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KNOWLEDGE IS POWER

What teachers believe about learning

Trisha Jha

EDUCATION

McKinnon

THE CENTRE FOR INDEPENDENT STUDIES

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Executive Summary

This report presents findings from literature about what teachers believe about how students learn: the prevalence of myths about learning, to what extent these myths inform practice, and what research there is to suggest teachers understand the facts about how students learn best.

In terms of teacher knowledge and beliefs, the report finds:

1. Teachers value brain-based knowledge, but this includes myths about learning.

- The belief that students have a 'learning style' that means they learn better if taught in line with that 'style' is widely held globally, including by clear majorities of Australian teachers.
- The belief that students can be left-brain or right-brain dominant is also very common globally, and held by around half of Australian teachers.
- Other common myths include the idea that physical coordination exercises improve mental coordination, and that people only use 10% of their brains.

2. Belief in learning myths can inform practice, but the relationship is not clear cut.

- Specific studies on certain neuromyths such as learning styles and hemispheric dominance suggest teachers do self-report incorporating myths into their teaching practice, but this differs based on the myth in question and the age group of students taught.
    - o An Australian study showed 35% of early childhood teachers incorporated left- and right-brain learners into their practice, compared to 29% for primary and only 20% of secondary.
    - o The same study asked participants about incorporating physical activity into the teaching of literacy, and results were much higher for early childhood (88%) and primary education (85%) than for secondary education (53%).

3. Evidence that teachers have science of learning knowledge is limited.

- 'Science of learning-related knowledge' refers to the growing body of knowledge drawn from cognitive psychology with direct implications for teaching.
- A handful of studies explored questions relating to attention and learning, working memory and its limits, memory systems and long-term memory, retention, recall and testing, spaced, massed and interleaved practice, prior knowledge, inquiry/project-based learning and explicit teaching, and problem-solving and critical thinking.
- Results varied across these topics (except for prior knowledge, where responses were generally accurate) but in most cases the strength of evidence behind a given principle was not matched by knowledge of it among educators, and views were often polarised despite a consensus of evidence.

In terms of what policymakers need to focus on next, the report finds concerted efforts are required to build up coherent mental models among Australian teachers, ensuring learning myths are rejected and teacher knowledge is consistently based on evidence about how students learn.

The report recommends the following:

1. Policymakers must ensure initial teacher education core content requirements are rigorously enforced.
2. The Australian Professional Standards for Teachers must be rewritten, and include knowledge-based self-evaluation.
3. Systems looking to scale science of learning-informed practices in schools should measure, monitor and develop teachers' knowledge.

Future CIS research will assemble, field test and report the results of a survey assessing Australian teachers' knowledge about the science of learning.

Introduction

What is good teaching? How do we know when it's happening?

Australian politicians and policymakers have historically been unwilling to answer the first question with reference to specific, observable actions and practices, and have preferred to leave answering the second question to schools, and teachers themselves.

But without being able to define good teaching, it's impossible to know when it's happening.

Student results across national and international testing have fallen and stagnated, despite record levels of spending on education. In response, policymakers have gradually come to accept the need to open the 'black box' of classroom practice and pursue approaches that aim to more explicitly shape how students are taught.

This means policies aim to scale practices directly informed by the science of learning: insights about how students learn, connected to implications for teaching practice. One such implication is the importance of explicit teaching of a knowledge-rich curriculum — a concept that has attracted bipartisan interest politically, and the interest of diverse school systems across sectors.

A prominent example of the science of learning turn in Australian education policy is the landmark Teacher Education Expert Panel report *Strong Beginnings* (2023), which aims to reform the nation's initial teacher education courses to include this body of knowledge. But it is also evident elsewhere within the education landscape, such as science of learning-informed instructional models being gradually adopted by more systems, government and Catholic alike.

But without changes to teachers' classroom practice, policymakers run the risk of what veteran education reformer Larry Cuban once called 'a hurricane at sea' — "storm-tossed waves on the ocean surface, turbulent water a fathom down, and calm on the ocean floor".[1]

Previous CIS research (see RR47, *Implementing the Science of Learning: teacher experiences)* has observed that while 'top-down' changes in policy and frameworks are vital to creating enabling conditions for changes in practice, 'bottom up' and lateral change is even more important. Such change occurs when schools and teachers influence each other to adopt teaching practices that improve outcomes for students.

Therefore, teacher knowledge about the science of learning, however it is developed, is key to the success of well-intentioned reform movements. This is because what teachers know or believe (whether tacitly or explicitly) can inform their practice — and only what teachers practice determines the success or failure of science of learning-informed policy. England's experience with its science of learning-informed Early Career Framework suggests policy can and does influence teacher practice,[2] although this is by no means a guaranteed outcome.

Teacher beliefs and knowledge are essential for policy-driven approaches to raise student achievement via adoption of science of learning-informed practices. So finding ways to measure, monitor and develop teacher knowledge should therefore be a priority.

However, this should begin with a process of investigating what is already known about teachers' knowledge, beliefs and practices. This report uses literature to show high proportions of teachers across the world — including Australian teachers — believe in myths about learning and may incorporate those beliefs in their teaching practice.

The report also reviews the much smaller evidence base about teacher knowledge of science of learning-related concepts. Finally, the report makes recommendations for policymakers about strengthening teachers' 'mental models' of teaching, and how teacher knowledge can be measured in future.

Finding 1: Teachers value brain-based knowledge, but this includes myths about learning

Following the declaration of the 'decade of the brain' at the beginning of the 1990s, the OECD began a program of work that aimed to use new insights from brain imaging technology and connect them to various areas of public policy, including education. Since that time, studies have aimed to measure teachers' perceptions of the relevance and utility of *brain-based knowledge (BBK),* here used as an umbrella term for findings derived from neuroscience, brain imaging, psychology and cognitive science.

One of the earliest studies of teacher views and perceptions of brain-based information and its relationship to teaching and learning and used a questionnaire in 2007 to gather responses from 189 teachers, with most subjects recruited from conferences about learning and the brain. The study found most participants thought the role of the brain was important for a range of activities, "including the design and delivery of teaching, provision for special needs, and the role of nutrition", but only 57% of participants thought knowledge of the brain was important for curriculum.[3]

More recently, a small sample of 22 pre-service teachers (PSTs) and 73 in-service teachers (ISTs) completed a pre-survey about their perceptions of the science of learning, and clear majorities (86% of PSTs and 84% of ISTs) said they 'agree' or 'strongly agree' with the statement:

> I think it is necessary for educators to understand the science of "how learning happens/how people learn" before learning about recommended teaching strategies (For example, to understand why something works and not just that it works).[4]

This aligns with the earlier research, where the authors concluded:

> … this survey of teachers' views left us with a clear impression that educators do not want simply to be "told what works" (Goswami, 2006); instead, they wish to know more about the brain and the mind… [to] support their own decisions about what works in the context of their particular classroom.[5]

However, this interest masks the fact that terms such as 'educational neuroscience', 'mind and brain education', 'brain-based knowledge' or 'science of learning' can mean very different things to different people. For instance, research from the 2000s shows teachers linked such learning to ideas such as 'learning styles' and educational kinesiology (e.g. the idea that movement contributes to learning, as in the Brain Gym program). This report now turns to outlining some of the most prevalent myths about learning.

What are neuromyths?

The OECD's first major report for its Learning Sciences and Brain Research program in 2002 noted the risk of a growing belief in 'neuromyths'. Neuromyths were defined as "misconception[s] generated by a misunderstanding, a misreading or a misquoting of facts scientifically established (by brain research) to make a case for use of brain research, in education and other contexts".[6] This was further addressed in a 2007 report, which contained an entire chapter dedicated to dispelling neuromyths.[7]

Theories differ as to why neuromyths have spread. Some scholars note they are quickly packaged into "low-cost and easily implemented classroom approaches" in hopes of better supporting student learning.[8] With students, parents and teachers not knowing any better, commercial incentives can fuel dissemination.[9] Eminent education theorist and knowledge advocate E.D Hirsch has observed that some neuromyths that emphasise the differences between students sit neatly within an educational zeitgeist that emphasises individuality.[10] Other research suggests confirmation bias plays a role, where neuromyths can provide a comforting narrative of success, or lack thereof.[11]

Though studies that attempt to draw a direct connection between classroom practices and underlying beliefs are limited, there is some evidence to suggest teachers do make instructional decisions based on myths about how students learn. For example, a Deans for Impact study of beginner pre-service teachers asked them to select between pairs of teaching strategy scenarios — one aligned with the science of learning, and one not — and found a majority of participants selected the latter on the basis of considerations such as the task being "more inclusive to visual learners" and "more hands on and is more inquiry learning", and because "some students are kinaesthetic learners".[12]

In any case, in recent decades, there has been significant interest from academia in attempting to measure the prevalence of belief in educational myths, and neuromyths are one of the best-studied aspects of teacher knowledge and beliefs. A review of the literature shows that, although there are differences between countries in terms of which neuromyths are prevalent and how prevalent they are, neuromyth belief can be observed in many countries around the world. The table included as Appendix A provides a summary of some key papers in this literature.

