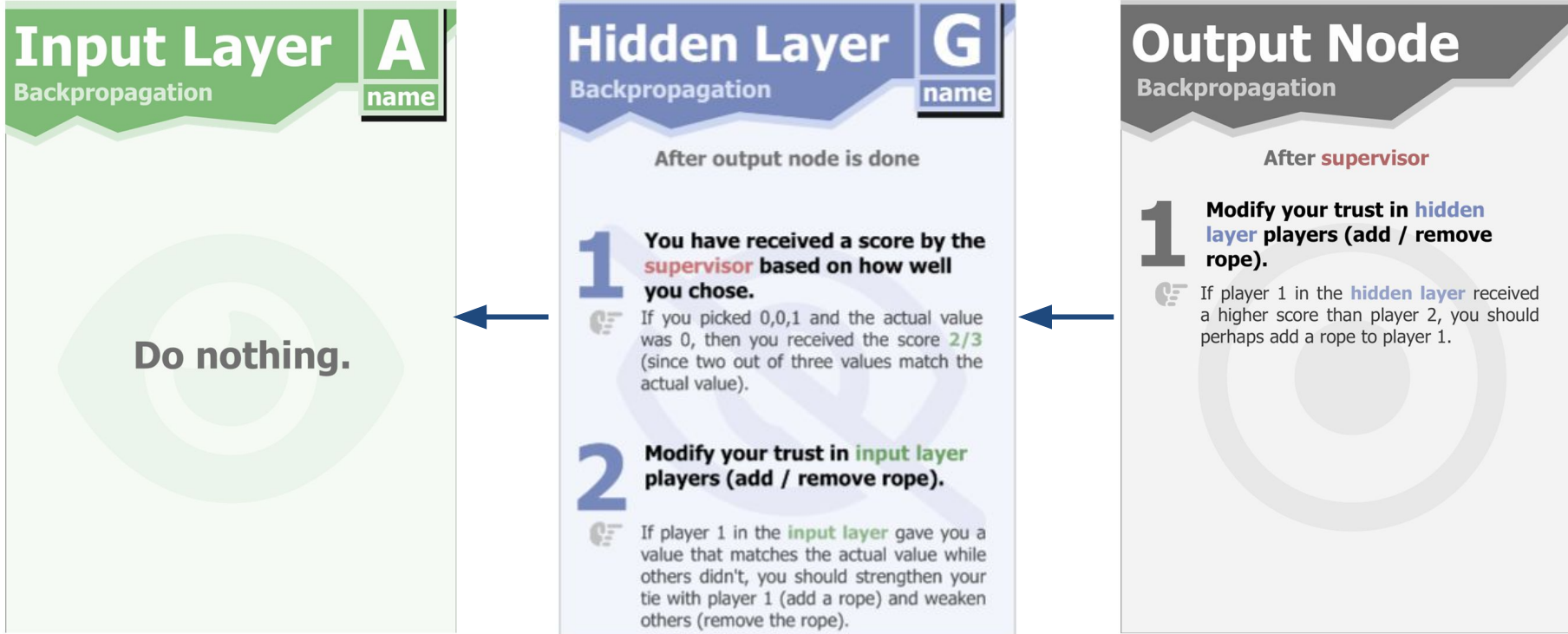
Backpropagation

You start

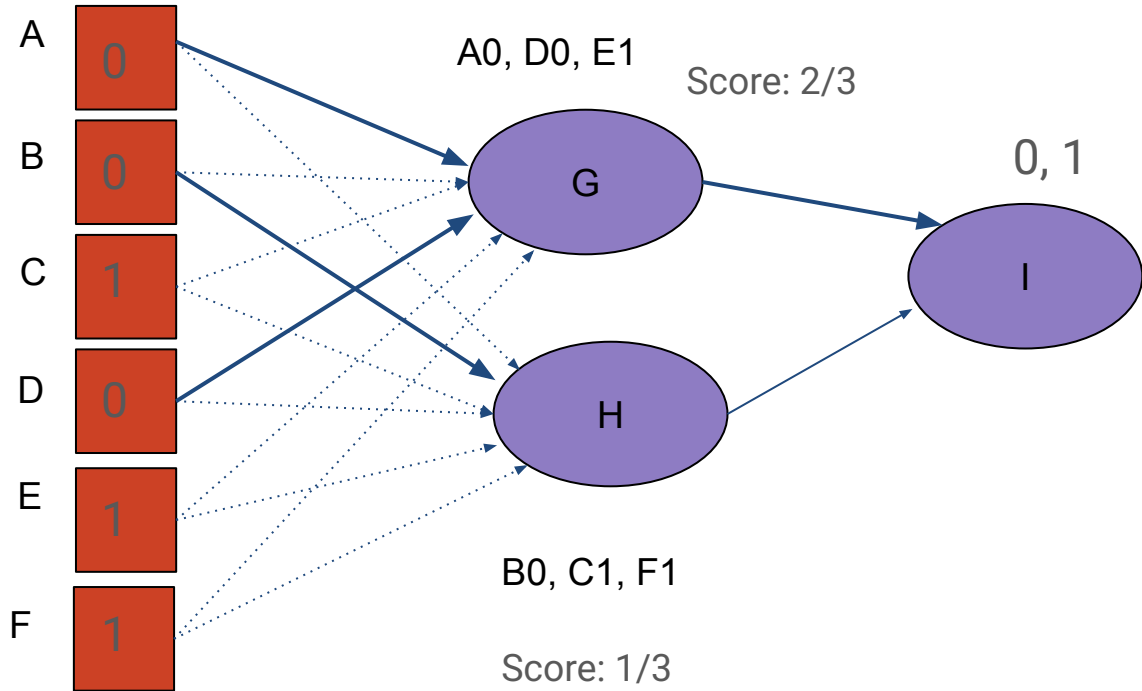
- 1 Evaluate prediction of the player as output node.**
 Player predicted 1 and the actual value was 0, the prediction was **wrong**.
- 2 Score the correctness of players in the hidden layer based on their choices.**
 Player selected 0,0,1 and the correct value was 0 they receive a score of **2/3** (since two out of three values match the actual value).

Round ends
- 3 When all players in the hidden layer have reinforced their connection.**

Progression of activity (backpropagation)



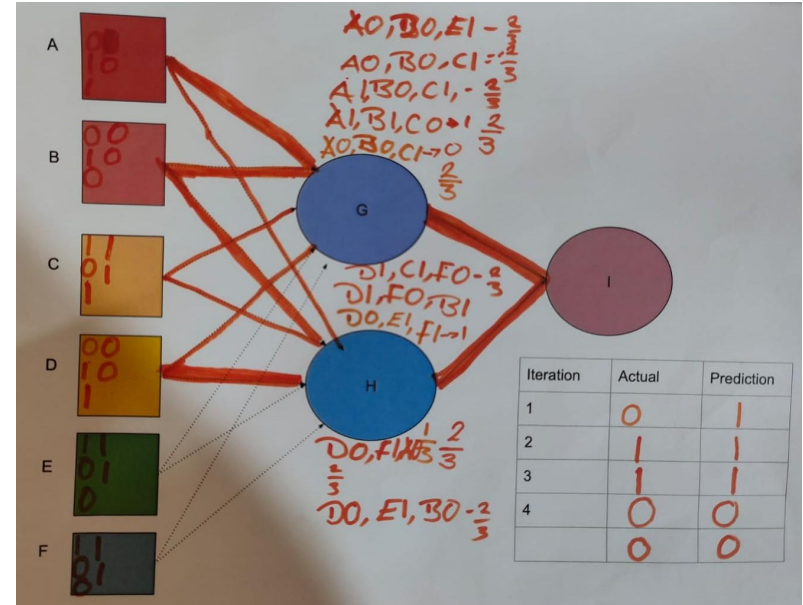
Backpropagation (Summary)



Iteration	Actual	Prediction
1	0	1
2		
3		
4		

The board game

- We designed a board game as a simplification of the role play.
- The same training data and processes are used, and it can be played with as few as two player.





How were the resources evaluated?

- ❖ We organised two workshops with 43 teachers where we assessed their self-efficacy beliefs to teach about neural networks using a pre and post-intervention surveys.
- ❖ 39 teachers completed the survey.
- ❖ Ten teachers implemented the unplugged activities in their classroom.
- ❖ We conducted 10 post-observation teacher interviews to obtain teacher feedback.

