The Annual Learnus Lecture 2020

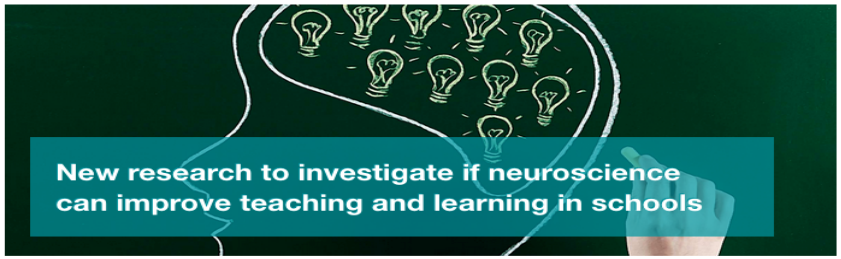
Prof. Denis Mareschal

From neuroscientific theories to effective practice in the classroom:

Lesson from the UnLocke primary maths and science intervention trial.

How do you get started…?

- Finding relevant questions…
- Finding the right science…
- Requires interactions between basic researchers and educational practitioner.



Six projects funded

- Teensleep
- Learning counterintuitive concepts (UnLocke)
- Fit to study
- Spaced learning
- Engaging the brain's reward system
- GraphoGame Rime

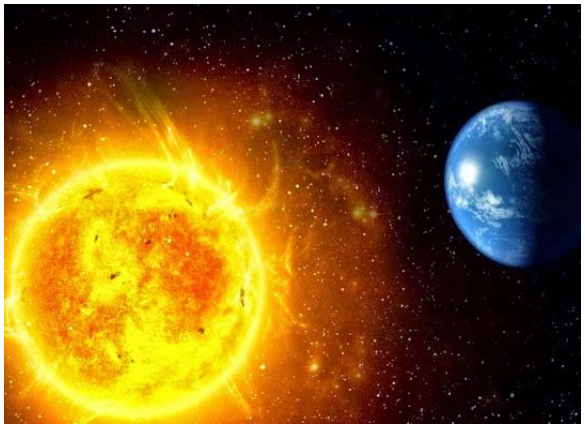
Education Endowment Foundation

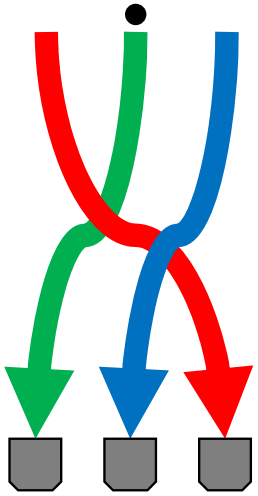
wellcome trust

More details:
https://educationendowmentfoundation.org.uk/evaluation/projects/

Science reasoning

Before starting school, children hold misconceptions about the world





Naïve, first-person experience-based science understanding

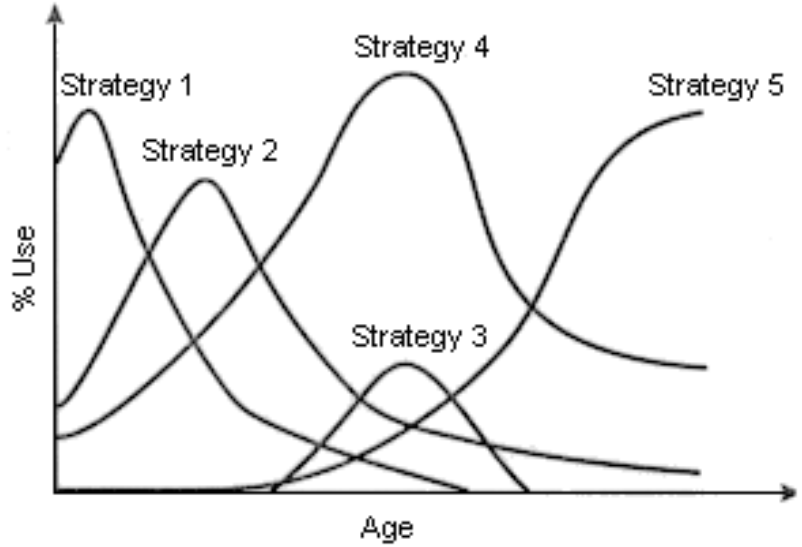
Baker, Gjersoe, Sibielska-Woch, Leslie, & Hood, *Dev Science* 2011

Science reasoning

- Before starting school, children hold misconceptions about the world
  - gravity (Baker, Gjersoe, Sibielska-Woch, Leslie, & Hood, 2011)
  - inertia (Kim & Spelke, 1999)
  - balance (Siegler, 1976)
- After school starts, misconceptions remain
  - life and death (Zaitchik et al., 2014)
  - temperature (Stavy & Tirosh, 2000)
  - states of matter (Stavy & Tirosh, 2000)
- And once school has finished, adults still hold misconceptions
  - gravity (Foisy, Potvin, Riopel, & Masson, 2015)
  - electric circuits (Masson, Potvin, Riopel, Foisy, 2014)

Maths reasoning

- Children hold competing theories and procedural strategies in maths



Overlapping waves model of cognitive development (Siegler, 1998)

How do you select one theory/strategy over another?

Maybe it has to do with Inhibitory control?

Maths reasoning

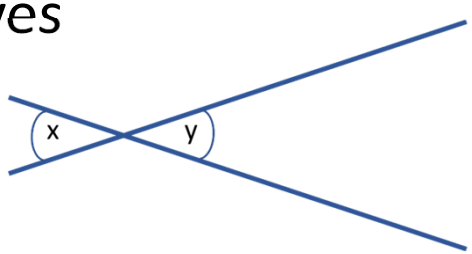
- Inhibitory control in three- to six-year-olds is associated with
  - standardised maths test performance
  - magnitude comparison
  (Merkley, Thompson, & Scerif, 2015)