Two early studies (Howard-Jones and colleagues in 2009 and Dekker and colleagues in 2012)[13] set the trend for research into neuromyths. These questionnaires are lengthy, and the statements tested have varying levels of relevance to learning and teaching. The full questionnaire from Dekker et al. is included in Appendix B. A sample of these items has been selected for further discussion based on their observed prevalence among teachers, as well as their direct relevance to learning and teaching.

'Learning styles' myth

One definition of the 'learning styles' construct at the heart of the myth is the following: "Different students have different modes of learning, and their learning could be improved by matching one's teaching with that preferred learning mode", with one model dividing these 'modes' into bodily senses — commonly visual, auditory, kinaesthetic (VAK),[14] sometimes with reading-writing added (VARK).

The origins of the learning styles (LS) myth are unclear, and there are several models that categorise learners differently. As there are differences between learners, and teachers will attempt to adapt instruction accordingly, LS may have intuitive appeal as a logical extension of that belief.[15] For learning styles to be true, some criteria would need to be met, according to cognitive scientist Daniel Willingham: "it should consistently attribute to a person the same style, it should show that people with different abilities think and learn differently, and it should show that people with different styles do not, on average, differ in ability".[16]

But these threshold criteria are not met on the basis of current evidence.[17] Teachers can't accurately assess their students' learning styles.[18] As Pashler and colleagues found almost two decades ago, even though people will express learning *preferences* and feel they perform better in particular modalities, experimental research does not support the idea that students learn better or worse depending on whether they have been taught in a way that aligns with their putative learning style.[19]

If the LS myth is endorsed by educators and this belief informs their approach to teaching, this can lead to several negative effects:[20]

- Pigeonholing students by making assumptions about what, or how, they will or won't learn;
- Wasted resources on ineffective methods and dilution of effective methods; and
- Creation of unrealistic expectations for teachers among students and families for appropriately individualised/ differentiated instruction.

Because LS is one of the most prevalent of the neuromyths, research has been conducted specifically about educators' belief in, use of, and attitudes to, LS theories. A complete list of studies is available in Appendix A.

As it is arguably the most prevalent myth about learning, it is one of the best-studied. A systematic review of the LS myth from 2020 included 37 studies (dating 2009-2020) covering 15,405 educators across 18 different countries, finding belief in, and incorporation of LS theory into teaching was high. 89% of educators believed in matching instruction to 'learning styles' (range: 58% to 97.6%).[21] There was no evidence qualified teachers were less likely to believe in it than pre-service teachers — suggesting this is not a belief that self-corrects with practical classroom experience.

Appendix A lists four studies using Australian PSTs and ISTs, with sample sizes being much larger in studies utilising a PST sample. Australian teachers do not appear to be different to international counterparts. One small study of teachers in learning support and special education showed two-thirds affirmed learning styles and three-quarters the concept of 'multiple intelligences'.[22] A larger study of 228 in service teachers showed 79% affirmed a belief in LS.[23]

There does not appear to be any correlation between career stage and likelihood of believing the myth. On the other hand, results vary from 97% in a study from 2017,[24] to 79% in the most recent Australian study from 2020.[25] It is possible this suggests belief in LS, at least in Australia, is waning over time, but there are any number of factors that could account for the difference. More research is needed to determine prevalence of the LS myth, both among early PSTs and ISTs.

Educators' specific understandings of LS also vary, and there is no guarantee that people mean the same thing when they use the term. Although the VAK/VARK framework and Gardner's multiple intelligences were common conceptualisations of LS in one sample of Greek teachers, the authors also note "the term seems to mean different things to different people",[26] suggesting the need for a deeper investigation of what is truly known or believed in this area.

'Hemispheric dominance' myth

The myth of 'hemispheric dominance' refers to the idea that individuals can be 'dominant' on one side of the brain or the other, so can be 'left-brained' or 'right-brained' learners. The kernel of truth at the heart of this myth is each hemisphere of the brain has specialisations, but the reality is both sides of the brain are connected and work together for most brain functions,[27] and any 'dominance' does not entail a different way of learning or a different level of aptitude or intelligence. Robert Louis Stevenson's classic novel about the duality of man, *The Strange Case of Dr Jekyll and Mr Hyde* (1886), has been posited as contributing to the myth, where the refined, logical, Dr Jekyll is contrasted with his violent, impulsive alter-ego Mr Hyde.[28]

As with the LS myth, the underlying belief appears to be one of affirming students' individuality in a way that informs how their capacities should be seen as learners. Thus, the problems with the myth as a belief in how learning happens are like those canvassed above for learning styles: the risks of pigeonholing students, and allowing students to pigeonhole themselves, thus shrinking their horizons to what is easy, familiar and comfortable.

No systematic reviews have been conducted specifically on the hemispheric dominance myth. Appendix A presents a summary of findings from global research. Studies use the phrasing from Howard-Jones et al. (2009) "Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners" as the statement to be tested, although minor variations on this wording are made in some of the listed studies.

As with LS, the myth of hemispheric dominance is highly popular, with most studies showing a clear majority of study subjects, covering countries all around the world, believe the myth. One bright spot is that two more recent studies of Australian pre-service and practising teachers both show prevalence just below 50%, although this is still a minority of reasonable size.

'Brain gym' myth

Brain Gym is a commercial program that aims to boost learning through movement, a form of educational kinesiology. In the mid-2000s, Brain Gym programs were popular in British schools, with science communicator Dr Ben Goldacre in 2006 calling it "a vast empire of pseudoscience being peddled in hundreds of state schools up and down the country".[29]

Perhaps due to the popularity at the time, the literature has tested teachers' perception of the science behind the program with the statement "Short bouts of co-ordination exercises can improve integration of left and right hemispheric brain function". Brain Gym itself has no conclusive evidence in support of its effectiveness, and the underlying neurological claims also lack empirical support.[30] It should also be noted there are other programs and approaches that make claims about hemispheric integration and mental function, but most studies use the generic statement above rather than specifying 'Brain Gym', so a belief in this myth could have implications beyond this specific program.

Compared to learning styles, the 'brain gym' myth is somewhat less popular, and there is greater variation across studies. Unfortunately for the Australian context, clear majorities of PSTs across two studies (57% and 87%) reported belief in the myth.[31] One of the two studies of practising teachers (Hughes et al. 2020) showed 94% of ISTs also believe in the myth. A similarly high proportion (91%) affirmed their belief in a similar idea, "Exercises that rehearse co-ordination of motor-perception skills can improve literacy skills". Concerningly, the same study noted that 86% of those surveyed reported being 'confident' or 'very confident' in their belief in coordination exercises improving brain function, compared to only 54% expressing confidence in their rejection.[32] Like other myths, this could result in wasted resources on ineffective methods and dilution of effective methods.

Drawing conclusions from this data about what teachers know or believe is made difficult by the fact that the boundary between fact and myth can be easily blurred on this issue. For instance, it's true that exercise can improve mental function, and the brain is separated into two spheres which have a degree of specialisation. But this does not mean coordination exercises or other educational kinesiology-related activities will have a positive impact on mental function for learning purposes.

'10%' myth

The '10%' myth refers to the idea that humans only use this small proportion of their brain capacity; the remaining capacity is there waiting to be unlocked. This is sometimes reflected in popular culture, such as the 2014 Luc Besson film *Lucy,* in which Scarlett Johansson's titular character gains superhero-like powers by unlocking this capacity.

In studies, this is tested with the statement: "we mostly only use 10% of our brains". This idea has been a talking point from as early as the 1930s, but possibly received a kickstart in the 'decade of the brain' due to the development of brain imaging techniques, with imaging purporting to show that specific areas of the brain are linked to specific functions. This may mutate into a belief that only those areas that are 'lit up' on these images are active and other areas are inactive, whereas even allegedly 'non-functional' glial cells and grey-shaded areas have their role in brain function.[33]

Overall, belief in the '10%' myth is somewhat less prevalent than belief in the other myths. The two more recent studies from Australia (Carter et al. 2020 of PSTs and Hughes et al. 2020 of ISTs) reported a prevalence of 27% and 38% respectively.[34]

Finding 2: Belief in learning myths can inform practice, but the relationship is not clear cut

Belief in neuromyths, or other false beliefs about how learning functions in the brain, should also be considered in light of whether these beliefs impact instructional decision-making. The four key myths (learning styles, hemispheric dominance, brain gym and 10%), with their high levels of prevalence, have a mixed level of instructional implications, with study participants likely to say views on concepts such as learning styles and hemispheric dominance informed their teaching.