Teachers' feedback after implementing the game in the class

Teacher	Category	Feedback
Enam	Simplify instructions	<i>“: I think the role play, what we could have done better. I think everything is on point. Maybe the instructions, if there is a way to simplify the instructions maybe it will help....”</i>
Sammy	Effective for classroom demonstration of neural networks	<i>“Where we did the propagation, when we aligned them they could detect which information was going to which part. So they were actually listening to what was happening. So they were actually enjoying the lesson. So they can [see] that this is the input layer, hidden and output layer.”</i>

Teachers' feedback after implementing the game in the class

Teacher	Category	Feedback
Judas	Learner-centered	<i>“ The children did all the work. We only had to walk around and check what they were doing, helping them to understand. ”</i>
Enam	Supports diverse learners	<i>“We have diverse students in the class. So it helps to some extent where if it is the traditional lecture method or teacher centered method most of them will not be engaged ordinarily in anything but because they have something hands-on to do they are able to take part effectively. Like one of the boys who was part of the hidden layer he is not the average student but because of the activity he responded. He was also here and then he was able to follow instructions from the supervisor..”</i>



Summary

- AI unplugged activities are useful resources/tools for teaching about AI in low-resource settings.
- They are effective for demonstrating technical concepts in AI, such as neural networks without the use of computers or the internet.
- They foster classroom engagement and learner-centered learning.
- They promote inclusivity and diversity in the classroom.



What is next?

I am currently analysing data collected for this study and I look forward to continuing my work on developing resources for teaching AI concepts in K-12 educational settings.



Wrap up and how to stay in touch



The Raspberry Pi Computing Education Research Centre

Who we are and what we do

- A joint initiative between the University of Cambridge and the Raspberry Pi Foundation
- Established in July 2021, formally launched in July 2022
- Investigate the teaching and learning of computing, computer science, and associated subjects.
- Focus on collaborative work with schools to ensure that research can readily inform practice.

Scope

- Young people (3-19)
- Formal and non-formal learning
- Equity, access and inclusion underpin all our work
- Primarily direct work with schools & teachers

Website at <http://computingeducationresearch.org>

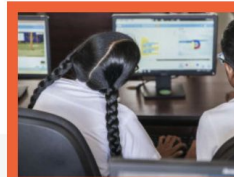


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AI education for young people

[View projects +](#)



Broadening participation in computer science

[View projects +](#)



Curriculum

[View projects +](#)



Pedagogy, including teacher professional learning

[View projects +](#)



Physical computing

[View projects +](#)



Programming education

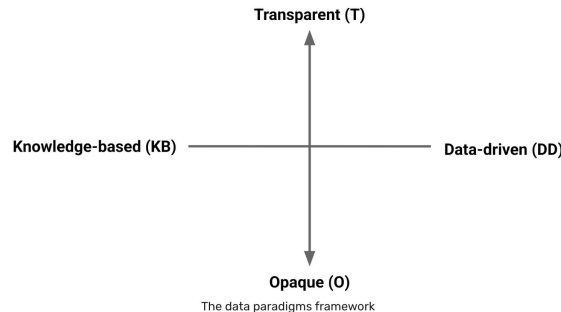
[View projects +](#)

Learning About AI - other current research

Developing a framework for data paradigms

Literature review (WiPSCE 2026)

Primary school study (ongoing) (7-11)



AI Ethics (11-14)

- Scoping literature review
- Analysis of interventions to teach about AI ethics
- Aligned to UNESCO framework
- Scoping a study in lower secondary school

What AI concepts and skills should we teach (14-19)?

- Experts', students' and teachers' perceptions of what young people need to know about AI
- Underpinning values and beliefs around AI education and the rationale for introducing AI in school
- Applying the four traditions of computing education to AI education

Keep in touch with us!

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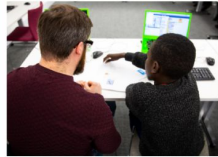
Learning about AI: AI Concepts and Skills

[Read more +](#)



Investigating K-12 data ethics education

[Read more +](#)



Teaching with AI: Integrating AI tools into the teaching of programming in K-12

[Read more +](#)



Exploring the role of data science in K-12 computing education

[Read more +](#)



Experience AI Design Principles Study

[Read more +](#)



AI in schools in the UK and Ghana

[Read more +](#)

Other non-AI work includes physical computing, cybersecurity education, sociotechnological agency, debugging

Follow our work at
<http://computingeducationresearch.org>

Sign up to receive our termly newsletter!

Attend Raspberry Pi Foundation research seminars (1st Tuesday of the month)!

Thank you and questions

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