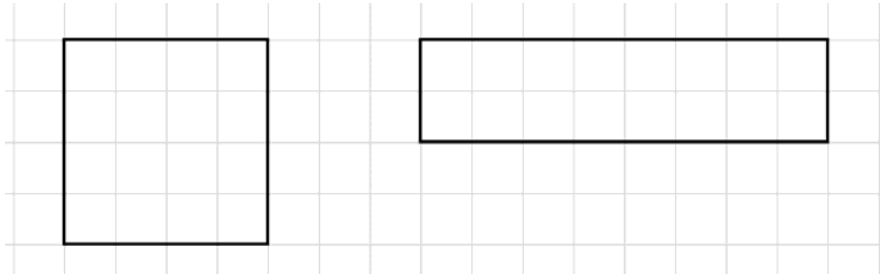
- Inhibitory control in 11- to 14-year-olds is associated with
  - procedural maths skill
  - conceptual maths knowledge
  (Gilmore, Keeble, Richardson, & Cragg, 2015)

- Inhibitory control in 14-year-olds predicts problem solving accuracy after being taught a new strategy
  (Khng & Lee, 2009)

Science and maths reasoning

- Perceptual imperatives
- Intuitive rules
  More A – More B
  Same A – Same B
  Everything can be divided
  (Stavy & Tirosh, 2000)





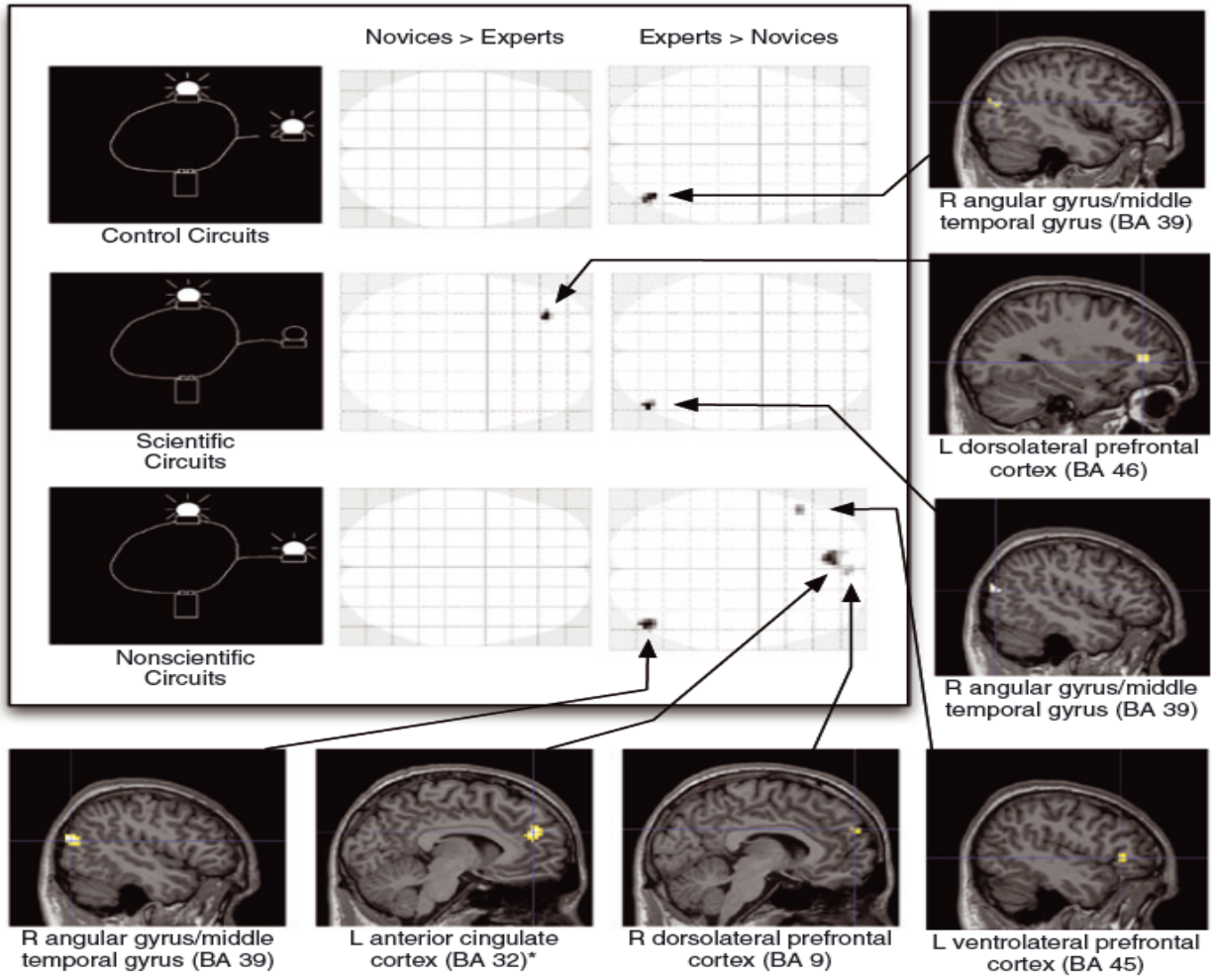
Area = 16 cm^2
Perimeter = 16 cm

Area = 16 cm^2
Perimeter = 20 cm

How do you overcome these intuitions?
Maybe it has to do with Inhibitory control?

Math and Science are typically studied separately, but similar inhibitory processes may contribute to both

