UNIVERSITY OF CAMBRIDGE

Raspberry Pi Foundation

Developing Unplugged Resources to Teach About Neural Networks in Junior High Schools in Ghana.

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RASPBERRY PI
COMPUTING EDUCATION
RESEARCH CENTRE

What we’re talking about today

- ★ Unplugged AI
- ★ AI Education in Ghana
- ★ Background to study
- ★ Description of role play and board game
- ★ Evaluation with teachers
- ★ Description of AI stories
- ★ Summary

AI Unplugged Around the World

What is CS 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)

AI in a Box (Germany)

Using AI systems to predict and prevent crimes.

Is it an AI application or not?

Developed using AI (fake) or not?

Lindner, A., Berges, M., Rösch, M., & Franke, F. (2023, October). Implementing a Portable Learning Lab on Artificial Intelligence: It's AI in a Box!. In *International Conference on Informatics in Schools: Situation, Evolution, and Perspectives* (pp. 26-39). Cham: Springer Nature Switzerland.

Examples of AI unplugged resources (Germany)

University of Würzburg

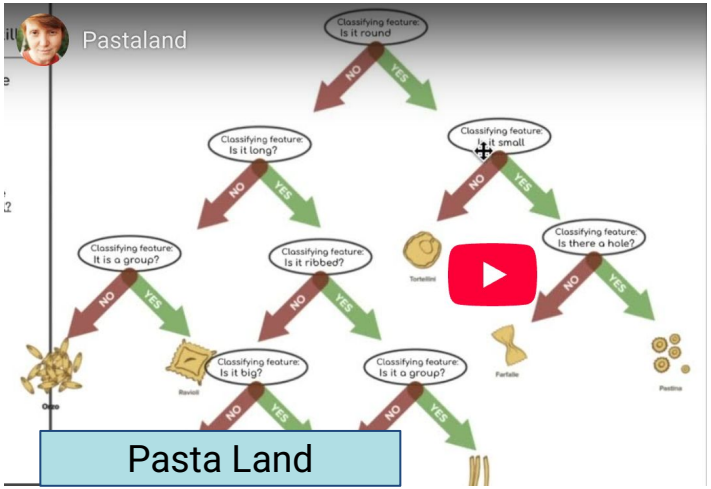
Professor Silvia Joachim

Learning k-nearest neighbours algorithm

Learning about decision trees

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

MIT's DAILY (Developing AI Literacy) curriculum (US)



Learning about decision trees

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

1.2 Neural Networks Lesson

Learning about neural networks

Summary of the benefits of learning unplugged

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

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

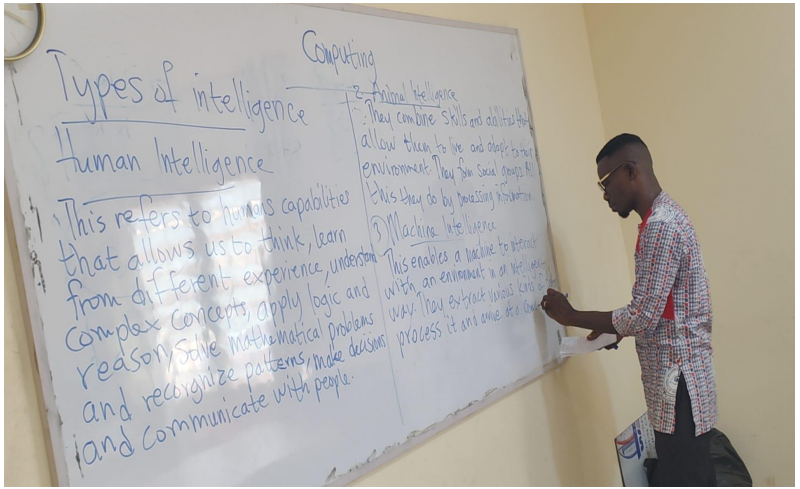
- Discuss artificial neural networks and compare intelligence in humans and machines.
- Discuss the difference between strong and weak AI.

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.

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.

