What has the Science of Maths Learning got to do with survival and what relevance does it have in education?

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For a very long time now, I have been putting much thought to the questions of: *Why teach mathematics? Why is it important for people's lives? How does it help?* In my day, mathematics, like literacy, was compulsory. But in some Australian states, maths is 'optional' in Years 11 and 12. Furthermore, there is a nationwide shortage of maths teachers in Australia, with many reporting they 'lack confidence' in how to teach it. This is not to mention Australia's declining mathematics PISA results (see www.acer.org/au/timss, www.acer.org/au/pisa/key-findings-2018). Additionally, several Australian universities have stopped mandating maths as a pre-requisite for courses which had previously required it. Yet we continue to have skills shortages in related industries, which have reportedly worsened over the past few decades.

It also seems to me that mathematics became somewhat abstracted from the world in which we live. There is curriculum content to cover but it is often unclear as to how it is all connected or why we would even *want* to teach these concepts to our students. In my own experience, when doing in-class support with students, I often asked them: "Why are we doing this mathematics?" Many of them replied that they did not know. Yet, all I could think was: "But how do they *not* know? Maths is related to *everything*!" Indeed, when listening to people speak, there is barely an utterance which does not include a mathematical concept. (Even in the preceding sentence, 'barely an utterance' refers to quantity.)

This is not to downplay the extraordinary dedication of many teachers, pedagogical leaders, curriculum coordinators and developers, mathematicians, educational product designers, academics and policymakers around Australia who are working tirelessly to rectify these systemic issues. Things are beginning to change! Furthermore, there have been important developments in neuroscience relating to the development of mathematical cognition in the past 20 years, and the dawn of the Science of Maths Learning is now emerging. But why did maths recede into the background and how do we get it back? Why is mathematics important? Why is it critically relevant to our lives and at least as relevant as literacy?

The brain and survival

As humans, we exist for survival: seeking ways to minimise threats and maximise rewards. Humans have basic physical drives which include seeking air, water, food, shelter and sex; and avoiding pain and physical injury. Furthermore, as our survival is largely dependent on our acceptance within the group, social acceptance and the avoidance of emotional harm are also very strong human drives.

The brain is constantly calibrating external/environmental and internal factors to determine: *What do I want/need to go towards (reward)? What do I want/need to go away from (threat)?*

Senses detect incoming information (e.g., the smell of fresh bread). The amygdala in the limbic system evaluates the emotional importance of the incoming sensory information, based on whether the stimulus is beneficial or deleterious for our survival. The pre-frontal cortex works with the amygdala to elicit an action plan in response to the stimulus (e.g., eat the bread), or to fight, freeze or flee. Then, neurotransmitters are released (e.g., dopamine creates feelings of satisfaction and pleasure in the case of the fresh bread). As a result of the neurotransmitter response, memories are recorded in the brain (hippocampus) about whether experiences have been rewarding or dangerous, allowing us to optimise favourable circumstances and avoid dangers in the future (*greater control*). Hence, a sense of control is another significant human drive.

How well we are doing at 'surviving', and its connection with mathematics

'Mastery' is an element of 'control' and is therefore implicated in the drive for survival. This is arguably why the brain is particularly attuned to whether the outcome of an action is positive or negative (correct or incorrect – ring a bell?), and why competency in mathematics goes to the heart of our perceptions of ourselves.

Anxiety results when the brain perceives a threat or potentially threatening situation which one is *unable to control* – for example, maths tasks in class which I do not understand and perceive I will fail at, based on past experiences of failure or perceived failure (maths anxiety).

Competence in maths also has social and physical elements. Feelings of social isolation may be elicited when it is perceived that others are competent, and I am not. Indeed, some students may sideline other students who they perceive as 'not smart' because of their difficulty with maths, thus, threatening that individual's sense of belonging to the group (social acceptance). Furthermore, as emotional pain is registered as physical pain in the brain, maths anxiety also has physical impacts.

In other words, it is plausible that our competence in mathematics is strongly connected with the story we tell ourselves about how well we are doing at 'surviving'. It is therefore little wonder that repeated failure in mathematics may have a devastating impact on our life trajectory. In school, this might look like anxiety, learned helplessness and poor self-concept, social isolation, behavioural implications, school refusal, leaving school early and school detachment. In transition to adulthood and adulthood, it often translates into difficulty maintaining employment, unemployment, not venturing into further study, low income, mental health problems, poor financial decision making, never owning one's own home, and in the direst of circumstances, incarceration.