Clues from cognitive neuroscience…

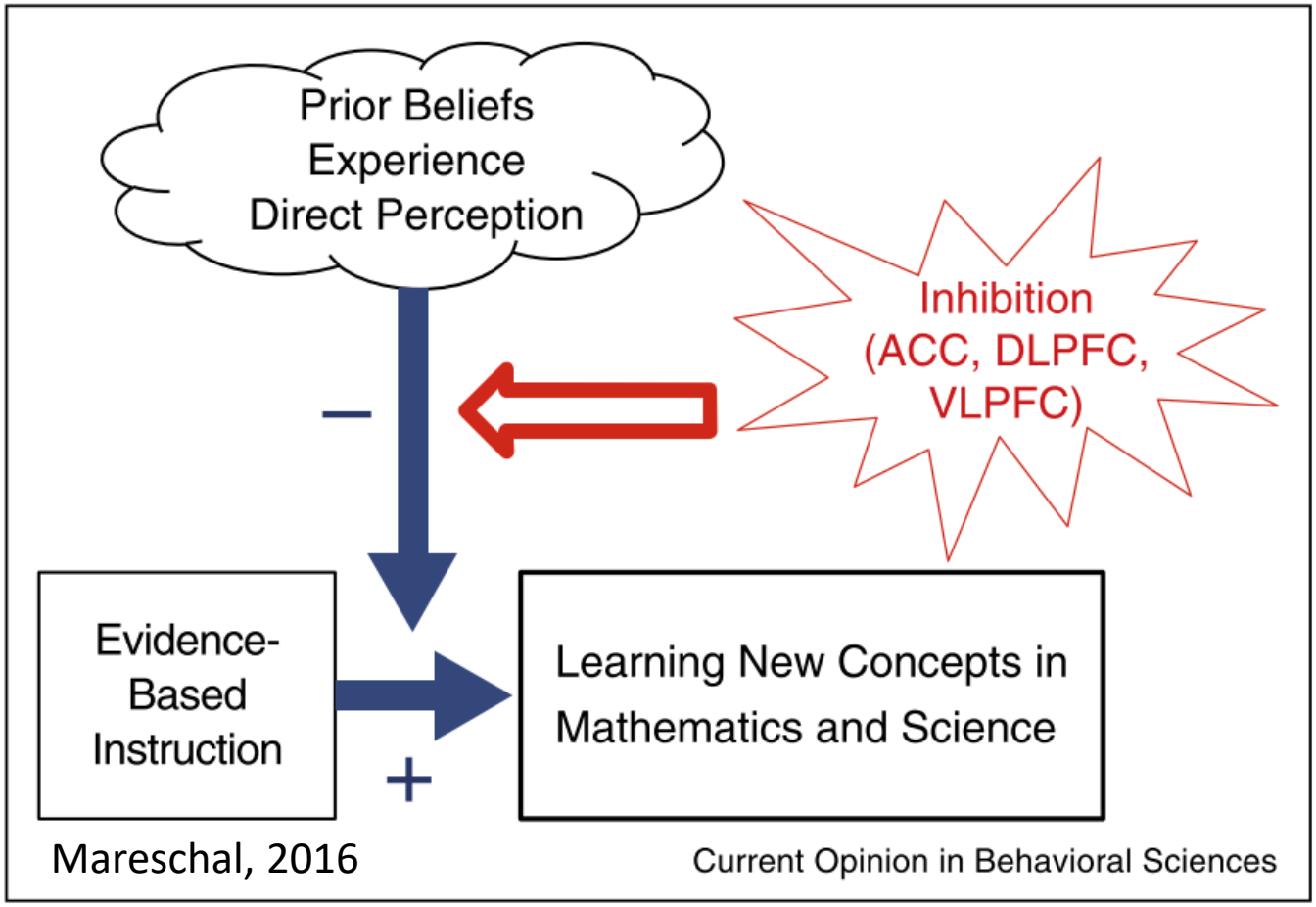


ACC and DLPFC are:

- part of inhibitory control networks
- involved in error detection and knowledge conflict resolutions

Masson et al (2014) *Mind, Brain and Education*

The role of inhibitory control



Old knowledge remains
(Dunbar, Fugelsang, & Stein, 2007; Masson, Potvin, Riopel, & Foisy, 2014)

Inhibitory control allows suppression of old knowledge
(Mareschal, 2016)

Intervention study

Intervention study

- Based on the cognitive psychology, educational psychology and cognitive neuroscience literature
- **Critical 18-month development phase**
- Developed an intervention programme to train children to use their **existing** inhibitory control skills to successfully solve counterintuitive problems
- Delivered through a computerise learning activity (game)

Stop and Think

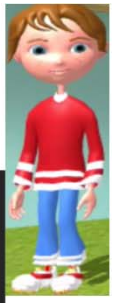
- 10 weeks
- 3 times a week
- At the start of maths or science lesson
- 12 min per session
  - 1 science counterintuitive concept
  - 1 math counterintuitive concept
- Content adapted to Year 3, or Year 5
- Whole class delivery (for pragmatic resaons)

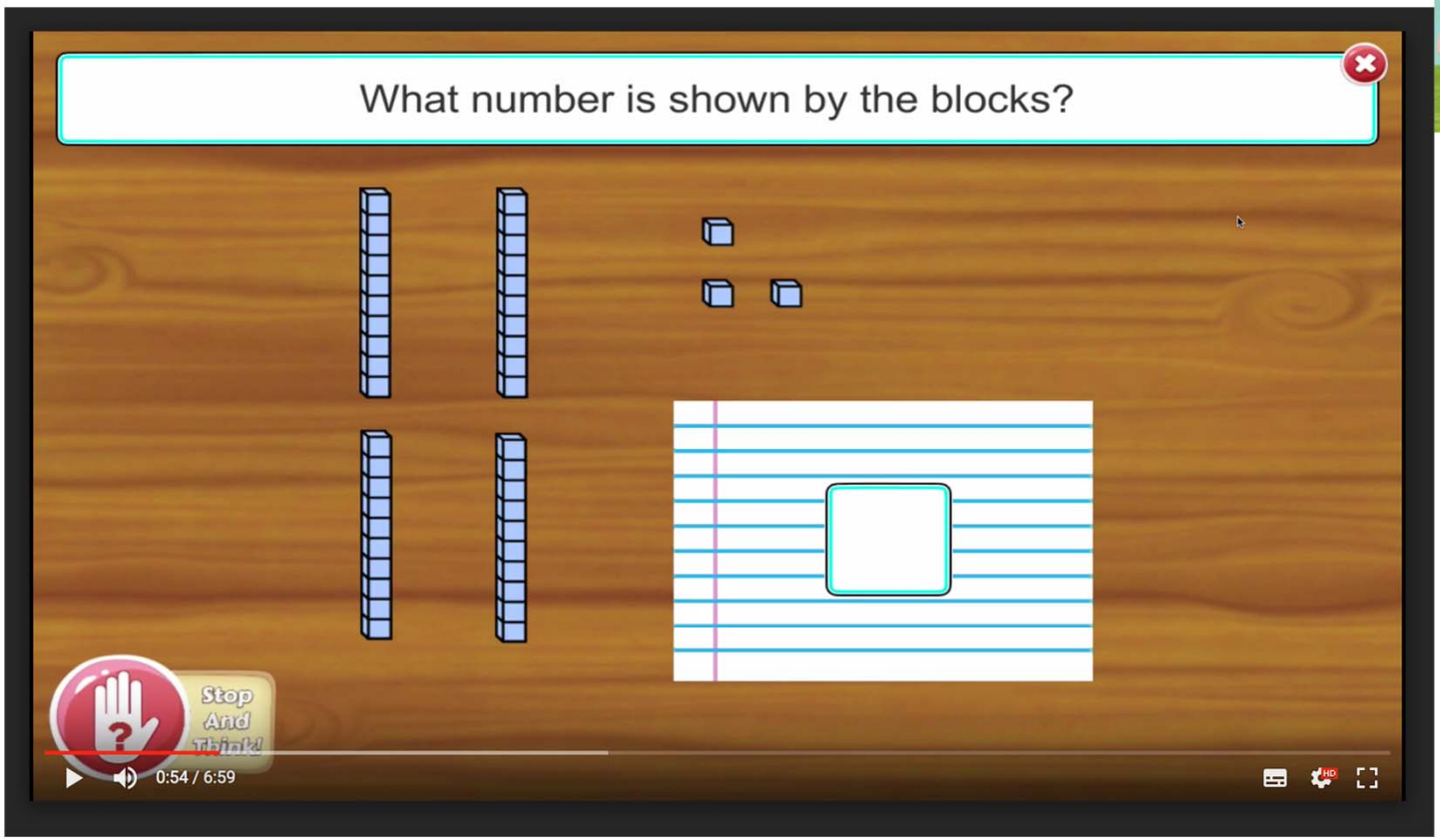
Demo of the Unlocke software:
https://drive.google.com/file/d/0B8eZJxdTwZq3Tkh0VWxpRmtLSEU/view