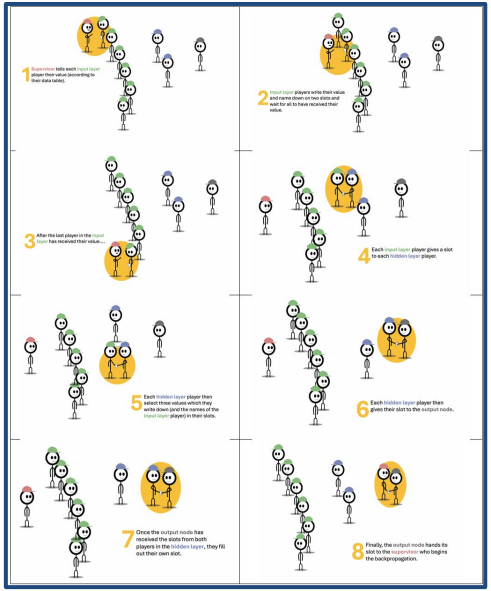


- Rather than use existing online resources relating to neural networks, I wanted to develop resources that were contextualised to Ghana.

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

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

- 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 and to facilitate connection between layers.

The role play (the data set)

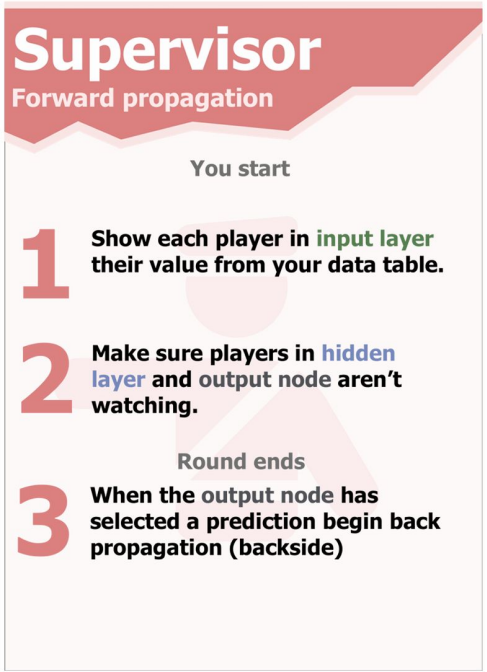
- We ensured data was in numerical format; hence not entirely a qualitative feel of neural networks.
- The features of the data are easy for the students to understand, e.g. Is the temperature suitable? (0=No, 1=Yes)

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 (forward propagation)

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

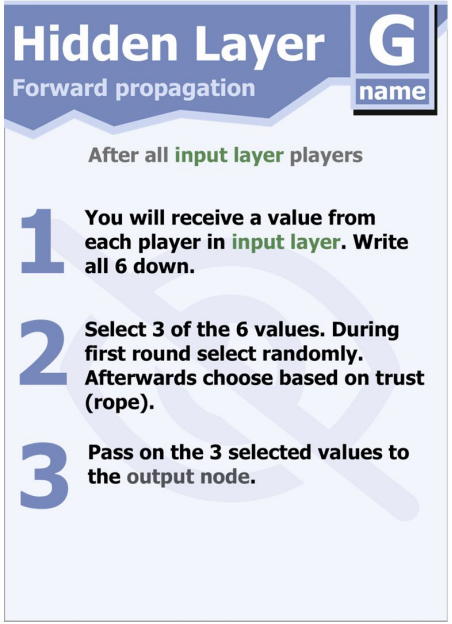


Progression of activity (forward propagation)

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.

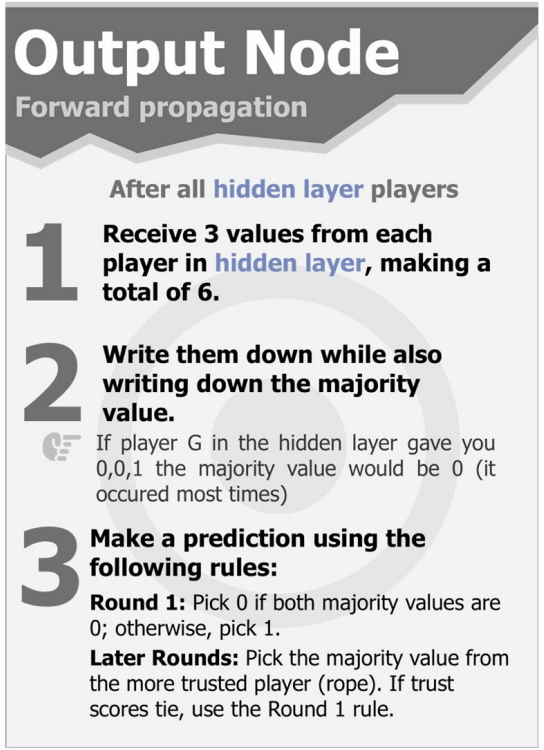
Students were also instructed to choose only three of the six input values, which represents the idea that some weights may initially be set to zero.