The 'learning styles' myth in practice

The aforementioned systematic review of the LS myth found overall 89% of educators believed in the idea of matching instruction to learning styles. The proportion of educators who reported matching teaching to learning styles in practice was lower, but at 80% still extremely high.[35]

Only one Australian study asked the question about LS and teaching, asking "Do you take into account individual Learning Styles (i.e. visual, auditory, kinaesthetic; multiple intelligences) in your teaching practice?" and revealed clear majorities of teachers in the sample did, albeit at different rates: 88% for early childhood, 85% for primary and 83% for secondary.[36] In a study of 283 French Swiss educators using different wording, 96% of participants agreed "some individuals are visual, others are auditory", 87% agreed "a pedagogical approach based on such a distinction favours learning", and 80% reported they either used or intended to use this distinction in teaching.[37]

Greek teachers reported LS-informed approaches in their teaching, such as through interactive boards and computers, motor activities like sensory play and working in groups.[38] While none of these are problematic approaches in and of themselves, if they are being used to achieve a goal of catering to LS, they may not serve to address core learning objectives — and will waste scarce instructional time as well.

A US study of 60 educators presented participants with lesson scenarios, in which one option would cater to the students' learning style (in only one of the VAK modalities) and the other delivered the lesson in each of the modalities. Participants were then asked to justify their choice, and these justifications fell into the categories of beliefs about modalities (embracing or rejecting LS or embracing multi-modal styles), practical considerations (like logistical constraints or planning, teaching and classroom management considerations) and learning and motivation (perceived need to address student choice and engagement or differentiation). Only a quarter rejected LS outright as a reason for selecting the multimodal lesson option, and some who selected the multi-modal style argued "a mix of presentation styles to engage multiple parts of the brain" and "a student can have more than one learning style".[39] The authors concluded that around 82% of educators surveyed embraced LS to some extent and perceived it as a "vehicle for choice and differentiation", but many reject it for teaching on the basis of practical considerations — not because of an underlying belief that the concept is unscientific.

There is evidence of LS incorporation outside school education. One study of 114 UK academics in higher education found 58% believed in LS, but a higher proportion (65%) reported they tried to accommodate LS in their teaching. On the other hand, only 33% reported using it in their teaching in the past 12 months. More concerning was that 32% said they would continue to use LS in teaching, despite being shown the lack of evidence to support it.[40] The fact that more instructors tried to accommodate LS than believed in it and a third had used it recently — seemingly contradictory findings — shows the difficulty in trying to assess teaching practices on the basis of self-report surveys.

The ‘hemispheric dominance’ myth in practice

In Australia, the single study that attempted to answer the question about whether belief in hemispheric dominance informed teaching practice showed a much lower prevalence than for learning styles. 35% of early childhood teachers answered in the affirmative to the question “Do you take into account left-brain versus right-brain learners in your teaching practice?”, compared to 29% of primary and only 20% of secondary teachers.[41]

A qualitative study of pre-service teachers in Hong Kong on the hemispheric dominance idea yielded some interesting comments from participants. One final year student said “[Left-brained versus right-brained] was discussed in the psychology course when I was in Year One. However, they just taught us what it means by left- and right-brained learners. They did not teach us the pedagogical way of dealing with or teaching them”. Another said “I remember that a tutor told us that a student good at memorizing words or numbers is a left-brained learner while one strong on remembering pictures or images is a right-brained learner. The tutor said that if I identify my students as being good at mathematics and logics, I should use more theories and graphics such as tree diagrams to teach them the language. If students are more sensitive to images and are creative learners, I should use more pictures and images to assist their learning”.[42] While this is hardly conclusive evidence, it is possible comparatively low reports of the incorporation into practice might reflect the perceived difficulty in translating the belief into practice, rather than a lack of desire to incorporate it because of a belief that it is false. This leaves open the possibility that if certain approaches claim to offer a practical method of incorporating hemispheric dominance into teaching practice, teachers will be vulnerable to it.

The ‘brain gym’ myth in practice

Data on the extent to which belief in the Brain Gym informs teaching practices is limited and unclear. 65% of the French Swiss educators surveyed in Tardif et al. 2015 reported they used or intended to use Brain Gym with their students.[43] When Australian teachers were asked about incorporating physical activity into the teaching of literacy (some examples were “Crawling during spelling games” and “Brain break activities including cross-laterals and stretching”), results were much higher for early childhood (88%) and primary education (85%) than for secondary education (53%).[44] The distinction between age groups is notable and may reflect a philosophical preference for certain instructional practices at certain ages that feeds the belief in the myth, rather than the belief in the myth directing teaching practice.

The ‘10%’ myth in practice

As with the ‘brain gym’ myth, there is limited data on the extent to which the ‘10%’ myth informs teaching, and the myth does not lend itself to a direct instructional implication. The risk is more that believing the myth makes it more likely teachers will make poor instructional decisions if they are told certain approaches are more likely to ‘expand student brain capacity’ or similar. As with ‘hemispheric dominance’, this means teachers may be susceptible to claims that incorporate these ideas into teaching practices if the myth is not radically dispelled.

Finding 3: Evidence that teachers have science of learning-related knowledge is limited

Having considered what myths teachers believe about learning, the next step is to address what knowledge teachers hold about the science of learning — what they know and believe about the truths about learning and teaching. It should be noted that the total volume of studies is much smaller, with only a handful addressing relevant constructs.

What is 'science of learning-related knowledge'?

Earlier CIS research defined the science of learning as "the connection between: 1) insights from cognitive science and educational psychology; and 2) the teaching practices supported (and not supported) by those insights".[45] This model — in which how teachers *teach* should be informed by how students learn — is a consistent thread throughout most of the instructional models and position statements issued by different school systems (see Box 1).

Furthermore, educational psychologist Barak Rosenshine observed that research in cognitive science, observations of the practice of master teachers and research on cognitive supports and scaffolds align despite being very different sources of information and argued "[t]he fact that the instructional ideas from three different sources supplement and complement each other gives us faith in the validity of these findings".[46]

The 'science of learning', as an interdisciplinary body of knowledge linked directly to teaching practice, is relatively new. Hence, it is currently poorly-studied and drawing firm conclusions is impossible. This section will focus first on discussing results that relate to teacher knowledge about some of the core concepts of how students learn, and some of the implications for instruction, that underpin developments in policy such as the Strong Beginnings report and other system-wide models. A summary of relevant ideas is included in Table 1.

Table 1: Summary of some common ideas embedded in science of learning-related frameworks

Ideas about learning	Ideas about teaching
• The environment and attention, including directing and securing attention as a precondition for cognitive engagement • Memory systems, including the distinctive features and functions of working and long-term memory, and the role of cognitive load in learning • Retention and recall, including how knowledge is encoded through repeated and diverse opportunities for thinking, and the role of forgetting • The novice-to-expert continuum, including how the volume and organisation of knowledge differs between novices and experts	• Carefully sequencing learning to build student knowledge over time • Providing clear explanations of new material in small chunks, providing multiple thinking and practice opportunities • Checking for student understanding and provide feedback frequently as new material is being taught • Using cognitive scaffolds such as modelling, worked examples and gradual release of responsibility • Conducting daily, weekly and monthly review to activate prior knowledge and embed new material in long-term memory

The remainder of this section discusses items that have been used in literature to test science of learning-related teacher knowledge, grouped into eight topics that span both ideas about how students learn and ideas about how teachers should teach.

Items are reproduced as they appear in the literature, including whether the statement is coded 'true' or 'false' in the original study. The inclusion of individual survey items from the various studies in which they have been used is not an endorsement of their definitional clarity or claim about their suitability for broader use.

Attention and learning

Willingham argues attention is the first step in the learning process, arguing "[t]here is lots of information in the environment, most of which we are not aware of… If you don't pay attention to something, you can't learn it".[47]

Knowledge about the relationship between attention and learning has been tested using the following statements:

1. To learn how to do something, it is necessary to pay attention to it (true) (Herculano-Houzel 2002, Howard-Jones et al. 2009, Van Dijk and Lane 2018, Khramova et al. 2023).
2. Focused attention is essential for learning new information (true) (Betts et al. 2019).

Statement 1 was first tested with the general public (not educators) in Brazil, where 73% of those surveyed agreed.[48] Educators, on the other hand, have varied levels of agreement, with 43% among a small sample of graduate teachers in the UK[49] and 47% for US educators,[50] but a much stronger 81% for Russian pre-service teachers.[51] A survey of 427 higher education instructors found 70% agreed with Statement 2.[52]

Working memory and its limits

Working memory has been described as "the limited mental space in which we think".[53] If this mental space is limited, knowing those limitations and ensuring teaching practices are designed around them is crucial to the work of teaching. Willingham specifies a 'modal' model (a simplified model that helps to organise empirical findings) of working memory should be something that goes into teachers' mental model of how students learn.[54]

While memory is relatively well-studied within the broader field of cognition and psychology, only one Australian study of educators has included items relating to how students learn, which reported that of the 87 learning support and special education teachers surveyed, all of them agreed "we can teach students to use their working memory more efficiently and effectively" and 86% agreed "students with ADHD are likely to experience constraints in the capacity and functioning of working memory".[55]

A study of 1,425 UK educators used a short online questionnaire to provide free text followed by multiple choice answers to questions about working memory.[56] In relation to the definition of working memory, free text responses were described by the authors as "a wide variety of responses reflecting less secure understanding", with only 10% referring to limitations of working memory and linking to long-term memory. More positively, 88% were able to identify working memory correctly from a list of five descriptive examples of memory types.