UnLocke Project: Stop and Think activity

UnLocke
Learning counterintuitive concepts

UnLocke Project: Stop and Think activity





UnLocke
Learning counterintuitive concepts

UnLocke Project: Stop and Think activity

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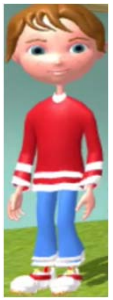
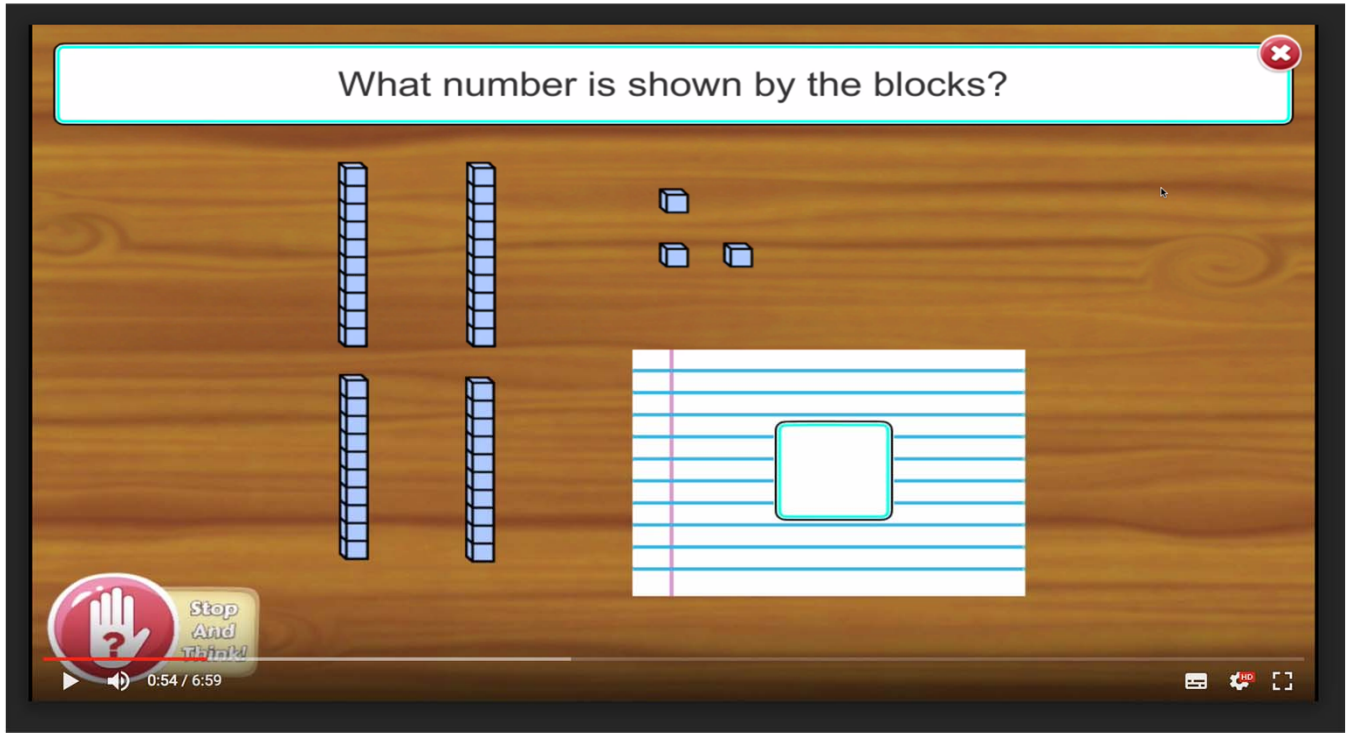
UnLocke Project: Stop and Think activity



BONUS ROUND



UnLocke
Learning counterintuitive concepts

UnLocke Project: Stop and Think activity

UnLocke
Learning counterintuitive concepts

Active control condition: See +

- Control for the effect of taking part in an intervention (Hawthorne effect), doing a novel –computerised-activity with peers and teacher
- Duration, frequency and computer software matched
- During Personal, Social and Health Education or at other times
- Social scenarios, predicting what comes next, recognising emotions

Dr Sveta Mayer

Post-test (whole-class)

- **<u>GL assessment standardised tests</u>**

Progress Test in Maths (PTM)