Progression of activity (forward propagation)

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.



Progression of activity (evaluation)

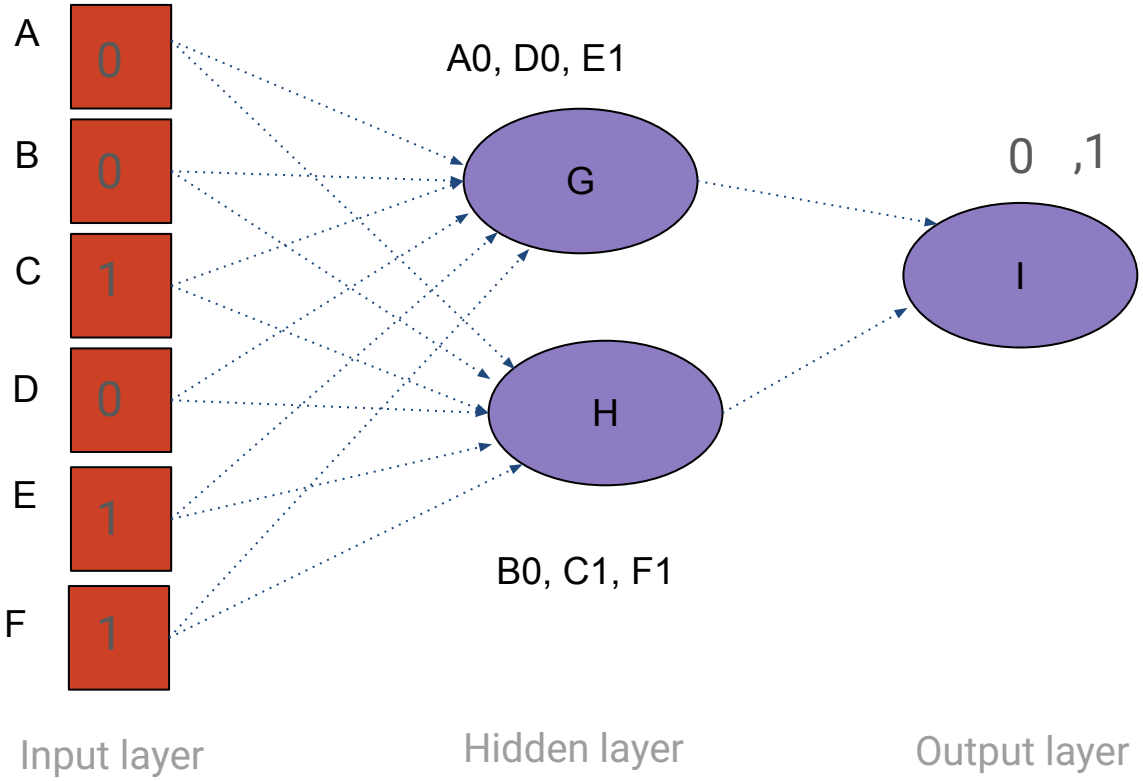
At the end of the feedforward stage, the output layer evaluates how well the network performed by comparing the predicted output (output generated by the forward propagation process) to the actual value.

