Executive functions: Controlling the learning brain?

Dr Jonathan Sharples
The Institute for the Future of the mind

The Young Mind
Effect of drugs on learning and memory
Digital technologies and cognition

The Ageing Mind
Identifying a marker for neurodegeneration and a novel mechanism for therapy

The Institute for the Future of the mind
High-quality, primary research

Policy and Impact

• How can we apply scientific understandings of learning to develop education policy and practice?

• Identify educational areas where scientific insights can improve pedagogy and policy. Translate between the two fields.

The Learning Brain

- Literacy
- Numeracy
- Memory
- Creativity
- Exercise
- Nutrition (e.g. omega-3)
- Early-years (0-5 yrs)

Teachers are the only professionals required to change brain connectivity and structure on a daily basis!

- In a survey of teachers attending in-service training, 90% thought that a knowledge of the brain was important, or very important, in the design and delivery of teaching.

"Science of Learning" pilot-project

Science insights on learning

Teachers' practical expertise

• How can engaging teachers with scientific ideas on learning develop classroom practice?
• 20 teachers - mixed subject and primary/secondary
• Series of workshops from neuroscientists and psychologists on different aspects of cognition
• Support them in integrating this knowledge into practice.

Adolescence
Memory
Creativity
Numeracy

How can engaging teachers with scientific ideas on learning develop classroom practice?

Brains are made for moving

• Motor (movement) systems make up large parts of the brain
• Evolutionarily advanced systems
• Recruit motor networks into learning - help deepen representation of concepts
  better chance of it being strongly laid down in memory

TLRP ‘Principles into Practice’ (2007) -
“In order to develop children as reflective learners, teachers first have to develop this disposition for themselves....”

“The project has got me out of the rut to deliver quick-fix strategies to deliver the usual learning objectives. This has me questioning, is this appropriate? are they learning? The positive feedback I have received has reinforced this shift in practice”

Executive Function (EF)

• Aspects of our relating how we control our thoughts and actions in order to respond flexibly to changes in the environment
• Used in novel situations or when you have to do something different to normal - organise our thinking
• Includes a number of different processes:
Executive Function - doing the weekly shop

- Remember a shopping list
- Plan your route around the shop
- Do I buy the organic chicken, even though it’s more expensive?
- One list for you, one for your mother
- Stop yourself from buying your favourite chocolate

Executive Function - pupils in the classroom

- Plan your experiment
- stop yourself from being distracted by others
- Do I work harder now or leave it for homework later?

Frontal Lobes - role in executive function

- **most interconnected region of the brain** - all other parts of the brain (sensory, motor, automatic emotions)
- well-designed for its coordinating roles - 1. Integrating diverse representations 2. Exerting control over systems

Frontal lobes (Prefrontal cortex)

Two types of mental processes taking place in the brain at the same time:

**Controlled (EF)**
- Thinking that takes effort
- One at a time
- Novel responses
- More frontal lobes
- e.g. planning a journey

**Automatic**
- Thinking that happens without conscious control
- In parallel
- Well-rehearsed (routine)
- At over the brain
- e.g. steering, braking, reading the road

Impossible to keep track of everything – most mental processes happens automatically

A quick language test!

**Aim:** Create four-word sentences

1. him was worried she always
2. from are Florida oranges temperature
3. ball the throw toss silently
4. shoes give replace old the
5. sky the seamless grey is
6. sunlight makes temperature wrinkle grapes.

Primed for action

1. him was worried she always
2. from are Florida oranges temperature
3. ball the throw toss silently
4. shoes give replace old the
5. sky the seamless grey is
6. sunlight makes temperature wrinkle grapes.

Automatic processing thinks about ‘old’

Walk slower after the test!
Automatic processing plays a big part in decisions

Evolution of frontal lobes

- Brain has expanded forward at a huge rate!
- Prefrontal cortex grown the most
- Also denser interconnections to other brain regions - freed us from responding to the immediate situation

Forehead change in humans

Forehead change in humans

Automatic processes
- Drive for food/sex, reacting to danger, moving, sensing etc

Controlled processes
- Conscious planning, reasoning, logical thinking, language

Executive Function - The brain’s “bouncer”?

or

Brain - ‘Elephant and rider’

Rider = controlled conscious thinking (EF)
Elephant = automatic processing
Executive functions and learning

Children’s ability to control attention and action are stronger predictors of academic performance than is IQ, or entry-level maths or reading skills.