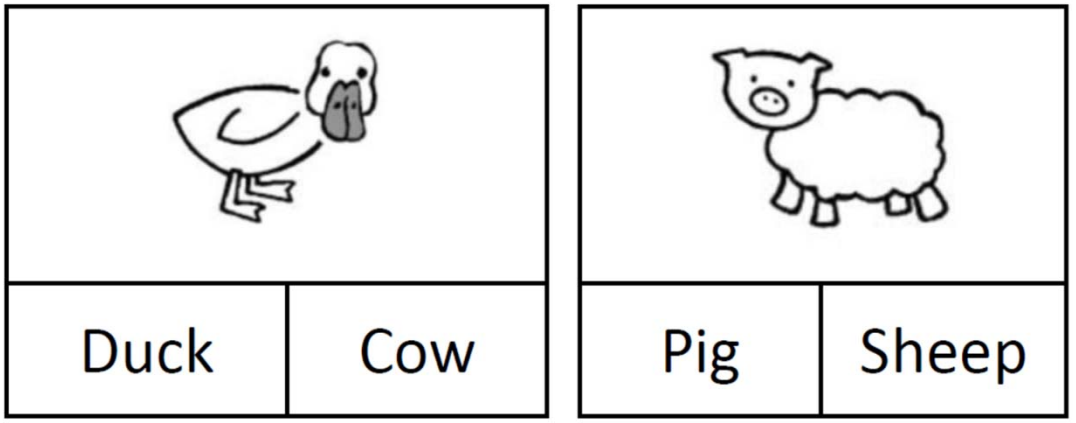
or

Progress Test in Science (PTS)

1 hour

- **<u>Chimeric animal inhibitory control task</u>**

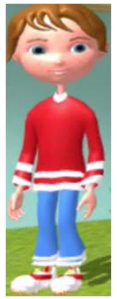
Which animal's **<u>body</u>** can you see?



Randomised control trial

- Early Years Foundation Stage Profile (EYFSP)
- Post-training assessments (whole-class): GL assessment standardised tests in maths or science
- Target Years 3 & 5:
- 6672 children in 87 primary schools (84 analysed) in England
- ~ 30% free school meals (> average)
- 370 children tested with in depth cognitive battery, of which 52 of these also had pre- and post- MRI scans
- Independent evaluators (NFER)

UnLocke Project: NFER roles



- Conducted the random allocation of classes to intervention or one of the control modes
- Delivered standardised post trial tests in maths and science produced by *GL assessment*
- Issued an online questionnaire to staff from all schools involved in the trial
- Conducted face-to-face and telephone interviews with teaching staff from a sample of schools
- Analysed the evaluation data and reported on their findings

(UnLocke team assessed inhibitory control and socio-emotional development through pen-and-paper tests)

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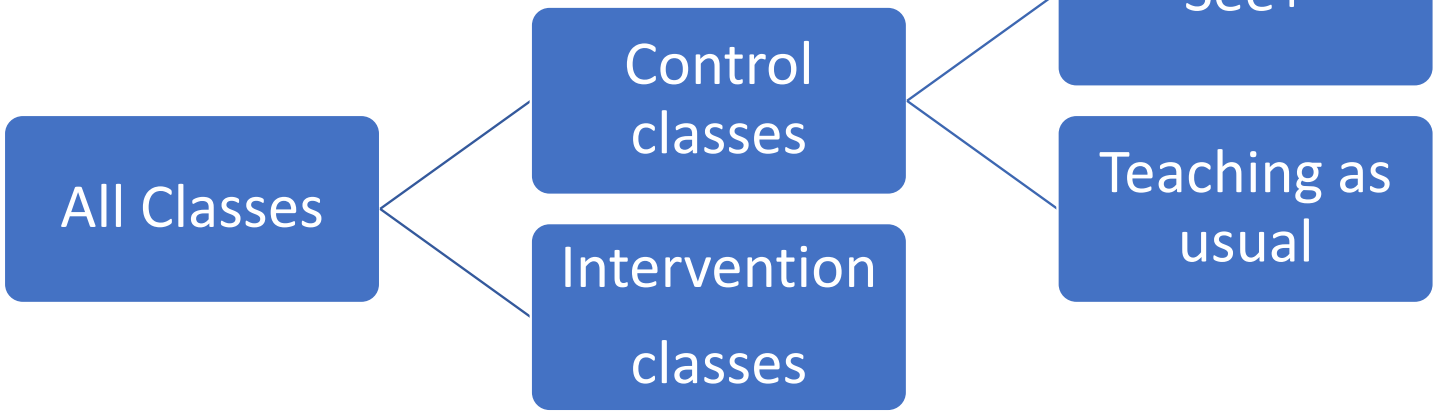
Learning counterintuitive concepts

UnLocke – a randomised controlled trial (RCT)



Allocations were completed by the NFER
All schools had an intervention class e.g.

- Y3 intervention but Y5 Business as usual
- Y3 Business as usual but Y5 intervention
- Y5 intervention and Y3 See+

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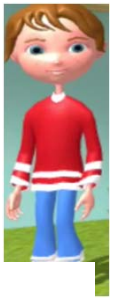
Intervention sample size

	Maths		Science		Total
	Intervention group	Combined control group	Intervention group	Combined control group	
Number of pupils meant to be followed up[12]	1605	1638	1602	1641	6486
Number of pupils analysed	1343	1359	1344	1391	5437
Pupil level attrition	16%	17%	16%	15%	16.17%
Overall attrition	17%		16%		

Attrition does not differ across condition groups

UnLocke project: EEF impact summary



Impact

Table 1: Summary of impact on primary outcomes of maths and science (GL test scores)

Outcome/ Group	Effect size (95% confidence Interval)	Estimated months' progress	No. of pupils	P value	EEF security rating	EEF cost rating
Maths (Year 3 and Year 5 combined) vs control	0.09 (-0.01, 0.19)	1	2,702	0.087	🔒🔒🔒🔒	£ £ £ £ £
Science (Year 3 and Year 5 combined) vs control	0.12 (0.02, 0.22)	2	2,735	0.018	🔒🔒🔒🔒	£ £ £ £ £