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

Output Node slots

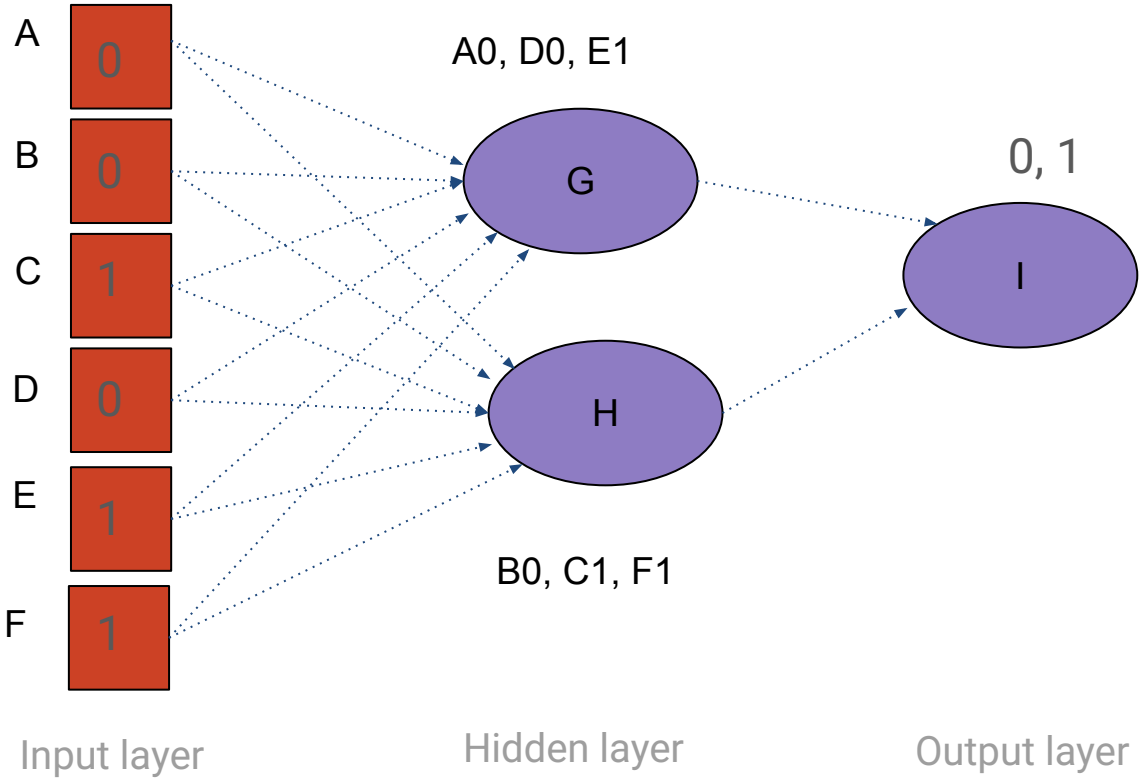
	G		H				
Round	Values	Majority Value	Values	Majority Value	Prediction	Actual	✓ ✗
2							
3							
4							
5							

Forward propagation demo



Iteration	Actual	Prediction
1	0	1
2		
3		
4		

Forward propagation demo



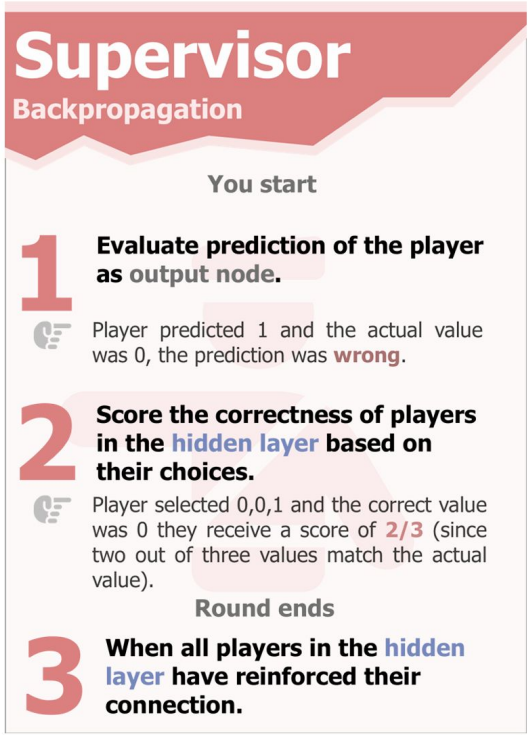
Iteration	Actual	Prediction
1	0	1
2		
3		
4		

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).



Progression of activity (backpropagation)

Input Layer
Backpropagation

A
name

Do nothing.

Hidden Layer
Backpropagation

G
name

After output node is done

1 **You have received a score by the supervisor based on how well you chose.**

If you picked 0,0,1 and the actual value was 0, then you received the score 2/3 (since two out of three values match the actual value).