Primary school teachers rank Executive Functions as the most important characteristic necessary for school readiness and indicate that over half their children lack effective EF.

Rimm-Kaufman et al. (2000)

Can we help young children develop these critical executive function/self-regulation abilities?

Executive function development

Tools of the Mind - preschool programme

• A US-based preschool curriculum that improves Executive Functions
  • based on the idea that teaching social, emotional and cognitive self-regulation is as important as teaching academic skills
  • training is embedded in all aspects of the school day

Educational Domains

creativity ‘Learning to learn’
early-years gifted and talented
Executive function adolescence
digital technologies and attention
development disorders


Walter Mischel - Classic ‘Marshmallow Experiment’
Importance of self-control

frustration self-esteem sociability SAT scores

4-year olds 19-year olds


Marshmallow Experiment

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Tools of the Mind - Curriculum

- Core of 40 activities to promote EF and self-regulation

  'Buddy reading' - improve attention and listening/self-regulation

Strong emphasis on intentional, make-believe play:
- remembering role (WM),
- inhibit acting out of character
- adjust to the evolving plot (cognitive flexibility)

Tools of the Mind - Conclusions

- EF skills are not fixed, even in very young children
- EF skills can be improved in preschoolers in regular classrooms by regular teachers, without expensive equipment or 1:1 attention
- Expect benefits from early EF-training to increase over time
- Tools of the Mind was named an exemplary innovation by the International Bureau of Education at UNESCO in 2001 - only one in US at the time
- Website: www.toolsofthemind.org/

The Executive

Preschool Program Improves Cognitive Control

- Randomised control trial of Tools of the Mind programme
- 20 classes in a low-income district in New Jersey
- Half assigned randomly to Tools of Mind, half on normal curriculum
- Comparable abilities at the start. Progress followed for two years
- Tasted independently on two standard measures of EF
- Academic scores of Tools of the Mind schools also followed

Diamond et al. (2007) Science, 318

Test of Executive Function - Flanker test

Inhibit influence of flanker fishes

reverse flanker

Inhibit influence of flanker fishes + remember new rule

Flanker task - 10-15% improvement on Tools of Mind

Reverse Flanker - 20-30% improvement on Tools of Mind

- Tools of Mind children met or exceeded all state and national standards for preschoolers in literacy and maths

Training the elephant - Improve ‘Metacognition’

- Adults are more aware of their thinking - introspection
- They tend to evaluate a task and work out the best strategy to make it easier
  - Work through things systematically
  - Use internal speech
- Children seem less likely to do this
- Is this an area where executive functions can be improved?
Entity view
Fixed mindset - pre-determined

Incremental view
Growth mindset - potential through effort

Fixed vs Growth mindsets

Fixed mindset - less motivated to learn, less resilient
Growth mindset - more motivated and resilient


“Success is the ability to go from one failure to another with no loss of enthusiasm.”

“Study and learning skills are inert until powered by motivation”
Carol Dweck

• improving metacognitive awareness of learning (improving EF) can help light the fire!

“Brainology”

• Illustrate the flexible nature of intelligence through an awareness of brain plasticity:
  1. learning changes brain connectivity
  2. this process continues through life
  3. you are in charge of that process

• 8 x 1/2hr intervention lessons - change mindset, motivation and grades

Primary/Secondary transition

Breaking news!

Working memory training increased brain activity related to working memory in the frontal and parietal cortices (in adults - 45min a day/5 weeks)

So what?!…

Jaeggi (2008) 105(19) Science

- WM training improves ‘fluid intelligence’
- Fluid intelligence: Reasoning and problem solving requiring no prior knowledge (i.e. mental horsepower)
- Closely linked to academic and professional success

SUMMING UP
- Executive functions are central to our day-to-day function and learning
- Executive functions begin developing at a young age and continue through our lives
- Executive functions CAN be improved through education - explicitly and by developing an awareness of children’s own thinking/behaviour
- As educators we should actively seek opportunities to train the elephant!

Thank you!