Understanding of the capacity limitations of working memory in this study was more secure. Two-thirds of free text responses gave an answer within the correct range of '2-9 items', rising to three-quarters for the multiple choice. However, respondents overestimated duration: about 20% of free text responses gave answers in the range of up to a minute, with the balance estimating duration higher. Multiple choice responses saw 12% select the option of 'a few seconds'. Considering the consensus on the average duration of working memory converges on 20 to 30 seconds, understanding of the limited duration of working memory was not strong in this sample.

Memory systems and long-term memory

Long-term memory can be described as "[a] vast store of knowledge and a record of prior events",[57] and learning "a change in long-term memory".[58] The fact that working memory acts as a bottleneck to long-term memory, but that deeper long-term memory can help make working memory more powerful, means that knowledge about memory systems is integral to teaching.

1. Keeping a phone number in memory until dialling, recalling recent events & distant experiences, all use the same memory system (false) (Herculano-Houzel 2002, Howard-Jones et al. 2009, Van Dijk and Lane 2018, Khramova et al. 2023).

2. Information that is studied over longer periods of time is better remembered than the same information studied over shorter periods of time (true) (Betts et al. 2019).

3. Repeated practice and rehearsal of learned material or a skill will help consolidate it in long-term memory (true) (Betts et al. 2019).

One of the earliest studies of neuroscience knowledge tested 'memory systems' with Statement 1. About half (51%) of the general public in Brazil disagreed with this statement,[59] as did 44% of UK graduate teachers.[60] Only 1 in 5 (21%) of US educators identified the statement as false,[61] and 36% in Russia.[62]

The survey of higher education instructors tested two statements about repetition and remembering over the longer term.[63] Both statements #2 and #3 are correct and broadly similar, except Statement #2 includes an alternative ("the same information studies over shorter periods of time"). The results show 55% of instructors agreed with Statement #2, but almost everyone — 93% — agreed with Statement #3. This points to the difficulty of designing items that accurately capture respondents' views. It's possible the use of the word 'information' in Statement #2 and 'material or a skill' in Statement #3 also invited people to respond differently.

Retention, recall and testing

Related to long-term memory is the question of retention or storage: given the difficulties inherent in encoding new material in long-term memory, how is learning retained and what practices enhance retention? While the importance of low-stakes tests and quizzes to learning and retention is well-established,[64] teacher knowledge of this is varied.

A survey of higher education instructors tested the idea of 'learning for retention' in the first three statements below:

1. Rereading course materials is an effective strategy for learning (false) (Betts et al. 2019)

2. Testing, in general, tends to detract from learning (false) (Betts et al. 2019)

3. Frequent, low-stakes tests do not enhance learning (false) (Betts et al. 2019)

4. Doing tests (not necessarily exams) is an efficient learning method (true) (Fernandez et al. 2025)

A troubling finding is that only 26% of those surveyed correctly identified Statement #1 as false. Respondents were more likely to recognise the positive relationship between testing and learning (54% recognised Statement #2 as incorrect, increasing to 72% for Statement #3 which clarified "frequent, low-stakes tests"),[65] but it is concerning that this presumably means instructors are more likely to be encouraging their students to engage in re-reading as a study technique than they are to be setting in-class quizzes to support student learning.

In a recent study, 3,158 teachers across Spain were asked to rate 27 statements relating to learning and teaching on a 6-point scale, with results reported in terms of mean, median and standard deviation. One statement was Statement #4 above. Participants scored a mean of 4.03, indicating a moderate level of agreement, and with a standard deviation of 1.38, this suggests considerable variation in responses across the sample.[66]

Spaced, massed and interleaved practice

'The spacing effect' refers to the idea that by spreading practice opportunities out over time, new knowledge is constantly reviewed, enabling consolidation in long-term memory (similar to the ideas about retention discussed above). The interleaving effect is an example of 'desirable difficulties'. By varying practice opportunities in a given study session once a base level of competence has been achieved, students are able to be more discerning about strategy selection when tackling problems.[67] These ideas have overlap and the grouping here is not intended to be definitive. Three studies tested educators' knowledge of these concepts across four statements:

1. Learners perform better when they are able to study different topics systematically one-by-one rather than intermingled with one another (false). (Grospietsch and Mayer 2019)

2. Learning should be spaced out over time (true). (Betts et al. 2019)

3. With respect to memory, massed instruction is superior to spaced instruction (false). (Betts et al. 2019)

4. Distributed practice is better than massed practice (true). (Fernandez et al. 2025)

Statement #1 was affirmed by 52% of this sample of 550 pre-service science teachers in Germany.[68] The authors code this statement as 'false' but the statement is also ambiguous in terms of whether it refers to initial instruction — in which case it is true — or whether it refers to subsequent study and practice. This again highlights the difficulties in attempting to assess knowledge through simple binary (true/false) questions presented without reference to instructional scenarios. Interleaving is less well understood among an Education Endowment Foundation (EEF) survey of UK teachers than spaced practice and retrieval practice.[69]

In the Betts and colleagues study of higher education instructors, Statement #2 saw 76% agreement whereas Statement #3 saw a lower level of agreement at 58%. This might be because Statement #2 is phrased more generally than Statement #3, with the latter also specifying 'with respect to memory'.[70]

Separately, the Fernandez and colleagues study saw Statement #4 scored a reasonably positive median of 4.23 and a standard deviation of 1.33,[71] nevertheless indicating a greater amount of variation than is warranted given the security of evidence as it relates to practice subsequent to instruction.

Prior knowledge

Attempting to measure teachers' knowledge about the role of prior knowledge in learning is conceptually tricky because while it is true that what we already know impacts how we interpret new knowledge and ultimately incorporate it into our pre-existing schema, this insight can be applied to practice in various ways. For instance, it could be used to justify 'personalising' learning, allowing the student to direct what he or she pursues, on the basis they will learn better with what is already familiar. On the other hand, when the role of prior knowledge is one part of a broader mental model incorporating long-term memory and schema theory, then this lends itself to teaching approaches which try to ensure those schema are as rich and dense as possible. While assessing perceptions of prior knowledge is potentially useful, it may not allow for effective discrimination between different sets of teachers' beliefs.

1. Finding related examples promotes learning (true). (Fernandez et al. 2025)

2. Students can only learn if they have some previous interest (false). (Fernandez et al. 2025)

3. The mind connects new information to prior knowledge (true). (Betts et al. 2019)

Respondents across the two studies expressed high agreement with Statements #1 and #3 — 95% of higher education instructors agreed with Statement #3,[72] and the study of Spanish teachers which included Statement #1 saw it receive the highest mean agreement score (5.07) with a very low (in the context of that study) standard deviation of .89, indicating respondents were mostly in agreement.[73]

Statement #2 was included in this topic to test the diverse ways 'prior knowledge' can be incorporated into teaching. This statement had very low agreement, with a mean score of 2.76 — but a standard deviation of 1.47 suggests the educators surveyed vary on this issue.[74]

Inquiry/project-based learning and explicit teaching

One of the main instructional implications about the body of scientific knowledge relating to attention, memory systems and learning is that new material should be taught using the principles of explicit teaching — as opposed to more student-led, minimal-guidance forms of teaching. The Fernandez et al. 2025 study assesses teachers' beliefs about these ideas in three items:[75]

1. There is still little evidence supporting the use of project-based learning (PBL) in basic education (true)
2. Learning to read is not a natural and spontaneous process. It requires explicit instruction (true)
3. Students learn better by discovering things on their own than through direct instruction (false)

Teachers do not believe that PBL in basic education lacks an evidence base. Statement #1 received a mean agreement score of 2.93 with a standard deviation of 1.59, suggesting teachers generally think PBL is evidence-based, but views are polarised — with a reasonable proportion of teachers believing the opposite.

This contrasts with Statement #2, specifically about learning to read, which had a mean agreement score of 4.27 and standard deviation of 1.48. Teachers showed clear agreement that learning to read requires explicit instruction rather than developing naturally. However, there was notable variation in how strongly teachers held this view, suggesting some diversity of opinion.

Statement #3 received a score of 3.8 and a standard deviation of 1.59. While the slight overall lean suggests teachers favour discovery learning, there appears to be substantial disagreement within the profession, with some teachers strongly favouring discovery approaches and others strongly supporting direct instruction methods.