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Primary analysis

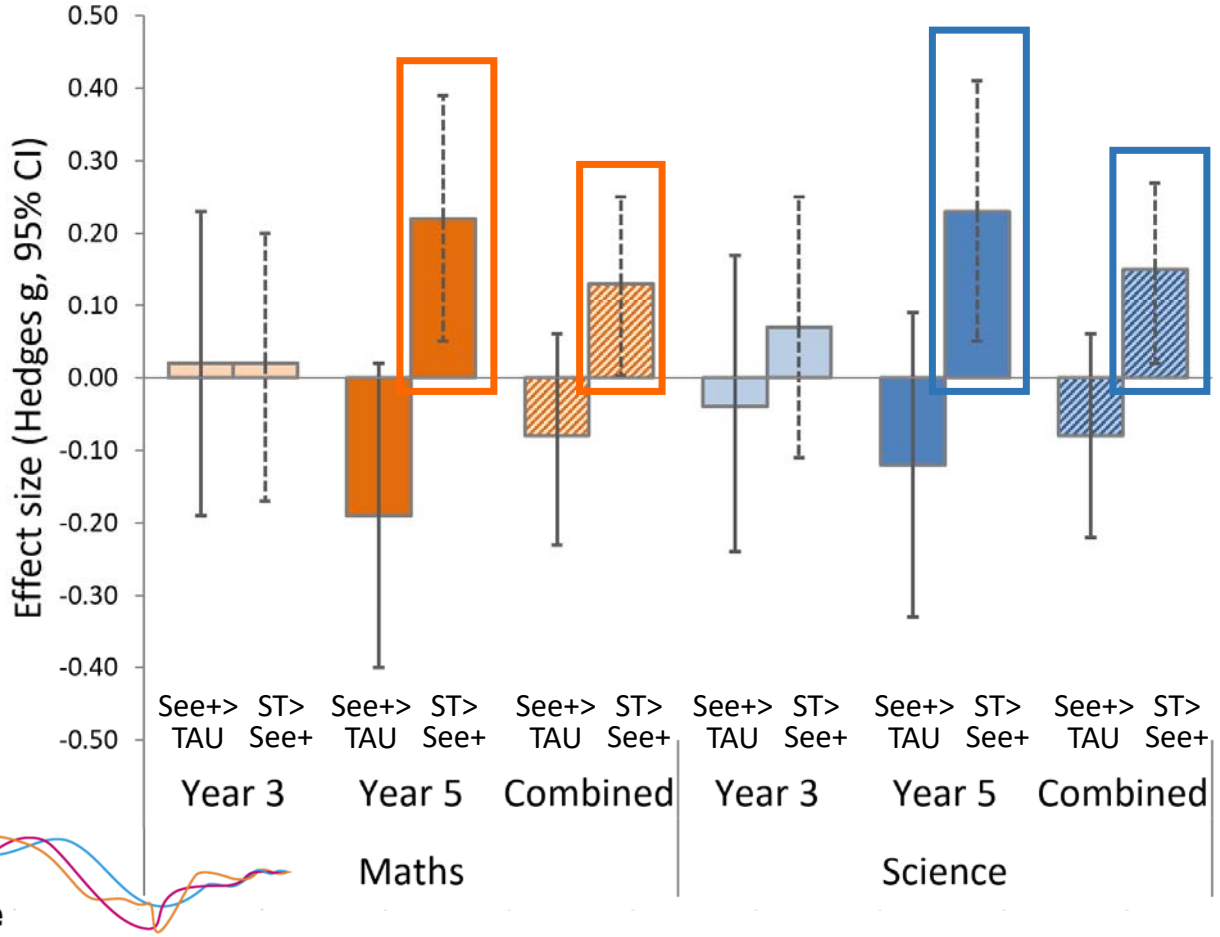
	Raw means				Effect size			Primary analysis:
	Intervention group		Control group					
Outcome	N (missing)	Mean (95% CI)	n (missing)	Mean (95% CI)	n in model (intervention; control)	Hedges g (95% CI) (secondary analysis)	p-value	combined effect size Y3 and Y5 (95% CI)
PTM8 GL test score Maths Year 3	656 (70)	25.7 (24.8, 26.6)	704 (122)	25.1 (24.2, 25.9)	1326 (647; 679)	0.03 (-0.12, 0.18)	0.67	0.09 (-0.01, 0.19)
PTM10 GL test score Maths Year 5	747 (89)	31.3 (30.3, 32.3)	703 (73)	29.7 (28.7, 30.8)	1376 (696; 680)	0.14 (-0.002, 0.28)	0.05	
PTS8 GL test score Science Year 3	661 (66)	23.2 (22.7, 23.7)	727 (97)	22.7 (22.3, 23.2)	1354 (651; 703)	0.07 (-0.08, 0.22)	0.34	0.12 (0.02, 0.22)
PTS10 GL test score Science Year 5	751 (81)	29.3 (28.7, 29.8)	712 (67)	28.4 (27.8, 29.0)	1381 (693; 688)	0.17 (0.03, 0.32)	0.02	

Secondary analysis – free school meals

	Raw means				Effect size			Primary analysis:
	Intervention group		Control group					
Outcome	N (missing)	Mean (95% CI)	n (missing)	Mean (95% CI)	n in model (intervention; control)	Hedges g (95% CI) (secondary analysis)	p-value	combined effect size Y3 and Y5 (95% CI)
PTM8 GL test score (FSM only) Maths Year 3	181 (28)	21.2 (19.5, 22.8)	210 (38)	20.9 (19.4, 22.4)	381 (179; 202)	0.19 (-0.02, 0.40)	0.07	
PTM10 GL test score (FSM only) Maths Year 5	260 (42)	26.5 (24.9, 28.1)	208 (33)	24.1 (22.4, 25.8)	444 (246; 198)	0.16 (-0.04, 0.36)	0.11	
PTS8 GL test score (FSM only) Science Yeas 3	176 (21)	20.2 (19.3, 21.2)	208 (27)	20.8 (20.0, 21.6)	377 (175; 202)	0.01 (-0.19, 0.20)	0.96	
PTS10 GL test score (FSM only) Science Year 5	262 (34)	26.0 (25.2, 26.9)	203 (26)	25.4 (24.5, 26.4)	442 (245; 197)	0.10 (-0.13, 0.33)	0.39	