2 **Modify your trust in input layer players (add / remove rope).**

If player 1 in the input layer gave you a value that matches the actual value while others didn't, you should strengthen your tie with player 1 (add a rope) and weaken others (remove the rope).

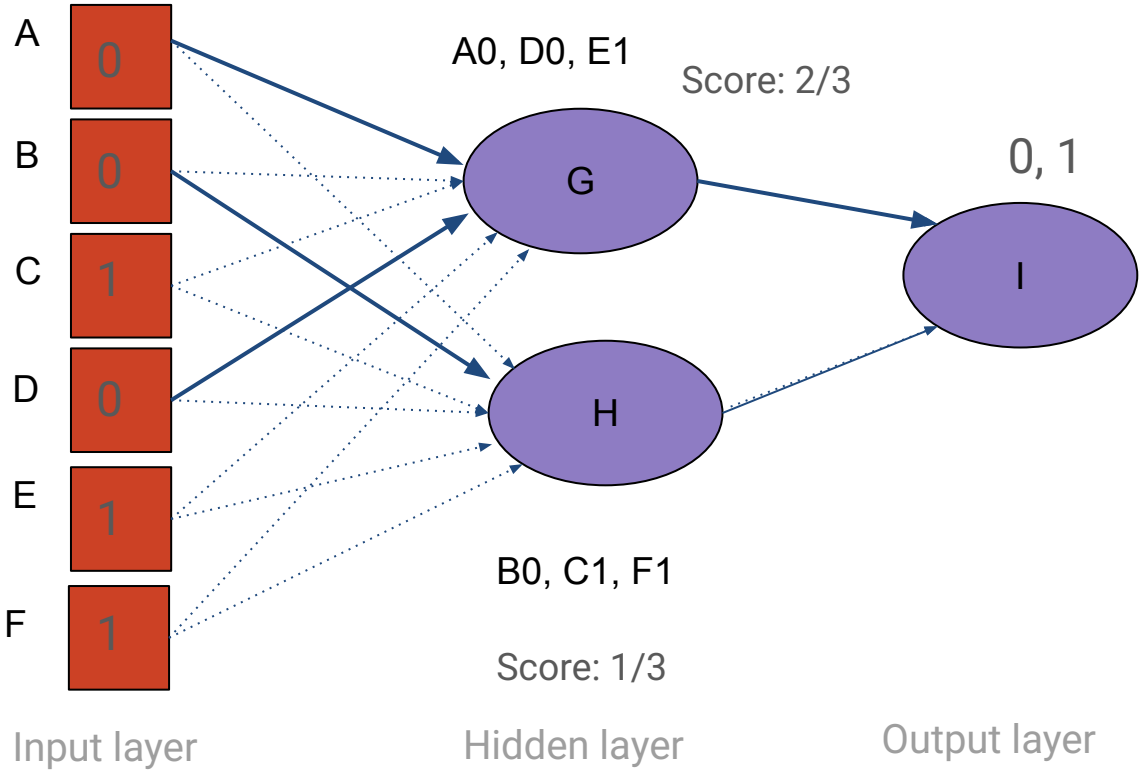
Output Node
Backpropagation

After supervisor

1 **Modify your trust in hidden layer players (add / remove rope).**

If player 1 in the hidden layer received a higher score than player 2, you should perhaps add a rope to player 1.