Problem-solving and critical thinking

Although the belief that education should train students to be effective problem solvers and critical thinkers is widespread, there are differences in how this translates to teaching practice. On one hand are those who believe that for students to develop these generalisable, 'higher order skills' (creativity is often included in this as well) they should be given lots of opportunities to practise them in whichever way, because they will transfer into different contexts. On the other hand, the evidence points to these 'higher order skills' being domain-specific (taught within subjects) and non-transferable across disciplines.[76]

Three statements have been used to test educators' perspectives on this issue:

1. Experts and novices approach problem-solving in essentially the same way (false). (Betts et al. 2019)
2. General critical thinking can be taught without appealing to concrete contents (false). (Fernandez et al. 2025)
3. Problem solving is a skill which needs to be practiced in context (true). (Fernandez et al. 2025)

76% of higher education instructors in Statement 1 were able to correctly identify that experts and novices approach problem-solving in different ways.[77] While positive, this does not mean they necessarily affirm the most logical instructional implication — that novices cannot be expected to approach novel problem-solving or critical thinking tasks like experts do.

The pair of statements from the Fernandez et al. study is interesting because they represent the two sides of the debate. Statement #2 received a mean of 2.8 and a relatively high standard deviation of 1.66, showing a moderate level of disagreement but a great deal of variation and polarisation. Statement #3 had a mean score of 4.34 and a standard deviation of 1.33, indicating a level of variation similar to most other statements discussed above.[78] This difference suggests respondents could interpret 'general critical thinking' and 'problem solving' differently.

Implications

Overall, this review of what educators know and believe about the science of learning and related teaching practices indicates highly variable levels of knowledge overall. When the same underlying concept is tested in the same survey with different items with different wording, as in the Betts et al. study of higher education instructors, results are not always internally consistent, indicating the difficulty of drawing a firm conclusion on the basis of one item per topic. Moreover, the Fernandez et al. study of Spanish teachers, which included a significant array of questions, had a 6-point scale design with reporting of the standard deviation, showing how varied teacher knowledge was within the sample for individual items, not just across topics.

There are some areas where the strength of empirical evidence of a particular science of learning principle was not matched by the level and consistency of knowledge among educators. This is particularly true of the areas of attention, working memory, and the testing effect, where results were highly variable across studies and within samples.

Of particular concern was the highly variable amount of knowledge of the relationship between attention and learning. Given this is a foundational principle upon which broader understanding of human cognitive architecture is based, if teachers do not understand it, it can negatively impact their decision-making. Knowledge of working memory was only tested in one study, albeit using a fairly sophisticated mechanism. The authors of that study (Atkinson et al.) found that while respondents knew working memory was limited in its capacity, what working memory is and its duration were less well known.

Another concern relates to re-reading versus testing as a tool of study and practice. The cognitive insight that underlies the 'testing effect' — that the student being forced to engage cognitively and experiencing a 'desirable difficulty' — also shows why re-reading is not an efficient technique. As Willingham has argued, "memory is the residue of thought"[79] — and re-reading does not require thinking. This might mean that those surveyed have a vague sense that quizzes are good, but not *why* they are good, potentially impacting their instructional decision-making, especially in terms of avoiding bad practices.

Another useful litmus test of teacher knowledge is attitudes towards explicit teaching, given the way explicit teaching practices in the classroom are informed by science of learning principles. Only one study investigated these and across the three statements, the one consistency was variation: teacher views tend to sit slightly above the midpoint or slightly below the midpoint, but with a large enough standard deviation that suggests different views across the profession.

Implication 1: Teachers' mental models need strengthening for teachers to be full professionals

Teachers show an inconsistent understanding of how students learn

The analysis of literature in the first part of this paper shows many teachers, including Australian teachers, believe in myths about how people learn, but it's less clear how this affects their practice.

Moreover, there is a much smaller quantity of evidence about what teachers know about the science of learning, but what evidence there is suggests teachers are reasonably divided even where the evidence is clear.

Another question is whether there are any individual teacher factors — such as gender, years of experience, level of qualification, age group taught — that make teachers more or less likely to hold evidence-informed views about learning and teaching?

Evidence about this question is mixed, with findings inconsistent across studies and some studies showing only weak correlations.[80] Some studies find practising teachers have more accurate knowledge than pre-service teachers,[81] and that pre-service teachers towards the end of their degrees are no less likely to believe in neuromyths than those earlier in their studies. Given the level of neuromyth belief in the general population is high, it is probably most true to say initial teacher education does not adequately dissuade future teachers from believing in myths (see Box 1). Whether practising teachers eventually come to reject 'folk knowledge' in favour of professional knowledge is probably a matter of chance.

Some authors have argued that whether teachers believe neuromyths is irrelevant to how effective teachers are, on the basis that teachers who win educational awards are just as likely as regular pre- and in-service teachers to believe or disbelieve neuromyths.[82] On the other hand, given teaching awards are typically focused on metrics of success that do not directly relate to objectively measured student learning, this is more likely to suggest that neuromyth belief is widespread across the teaching profession.[83]

Evidence-based mental models are needed to improve practice

Nevertheless, not believing in neuromyths does not necessarily mean teachers hold evidence-based ideas about learning. Willingham advocates teachers having a "mental model of the learner" based on empirical generalisations: observations made consistently over time and context that can have a reasonable amount of confidence that they are generalisable to the general population. These empirical generalisations should also meet the requirement of having direct implications for instructional practice.[84]

As noted by Deans for Impact, teachers have different mental models that inform their teaching, whether they know it or not:

> All teachers, whether implicitly or explicitly, employ a theory of learning when they teach. By this we simply mean that teachers have a *set of beliefs and expectations about how their instructional decisions will foster learning with their students.* Those beliefs and expectations comprise a teacher's mental model — and we believe *that model should be informed by our best available scientific understanding of how we learn.* [emphasis added].[85]

In keeping with the idea of the mental model, teachers' beliefs can also be seen as 'filters for instruction'.[86] If these 'filters' are such that they lead to effective practices being discarded and less effective ones surviving, this will impact instructional decision-making, and lead to sub-optimal uses of resources such as time, money and attention, and displacing better use of those resources.[87] This makes the contents of teachers' mental models critical if the desire is to improve teachers' instructional decision-making — thereby lifting student outcomes.

Willingham advocates providing simple 'modal models' to teachers — simplified cognitive models that organize empirical findings without introducing risky, untested predictions. These models help teachers connect and remember key facts about learning without getting bogged down in academic debates.[88]

An extensive body of work on teacher beliefs suggest they are complex, only partly driven by explicit knowledge (what they have been taught), and the role of empirical evidence could vary from person to person.[89]

The notion of internally contradictory mental models, where fact and fiction sit side by side is supported by research.[90] For instance, one study of German pre-service science teachers showed participants could express agreement with valid scientific concepts and endorse neuromyths at the same time. This study also found some correlation between constructivist views of teaching (which the authors defined as viewing "learning as an active, self-directed, constructive process in which knowledge cannot simply be transferred to the learner") and greater endorsement of neuromyths. The authors argued "… neuromyths seem to be integrated into the semantic network of theory-based learning beliefs despite their scientific inconsistencies, which can make them more difficult to change" and interventions "must begin deep in participants' belief systems."[91]

More recently, the Fernandez et al. study of Spanish teachers, investigating views about learning and teaching, found diverse beliefs across the sample on most surveyed items, with scores clustering around the middle — regardless of how clear the empirical evidence was on the matter at hand.[92]

In addition, the authors found some of the beliefs correlate with each other in unexpected ways. Carl Hendrick, who is a professor of education and specialist in learning and instruction, argues "[t]he authors' analysis suggests that misconceptions are not isolated errors but components of larger mental models: coherent, but often scientifically inaccurate, worldviews about learning. And here's the worrying implication: correcting a single myth in isolation may have little impact if the underlying belief system remains intact."[93]

A previous section observed that when teachers consider brain-based knowledge (what science can tell educators about learning) they have historically interpreted the term in broad and diverse ways. As early as 2009, the risks of a non-prescriptive approach to mind, brain and education training were apparent:

> [A] 'hands off' approach based on encouraging engagement with educational research may not, however, have adequately protected teachers and their pupils from a host of inappropriate practices associated with unscientific ideas about the brain. Indeed, it is possible to find examples of unhelpful brain-based ideas being promoted rather than scrutinised in the educational research literature.[94]

The evidence explored in this paper suggests Australian teachers have not been adequately trained and supported to develop mental models based on the empirical generalisations Willingham advocates. In part, this is because policy settings have not expected them to.

But policy changes in England that have affected initial teacher training, as well as the professional development of early career teachers,[95] appear to have had some impact in shaping teachers' understanding of broad terms in ways that align more closely with evidence.