Secondary analyses: active control

TAU= Teaching as Usual
SEE+ = Active control
ST= Stop & Think



Centre for Educational Neuroscience

Summary of results

- Improved performance on standardised tests **(medium/far transfer)** across Years 3 and 5
- Leads to improvements of 2 months in science (significant at the 0.05 level) and 1 month in maths (not significant at the 0.05 level)
- On the basis of 7.5 hours input at a cost of £5.65 per pupil
- Effects driven by Year 5 in both maths and science
- Significant against an **active control condition**
- Not enough power, but intervention may benefit children on free school meals for maths in Year 3

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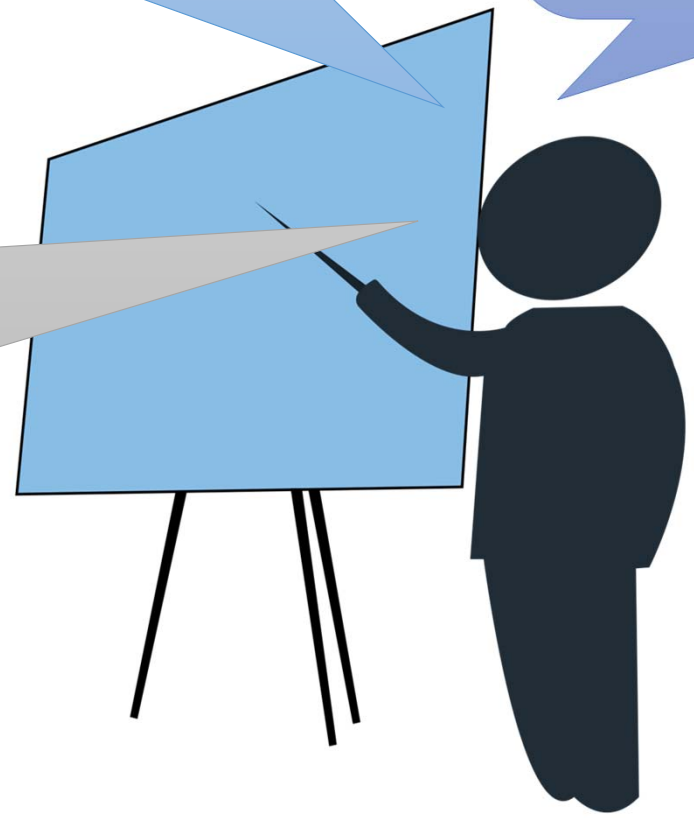
So … What did the teachers think?

“Stop and Think helped pupils to further develop social skills such as listening and considering other pupils’ points of view. “

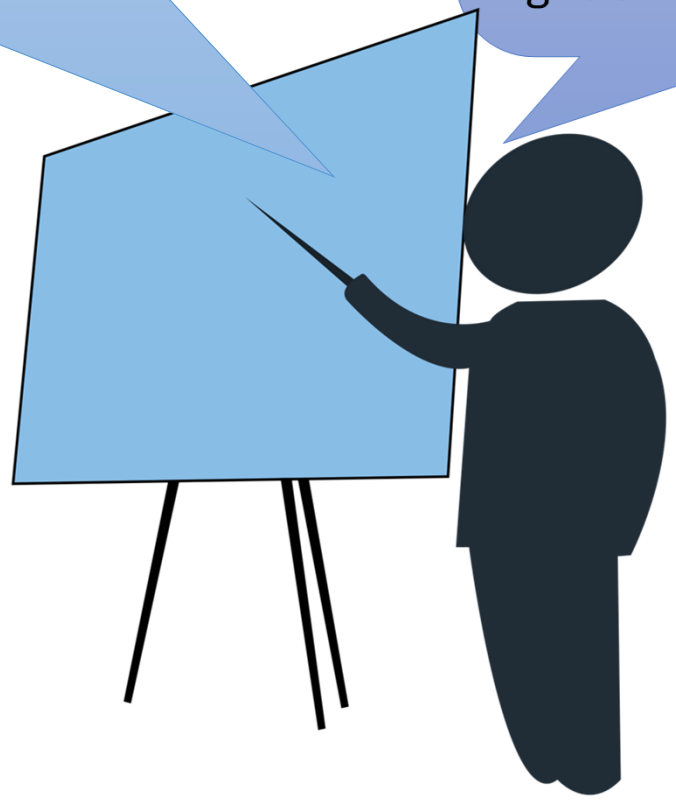
“Some pupils took the Stop and Think idea into other lessons, that is to say, pupils were taking time to consider questions before answering.”

“The Stop and Think game show contestants and animations in the programme, encouraged pupils to reason more which enhanced their learning.”



“It allowed me to develop my understanding of how the children in my class learn and to analyse what they know, how clearly they understand concepts and to identify misconceptions that some/most or all children in my class have.“

“It gave me an insight into how children’s ideas can change when given thinking time and how they are able to reason as to why something is right or wrong.”



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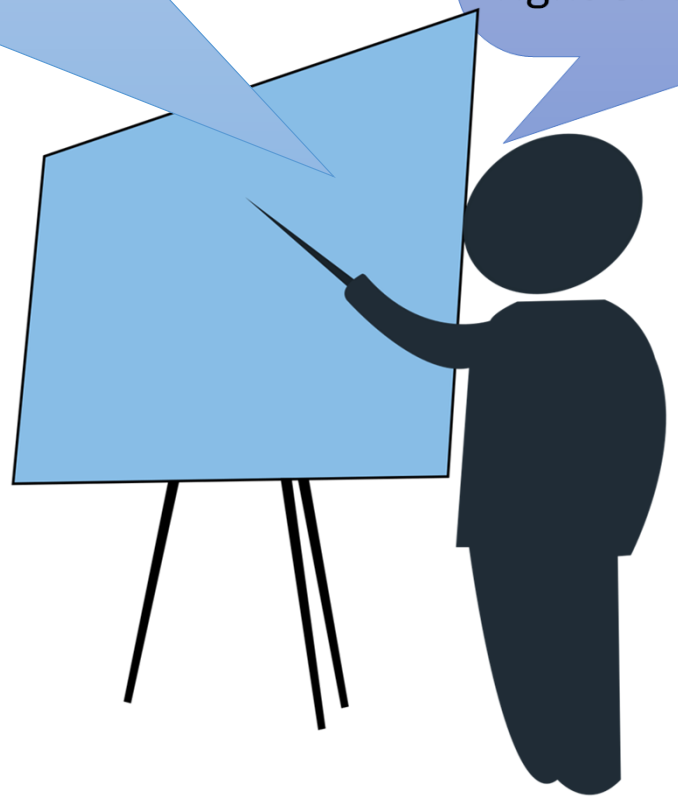


Preregistered quantitative measures do not assess these secondary benefits!