Backpropagation demo



Iteration	Actual	Prediction
1	0	1
2		
3		
4		

An example of a board game

Supervisor data table: Farms

Give to	A	B	C	D	E	F		
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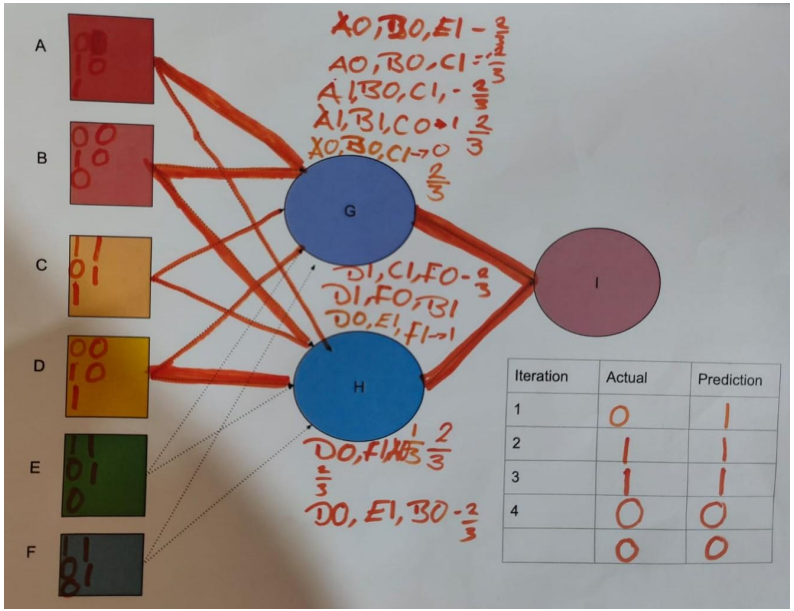
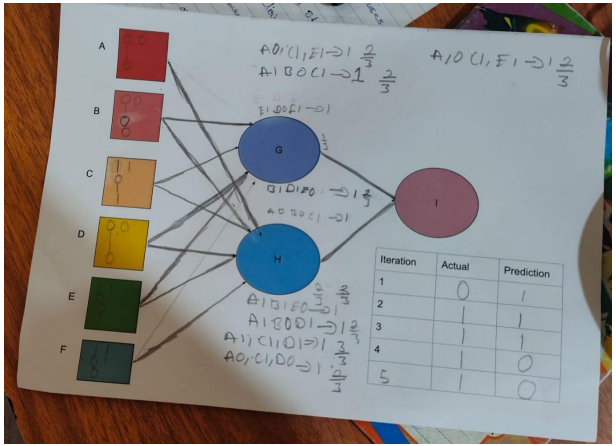
5	0	0	1	0	1	1	0	

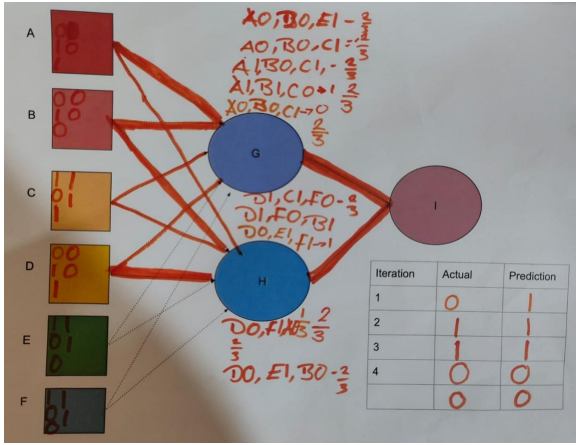
Fertilizer is a noisy feature!

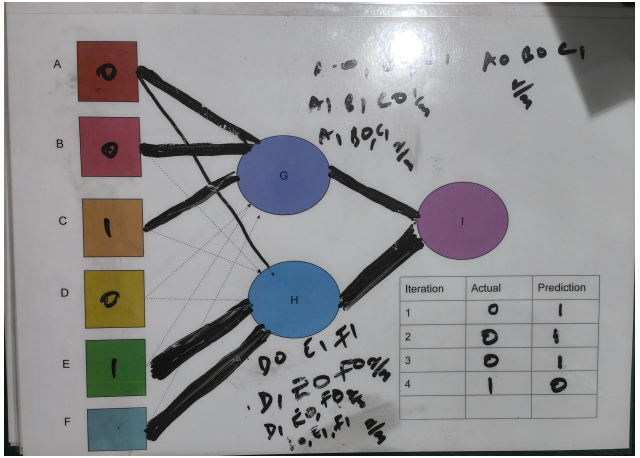


An example of students' board game.

More examples from students!







High ceiling! More opportunity to teach about overfitting, underfitting and what a good fit could look like!

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 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….”*
Sammy	Effective for classroom demonstration of neural networks	*“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.”*

Teachers' feedback after implementing the game in the class

Teacher	Category	Feedback
Judas	Learner-centered	*" The children did all the work. We only had to walk around and check what they were doing, helping them to understand. "*
Enam	Supports diverse learners	*"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.."*

Developing AI stories

Who do you trust?