One small example is a 2022 survey commissioned by UK charity Learning Skills Research about educational neuroscience. Of the six reported responses to the open-ended question "Can you please summarise for us your understanding of the concept of educational neuroscience?", teachers responded with ideas like "capacity of working memory", "pressures of cognitive overload", "how our brains learn and store information into memory" and "knowledge of how the brain works to improve learning".[96]

Similarly, an Education Endowment Foundation (EEF) survey of around 500 UK teachers (a sample noted by the paper's authors to be more experienced and potentially positively predisposed to cognitive science-informed approaches to teaching) found over 90% of teachers agree with the statements "Learning about cognitive science has improved my teaching" and "All teachers should be taught cognitive science informed teaching strategies".[97]

Australian education is catching up in this area. Dr Mark Carter, formerly of Australia's Macquarie University, argued in a study he co-authored of neuromyth belief that initial teacher education should, at a minimum, have an immunising function through the "provision of accurate knowledge about the brain, and about learning more broadly".[98]

Previous CIS research has observed that teachers essentially 'discovery learn' their way to science of learning knowledge rather than being explicitly taught, either in initial teacher education or through professional development opportunities.[99] The EEF survey of teachers about cognitive science in the classroom found around 40% of teachers said their knowledge of concepts such as spaced practice, interleaving, retrieval practice, dual coding and managing cognitive load came from independent learning, with "training provided by own school/trust" a distant second (around 20%).

While it is positive news that teachers are encountering this information, there are also risks involved if educators are forced to rebuild new mental models without proper care and understanding of the underlying evidence base. One risk is of 'lethal mutations', where evidence-informed strategies are implemented in ways that lack nuance or awareness of context, or contradict rather than complement other effective strategies.

In the school context, too much time spent on strategies that have diminishing returns beyond a certain point could mean other important strategies are ignored or not given the amount of time that their impact on student achievement would warrant. These are context-dependent complexities, but the best chance of success derives from decision-making from those who have a deep rather than superficial mental model of the theories and practices involved.

Implication 2: The success of reform efforts depends on how successfully teacher knowledge is developed

Teaching cannot be a full profession without better knowledge

Teaching can be described as a semi-profession in part because, unlike other professions, teaching lacks "a profession-specific, systematised and scientific body of knowledge that informs the daily activities of practitioners",[100] nor does it have "a shared professional vocabulary"[101] where the meaning of terms is construed similarly among different individuals.

Box 1 shows that myths about learning exist outside the teaching profession, and it's not necessarily true that teachers believe myths because they have been taught them in their training. Part of becoming a professional is the shedding of 'folk knowledge' about a given discipline and replacing it with professional knowledge. But the strength of beliefs in myths evident in this report suggests teacher training (from initial training through to continuous professional development) has not had a strong enough focus on refuting neuromyths and ensuring brain-based ideas about learning and teaching are based in evidence.

Box 1: Myths about learning outside the teaching profession

It is to be expected that members of the general public will develop a kind of 'folk wisdom' or 'folk knowledge' about learning, and if this folk knowledge includes myths, people entering into initial teacher education would thereby believe in myths about learning.

Some literature has attempted to survey belief in learning myths among non-teachers, with the aim of discerning how much observed neuromyth belief in the teaching profession could be attributable to teacher training. For example, if teachers are more likely to believe in neuromyths than the general population, it suggests their training experiences may be to blame. One study of pre-service teachers towards the very beginning of their course, when no neuroscientific material has been taught, find they had nevertheless encountered 'brain-based' ideas about teaching and learning.[102]

The evidence indicates learning myths indeed exist in people's 'folk knowledge' about how learning happens. A 2002 survey of 2,158 members of the public in Rio de Janeiro were contrasted with the opinions of 35 senior neuroscientists on issues relating to mind and brain, memory, and learning. The author found the public held misconceptions about memory, believing there was only one memory system and the brain functioned like a computer, and they also believed people only use 10% of their brain.[103] Some of these question items were reused by Howard-Jones et al. in 2009. The response to the statement "We mostly only use 10% of our brains" was believed by 52% of the teacher training graduates in the Howard-Jones sample[104] and 48% of the general public surveyed in Herculano-Houzel.[105]

Similarly, a 2021 study compared belief in neuromyths between 366 members of the public and 203 people working in education, and found the average correct responses to neuromyth identification were the same for both groups.[106] On the topic of LS in particular, one study investigated belief in LS from a US sample of non-educators and found that in comparison to another US sample of people working in education and training, both groups had similar (upwards of 90%) belief in LS — although educators working with very young children were the most likely to believe LS had a biologically-essentialist component.[107]

Some research compares the neuromyth belief between teacher education students and those from other university majors. One 2023 study from Austria compared belief in neuromyths and 'neurofacts' across a 40-item questionnaire between psychology students and teacher education students. The study found that while the psychology students were less likely to affirm neuromyths than trainee teachers, the most prevalent in each group were shared: "students learn better when information is presented according to their learning type" was the most frequently affirmed by both groups, with 91% agreement for psychology students and 97% for trainee teachers.[108] A 2023 study from Russia compared brain-related facts and myths among students in four disciplines: pedagogy (teaching), chemistry/biology (CB), psychology, and physics/mathematics/computer science (PMCS).[109] The study found CB and PMCS students were overall more likely to make correct identifications (that is, myths as myths and facts as facts). While this was true overall, looking at the specific question items with most proximity to learning and teaching, most showed similar results (within a few percentage points) regardless of the respondents' disciplinary specialisation.

Teachers and other education professionals are members of a general community before they move into these professions, so it should be expected they will initially hold views that are not significantly different from the rest of the population. However, this is the role of professional training to rectify.

In other professions and in other countries, defined professional standards, obtaining an approved qualification (in this case, initial teacher education), sitting a certification exam, seeking registration with a professional body, and ongoing professional developments to maintain registration interlock and overlap to create a functioning profession. Teaching in Australia has all these, except for the certification exam.[110]

But in reality, all professional mechanisms have at their heart the Australian Professional Standards for Teaching (APST). In their current iteration, the APST do not foster this form of professionalism, as school leader Rebecca Birch has argued.[111] For example, knowledge of "how students learn", and how this relates to teaching, is a requirement of Standard 1.2 of the APST, but what the best evidence shows about how students actually learn is not articulated anywhere, and nor is there an expectation that teachers interpret that phrase in roughly the same way.

As the other regulatory mechanisms, such as many previous reforms of initial teacher education and state-based registration and ongoing professional development requirements, have thus far merely reflected the pedagogically agnostic APST, it is difficult to argue the presence of shared knowledge or vocabulary that is definitive of a profession.

It is only recently that, with the publication of the *Strong Beginnings* report to reform initial teacher education, which knowledge teachers require has been broadly identified.

The *Strong Beginnings* report made recommendations across four areas, of which the first two are most relevant to the question of teacher knowledge:[112]

1. **The brain and learning:** content that provides teachers with an understanding of why specific instructional practices work, and how to implement these practices; and

2. **Effective pedagogical practices:** practices including explicit modelling, scaffolding, formative assessment, and literacy and numeracy teaching strategies that support student learning because they respond to how the brain processes, stores and retrieves information.

Against this backdrop, increasing numbers of Australian school systems — both government and non-government — are adopting models of pedagogy (approaches to teaching and student learning), that reflect the science of learning (see Box 2). Essentially, these systems have attempted to capture and distil what they think the 'mental models' of teachers in their systems should contain, in line with the "best available scientific evidence of how we learn".

Box 2: A growing 'science of learning' movement

In the past five years, there has been a strong growth in the number of systems adopting educational models that emphasise the cognitive science and educational psychology insights of how students learn and uses this to direct teaching practice.

The Catholic education systems of Canberra-Goulburn (Catalyst program, October 2021), Tasmania (Insight into Learning program, November 2022) and Melbourne (Flourishing Learners, February 2024) and Sandhurst (January 2025) have launched programs aimed at embedding greater knowledge of scientific concepts relating to learning and fostering reading skill, as well as high-value practices to support students, within their schools and for their students. Systems use a combination of position statements and 'big ideas' lists, reading and resource packs and professional learning opportunities led by carefully selected experts, with the shift in pedagogy supported with curriculum-aligned lesson plans. With supports for practice selected based on their alignment with the science of learning, the aim is to develop common mental models of teaching.

Efforts from state systems have not been as broad-ranging, but are nevertheless based on similar ideas. In October 2023, head of the NSW Department of Education, Murat Dizdar, announced his support for explicit teaching in NSW public schools, supported by a professional learning day in April 2024. In June 2024, the Victorian Education Minister Ben Carroll and the Department of Education released the Victorian Teaching and Learning Model 2.0, which was based on the work of the Australian Education Research Organisation (AERO): aligning teaching practices with what is known about learning. Similarities are evident between AERO's model and Tasmania's Pedagogical Framework. There can be more subtle allusions to these ideas as well, such as WA's Teaching for Impact framework, informed by the work of John Hattie, which includes teaching in accordance with cognitive load theory.

Teachers need a science of learning knowledge toolkit to be effective, discerning practitioners

Teachers have historically operated within an education ecosystem in which a smorgasbord of contradictory ideas have proliferated. Without clear and robust mental models about how learning occurs, teachers face significant challenges in extracting effective practices from a great deal of educational noise.