Feedback from teachers

- Majority of teachers interviewed (47/61) did not endorse the roll-out of the programme in its current form because of:
  - Difficulty in fitting delivery into the school day
  - Inability to select content
  - Software problems
  - Pupil engagement
  - Quality of animation
  - Content perceived as being too easy
    - A majority of teachers thought S&T content was appropriately aligned with the curriculum for science and suitable for their class
    - Half found it was suitable for maths, just under half thought it was too easy

Accounts for some of the maths/science differences in results?
Perhaps there is already more support available for math than science

Full report

https://educationendowmentfoundation.org.uk/projects-and-evaluation/projects/learning-counterintuitive-concepts/

http://www.unlocke.org

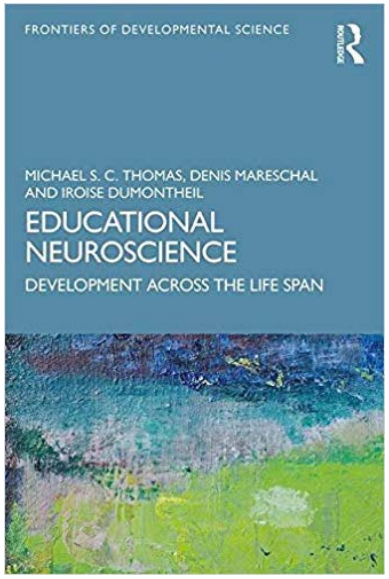
Wilkinson, H. R. , Smid, C., Morris, S., Farran, E. K., Dumontheil, I., Mayer, S., Tolmie, A., Bell, D., Porayska-Pomsta, K., Holmes, W., Mareschal, D., Thomas, M. S. C. & the UnLocke Team (2019) Domain-specific inhibitory control training to improve children's learning of counterintuitive concepts in mathematics and science. ***Journal of Cognitive Enhancement***. doi.org/10.1007/s41465-019-00161-4.

We are currently further developing the software and running an effectiveness trial with the EEF

Lessons and unanswered questions…

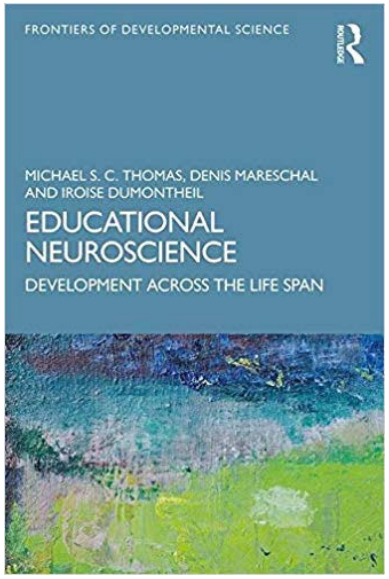
In Chapter 19 by Bell & Darlington….

- *How can the benefits of personalised learning be maximised within the social context of the school and its environment?*
- *How can research findings inform practice more effectively?*
- *To what extent is it ethical to 'test' things out on students?*
- *How can the impact of interventions be maximised?*



Lessons and unanswered questions…

- *How do you set up that initial bi-directional dialogue?*
- *Problems with RCTs…*
- No single magic bullet… an accumulation of small effects
- “One size fits all” does not work
- What counts as success?
- Who decides what it means?
- Always keep improving



Even if there are challenges… we should not give up.

UnLocke

Learning counterintuitive concepts

Prof. Denis Mareschal
Dr. Iroise Dumontheil
Prof. Andy Tolmie
Prof. Michael Thomas
Prof. Emily Farran
Prof. Kaska Porayska-Pomsta
Dr. Sveta Mayer

Prof. Derek Bell
Dr. Hannah Wilkinson
Claire Smidt
Roshni Modhvadia
Su Morris
Dr. Dilini Sumanapala
Roos de Jong
…

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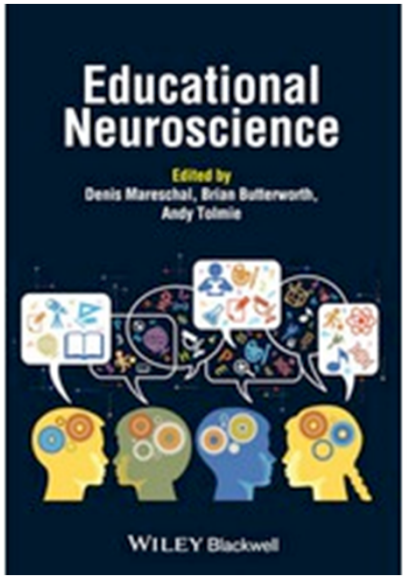
Birkbeck UNIVERSITY OF LONDON

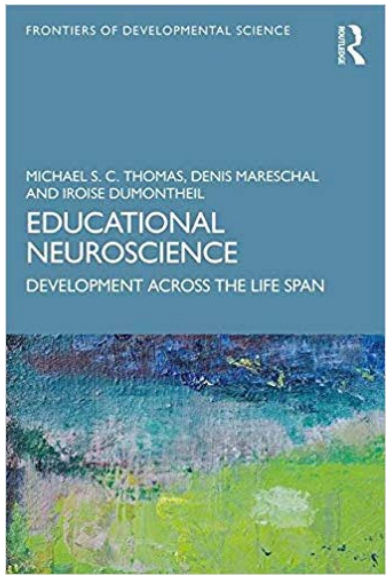
UCL Institute of Education

Learnus® Understanding Learning

Centre for Educational Neuroscience

Thank you for your attention!





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