Motivation of the story

In this age where information and knowledge are easily generated using AI tools, children around the world are exposed to misinformation!

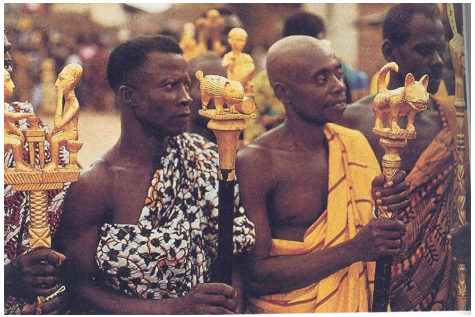
Now is the time for teachers and parents to reinforce the importance of fact-checking to children.

How should children fact-check?

In this story we would see how a young girl called Tyeli fact-checked information she received from her friends about life in the city.

Story emphasising the importance of fact-checking in the age of AI.

The training of the linguists: a tale of how ordinary men become great orators



'Woforo dua pa a na yepia wo', (When you climb a good tree, you are given a push). His voice, carried the cryptic message to the ears of the would-be linguists.

1. Role of elders and councils as oversight structures (AI could help one form an opinion, not decision-maker)
2. Use of proverbs to illustrate that meaning requires contextual interpretation rather than literal acceptance
3. Traditional apprenticeship systems to demonstrate gradual trust, supervision, and accountability
4. **Enable context-aware, cautious, and accountable use of AI systems in everyday, educational, and professional settings**

Teachers' feedback about the use of AI stories

Teacher	Category	Feedback
Boney	AI stories as an assessment tool	*"The story will also be a form of assessing them; you read the story then you explain how it is related to AI"*
Danny	Eliminate technical words	*"Most of the students were having some small challenges because of the technical words in the story when they were reading."*
Josephina	Stories are relatable	*"Story is life. It is part of life whatever you read in a story, you will find a part of you relating to it. They relate to the story more… the stories make them think deep and other senses, emotions and other things are added to it."*

Teachers' feedback about the use of AI unplugged

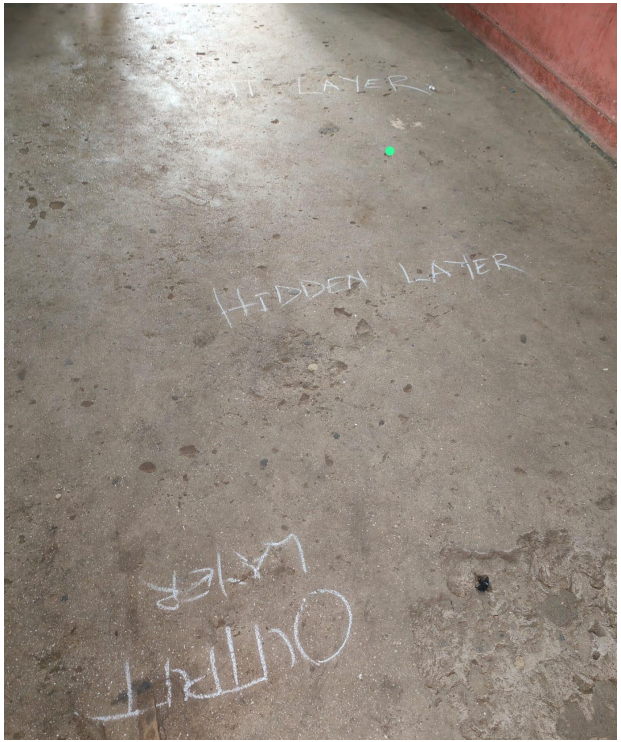
*"When it comes to the **story**, you realise that the story has all the literary devices, so there was some kind of suspense. They would want to know what will happen next. So that technique alone will **sustain their interest**, and then when it comes to the **role play** because it is activity based, **the children get involved** , they are part of the lesson so they learn, and the **board game** is **collaborative**, they are working in a group,... they all have diverse ways they contribute to the lesson."* [Josephina]

Impact of the lesson

- Gained exposure to reading and interpreting structured data
- Explored the structure and components of a neural network
- Explored the principles of feedforward, evaluation, and backpropagation
- Evaluated the opportunities and risks of AI systems
- Activity fostered teamwork, collaboration and communication

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.

Thank you and questions

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