The language of 'evidence-based' is quite common in education, but ideas such as a spectrum or hierarchy of evidence are less understood. Policymakers have not always used this language in their guidance to teachers, perhaps from a well-intentioned desire to keep things simple for teachers. But this has its downsides. As previous CIS research has observed, instructional advice from school systems can include the importance of teacher-led explicit instruction, alongside resources advocating student agency over learning activities and assessment, running counter to the philosophy and evidence behind explicit teaching.[113] If advice from systems hasn't been consistent, then how can time-poor teachers be expected to puzzle out the truth?

Other strategies have been employed, with varying levels of teacher or policy involvement, to improve the use of evidence-informed approaches within the teaching professions while acknowledging teachers' limitations (time, access to literature, knowledge).

This is where third parties such as Evidence for Learning (based on a UK tool funded by the Education Endowment Foundation) come in as independent brokers and communicators of the evidence, using criteria such as strength of evidence and relative costs to help teachers make decisions.[114] John Hattie's Visible Learning toolkit uses 'effect sizes' from aggregated meta-analysis to provide advice about relative effectiveness of different educational approaches.[115]

While such an approach could be helpful in assessing the relative merits of packaged materials (e.g. curricular resources or intervention programs), what is lacking is a set of 'first principles' about how students learn that helps teachers make informed judgements about different approaches to teaching.

One participant in the research for *Implementing the science of learning: teacher experiences* noted the Catalyst program's (Box 2) set of eight 'Big Ideas' represented foundational principles against which teaching practices can be assessed:

> *The Canberra Goulburn diocese has got principles instead of just saying everything is evidence based. And they've sort of tried to lay out their principles so that you can test whatever this [new] research is against those principles and see if it fits with those principles…*[116]

This is the gap currently being filled by the relatively-new Australian Education Research Organisation (AERO), which has produced resources relating to how students learn best.[117] In conjunction with system-level policies — Victoria's Teaching and Learning Model 2.0 draws heavily on the AERO work[118] — there is potential for this work to gradually shape the profession's mental models.

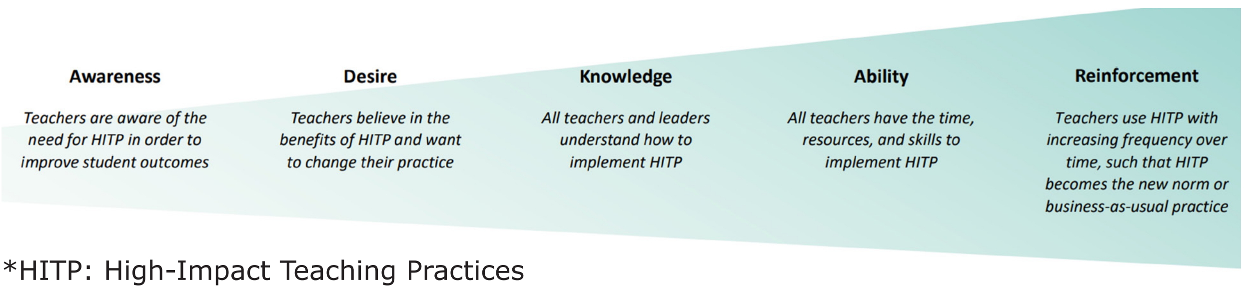
But between policy and research lie layers of independent providers of consulting services, curricular programs, interventions, professional development options and so on. It's plausible that these offerings can tweak language used to describe what they provide but without changing the underlying philosophy or evidence base. Because there is a relatively open market in this regard, teachers need a strong knowledge base to empower them to effectively discriminate and make better decisions.

Teacher knowledge is essential to implementing reforms

"[H]ow can one expect teaching-learning processes in schools to unfold in line with a reform, if its priorities are not shared by the teacher?"[119] This sits at the heart of why measuring, monitoring and developing teacher knowledge is essential for system-level reforms to have the desired impact.

Accordingly, implementation science frameworks — such as the awareness/desire/knowledge/ability/reinforcement (ADKAR) framework, used by Catholic Education Canberra-Goulburn for its Catalyst program — recognise knowledge as a key ingredient in any change implementation process (see Figure 1).

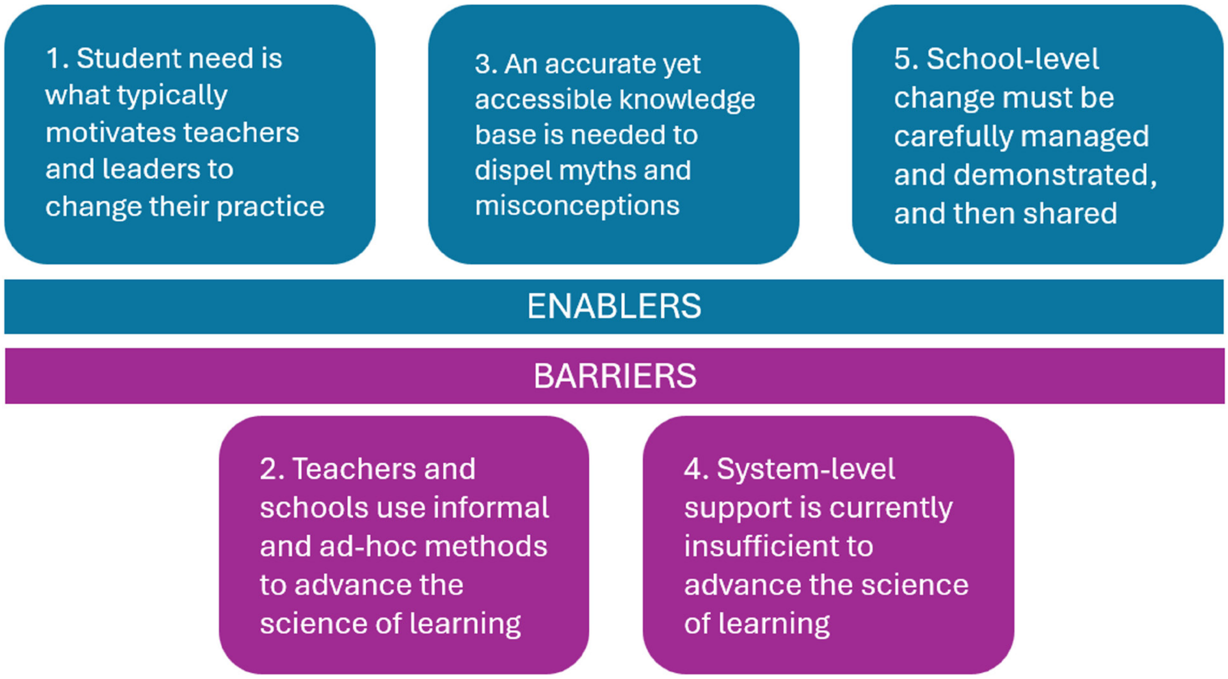
Figure 1: Catalyst model of the 'teacher change journey' using the ADKAR framework[120]



*HITP: High-Impact Teaching Practices

There is some overlap between the (prescriptive) implementation science framework used in the Catalyst program, and the (descriptive) framework outlined in previous CIS research, *Implementing the Science of Learning: teacher experiences* (RR47). That report used data from interviews and focus groups with teachers who were using science of learning-informed practices such as explicit teaching in their schools.

Figure 2: CIS 'pathway' model of science of learning implementation[121]



As Figure 2 shows, teachers in the study reported "us[ing] informal and ad-hoc methods" to build knowledge and advance the science of learning, and participants pinpointed the need for "an accurate yet accessible knowledge base" about the science of learning. The report also highlighted systems using their position of authority and 'scale power' to make changes and provide practical supports as critical enabling factors.[122]

This puts a great deal of pressure on policymakers to work to shape the knowledge base that teachers use in their day-to-day instructional decision-making. In response to some of the policy changes described in Box 2, it is common for many practitioners (both in schools and universities) to express some variant of 'we already do this', with the implication being 'therefore we do not need to change'. Given the practical difficulty of measuring practice, promoting the development of a sound base of knowledge and instigating ways to measure and monitor progress should be a core output of policymakers looking to shift practices at scale.

Implication 3: Measure teachers' knowledge, not their beliefs or self-reported practice

Problems with measuring beliefs or practice

The main way teacher beliefs, knowledge and practice have been assessed is via a standardised instrument, typically a questionnaire.[123] But each of these domains cannot necessarily be measured in the same way.

Whether teacher beliefs inform teacher practice is referred to as "the congruity thesis". On the face of it, it is not a controversial observation to say people's stated beliefs don't always align with reality; economists discuss stated versus revealed preferences in recognition of this exact fact. On the matter of capturing teacher practices via self-report survey, there is the considerable risk of social desirability bias — that is, to over-state a given characteristic that one thinks they are 'supposed' to have. In this case, teachers asked if they account for individual learning styles or left-brain versus right-brain learners in their practice may respond in the affirmative because that is what they think they are supposed to do, rather than what they actually do.