Why teaching mathematics helps children 'survive' and develop a sense of control and competence

Mathematics education equips children with important skills and knowledge

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they need to survive, including critical-thinking skills and logic to make astute decisions. Their ability to solve problems effectively enables them to optimise favourable circumstances and minimise unfavourable ones throughout their lives. Importantly, to get where they need to go and avoid what they don't want, they need to be competent in the socially agreed upon mathematical conventions by which to communicate in their interactions with others. Society uses multiple means to do so, including via language (e.g., describing properties of objects, where and how they are positioned, and how to get somewhere), the use of visual representations (e.g., clocks for time, maps for location, graphs and diagrams), symbolically or abstractly (e.g., numbers to represent size/how much/how many), and artefacts (e.g., money). These multiple modes of communication and interaction form the foundation of our mathematics curriculum and are useful tools in the toolbox which children can leverage when faced with more abstract problems to solve or important decisions to make. Equipping children in these ways gives them agency in their lives.

Although by no means exhaustive, here are some questions which link aspects of the maths curriculum to the relevance for survival:

Properties of objects

- What is it? Is it the same or different to something I have sensed before? Is it dangerous or could it be useful?
- How do I know it is what I think it is? Does it move or is it inanimate?
- What does it look like from different angles to confirm or disconfirm my hypotheses? (mental rotation/perspective)
- What can I do with it? Can it help me to get what I want or need? (tools)
- Can I manipulate it or combine it with something else to create something useful or rewarding? (mental rotation/composing/decomposing)
- How can I represent my understanding of properties of objects pictorially/diagrammatically to others? (visuo-spatial communication)
- How can I describe its properties to somebody else? (verbal communication)

Magnitude/number

- How big is it? Is it something I want (e.g., a big piece of cake), or something I want to get away from (e.g., a big dog)?
- How much is there? Is it something I want more of or need (e.g., fresh air), or something I want or need less of (e.g., too much rain)?
- How many are there? Are they something I want to go towards (e.g., family/friends), or get away from (e.g., traffic)?
- How do I describe how much/how many to others?
- How hungry am I?
- How tired am I?
- How sick am I?
- How heavy is it?

Importantly, to get where they need to go and avoid what they don't want, they need to be competent in the socially agreed upon mathematical conventions by which to communicate in their interactions with others.

- How can I represent my understanding of magnitude pictorially, symbolically or verbally?

Location/position
- Where am I?
- Where do I want to go to?
- Where is it?
- How can I represent my understanding of location/position pictorially? (visuo-spatial communication, e.g., maps, coordinates)
- How can I explain to somebody else where I am/it is? (verbal communication)

Movement
- How do I get to what I want or need? How do I get away from something I don't want or need?
- Is it something that moves? (distinction between animate and inanimate objects)
- Is it moving?
- Can it come to me? If so, what can I do to make that happen (e.g., Mum bringing lunch to school because I forgot it)? What can I do to get away from it (e.g., snake)?
- How do I catch it/use it/stop it?

Direction
- What route will I take? Which way is it?
- How can I explain to somebody else how to get there?
- What direction is one object from another?
- What are possible obstacles? How do I get around them?
- How can I represent my understanding of direction pictorially? (visuo-spatial communication, e.g., maps, coordinates)
- How can I explain the direction I am going to, or coming from, to others? (verbal communication)
- Is it up/down, backwards/forwards, left/right, north/south/east/west? (navigation)

Proximity/distance/length
- How far is it? (mapping and scaling)
- How can I represent my understanding of proximity/distance/length pictorially? (visuo-spatial communication)
- How can I explain to somebody else how far away it is? (verbal communication)

Speed
- How fast will I travel?
- How fast is it/are they travelling?
- Is it/are they travelling faster than me?
- How can I explain to somebody else how fast I am/it is/they are travelling?

Time
- What time is it? When do I have to be there?
- How long will it take to get there?
- Which way is quicker/slower?
- How can I represent my understanding of time pictorially? (visuo-spatial communication)
- What can I say to somebody else about what time it is or how long it will take? (verbal communication)

Money
- Will I have enough money to cover my essential costs (e.g., food and bills)?
- How much do I need to earn so that my earnings exceed my spending?
- How much will it cost to buy something rewarding (e.g., new console)? How much pocket money do I need to save each week to get it in 10 weeks?
- Can I afford it?
- Which interest rate is better?
- What jobs earn a good income?
- How do I negotiate a pay rise?
- How can I communicate about money? (symbolic/verbal communication)

Chance and data
- How likely is a certain outcome? (probability)
- How can I work this out? (analysis)
- What additional data can I collect to inform my decision? (data)
- Is it worth the risk? Costs? Benefits? (analytical decision-making)
- How can I represent this pictorially? (visuo-spatial communication, e.g., graphs)
- How can I explain my reasoning? (verbal communication)

Conclusion

So, what has mathematics education got to do with life? The answer is – just about everything! As the Science of Maths Learning is emerging, it is interesting to reflect on how connected the content of our curriculum is aligned with our biology. Children need to build the foundational skills necessary and be versed in the mathematical conventions to communicate and interact with others, so that they can use critical thinking and logic to make astute decisions and solve increasingly complex problems. In these ways, they are able to optimise favourable experiences and minimise negative outcomes. Thus, mathematics is not only relevant, but it also gifts children with agency in their lives and is essential for survival.

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