But scholarship that focuses on this congruity thesis argues that the evidence is truly mixed, with "as many studies questioning it as there are supporting it".[124] To this we must add the methodological problems that abound in measuring beliefs via self-report tools. Beliefs and knowledge can be deeply implicit, and resist being clearly articulated. Researchers and respondents may interpret terms differently. Interviews and focus groups may yield data that defies categorisation; but closed-response tools such as questionnaires may unwittingly bias respondents through limiting their answers.[125] The more contested the terms used within the items, the more likely methodological problems are to emerge. Terms like 'explicit instruction', 'constructivism' or 'student-centred' would be especially prone to generating muddy data due to the highly contested nature of these terms.

One note of interest from the teacher beliefs literature is that it operates primarily at the individual teacher level, meaning that an individual teacher may have a certain 'mental model' of teaching and learning practice, but operate within a school where the dominant modes of thinking about teaching and learning are distinct. In this scenario, a teacher's observed practice might not be congruent with the stated beliefs.[126]

The reverse is also true — whether sustained efforts to define and inculcate a certain interpretation of 'good' or 'desired' teaching practice inform teachers' beliefs and practices, through mechanisms like shared professional development, or changing behavioural norms in their operating environment. This is what is currently underway in the systems listed at Box 2, albeit at a system rather than school level. Further case study research of individual schools could be valuable in deepening 'teacher beliefs' research beyond the individual teacher.

Other researchers of teacher change reject the *beliefs* ▶ *practices* ▶ *student outcomes* framework, in which the main purpose of professional development is to generate a change in beliefs that sustains the remainder of the causal chain. Guskey argues that professional development should aim to change teachers' classroom practices, which will change (improve) student learning outcomes, and this process of making the fruits of change visible is what generates change in beliefs and attitudes[127] — in keeping with the idea that 'seeing is believing'.

Some of the methodological problems inherent in measuring the more subjective concept of 'beliefs' may reduce if what is being measured is based in concrete knowledge items than contestable constructs. Given these problems, surveys of teachers that aim to evaluate their readiness for science of learning-aligned practices should incorporate features of question design and response type that focus on knowledge, rather than beliefs.

'Knowledge' here refers to that which has "a truth component that can be externally verified or confirmed"[128] and although it plays a role in beliefs, little research is done just on knowledge. Research on neuromyths or learning myths aims to expose whether teachers think they 'know' something that is in fact false. Knowledge-based surveys have been used to measure the preparedness of teachers for evidence-based reading instruction.[129] Attempts to measure science of learning knowledge should probably involve at least some contextualised statements or teaching scenarios; particularly when statements can be true in one instructional context but not in another.

Conclusion

This paper has sought to bring together a vast array of literature to draw conclusions about what is known about teachers' beliefs (myths, misconceptions and truths) about the teaching and learning process.

This research, particularly into neuromyth belief, has been done around the world, including four studies that use Australian pre- and in-service teachers. While teachers typically value the idea of brain-based knowledge, studies dating back two decades show they are susceptible to believing neuromyths, with the belief in LS — that students will learn better if you identify and attempt to teach to a student's learning style — being among the most prominent.

However, given neuromyth belief can also be common in non-school teaching professions and among the general public, it is hard to conclude initial teacher education is necessarily always to blame for the belief in such myths. It is more plausible that initial teacher education — but also other formal training avenues for in-service teachers — fails to adequately equip teachers with evidence-based mental models in the face of a broader culture or mindset which makes many neuromyths feel intuitively correct. Both pre-service and in-service teacher education have promoted discredited approaches in the past, and may still continue to do so.

After the Teacher Education Expert Panel's *Strong Beginnings* report made significant recommendations about the core content for future degrees, including the role of science of learning-related knowledge, the response from the sector was tepid. As Dr Jennifer Buckingham observed, "People in university schools of education are equally adamant that what they provide is high quality. In response to proposals that teaching degrees should include specified content, the defenders of teacher education say, 'we already do that' in one breath and 'don't tell us what to do' in the next".[130]

While it is impossible to generalise what the 40-odd Australian providers of initial teacher education do or don't do in terms of training future teachers, it is true that Australian teachers are no less likely than international counterparts to believe in myths about learning. On the other hand, no Australian research using a questionnaire-based method exists to investigate teachers' science of learning-related knowledge (with the exception of two questions about working memory from one small study). This is against a backdrop of more studies emerging from other countries that attempts to move past measuring neuromyth prevalence, and towards measuring pedagogically-relevant science of learning knowledge.

This report recommends the following:

1. Policymakers must ensure ITE core content requirements are rigorously enforced.

Australian ITE providers are due to have the requirement for 'core content' – content aligned with the science of learning – by the end of 2025, and this will be monitored by a Quality Assurance Oversight Board. But the Board does not contain any subject matter experts who would be able to monitor providers' course materials to ensure they are compliant.

2. The Australian Professional Standards for Teachers must be rewritten.

Professional safeguards for teaching stand or fall on the basis of the APST, which does not adequately reflect what needs to be in teachers' mental models as they approach their work in the classroom. Resources such as the self-evaluation tool currently available on the Australian Institute for Teaching and School Leadership should be replaced with a knowledge-based tool.

3. Systems looking to scale the science of learning in their schools should measure and monitor teacher knowledge.

This would first require codifying the knowledge teachers are expected to have, and should be utilised both at the beginning of a set of reform initiatives, as well as subsequent intervals, to monitor how knowledge develops among staff as reforms continue to have impact.

Future research will use the studies and findings of this report to assemble, field test and report the results of science of learning knowledge-based questionnaires with large, representative samples of in-service Australian teachers.

Appendix A: Table of selected studies examining neuromyth prevalence, in order of publication

Study	Country	Sample	'Learning styles' myth	'Hemispheric dominance' myth	'Brain Gym' myth	'10%' myth
Howard-Jones, P., Franey, L., Mashmoushi, R. and Liao, Y (2009). The Neuroscience Literacy of Trainee Teachers. Paper presented at the British Educational Research Association Annual Conference, University of Manchester, 2-5 September 2009 http://www.lscp.net/persons/dupoux/teaching/JOURNEE_AUTOMNE_CogMaster_2011-12/readings_neuromyths/Howard-Jones_et_al_(2009).Neuroscience_litteracy.pdf	United Kingdom	158 graduates of PGCE (teaching qualification)	82%	60%	65%	52%
Dekker, S., Lee, N. C., Howard-Jones, P., & Jolles, J. (2012). "Neuromyths in Education: Prevalence and Predictors of Misconceptions among Teachers." *Frontiers in Psychology*, 3, 429. https://doi.org/10.3389/fpsyg.2012.00429	UK and Netherlands	242 practising teachers	93% - UK 96% - Netherlands	91% - UK 86% - Netherlands	88% - UK 82% - Netherlands	48% - UK 46% - Netherlands
Bellert, A. and Graham, L. (2013). Neuromyths and neurofacts: Information from cognitive neuroscience for classroom and learning support teachers. Special Education Perspectives, 22:2, pp. 7-20. https://hdl.handle.net/1959.11/14314	Australia	87 special education/ learning support teachers	64.37% (Phrased as "Individual differences in academic abilities can be partly attributed to individual learning styles (e.g. visual, auditory, kinaesthetic.")	90.81% (Phrased as "The different hemispheres of the brain have different functions. For example, creative thinking happens in the right hemisphere of the brain.")	34.5% (Phrased as "Brain Gym is a well-researched program with demonstrated outcomes for improved student learning")	64.4%
Gleichgerrcht, E., Luttges, B. L., Salvarezza, F., & Campos, A. L. (2015). Educational neuromyths among teachers in Latin America. Mind, Brain, and Education, 9, 170—178. https://doi.org/10.1111/mbe.12086	Latin America (Argentina, Chile, Peru)	3,451 teachers	90.5%	73.3%	77.9%	61%

Karakus, O., Howard-Jones, P.A. and Jay, T. (2015). Primary and Secondary Teachers' Knowledge and Misconceptions about the Brain in Turkey, Procedia - Social and Behavioural Sciences, vol 174, pp. 1933-1940. https://doi.org/10.1016/j.sbspro.2015.01.858	Turkey	278 primary and secondary teachers	97.1%	78.8%	72.3%	50.4%
Tardif, E., Doudin, P. A., & Meylan, N. (2015). Neuromyths among teachers and student teachers. Mind, Brain, and Education, 9, 50—59. https://scispace.com/papers/neuromyths-among-teachers-and-student-teachers-ch3h4a7vzv	Switzerland	283 French Swiss educators	96% (phrased as "Some individuals are visual, others are auditory")	85% (Phrased as "Some people use their left hemisphere (left brain) more whereas others use their right hemisphere (right brain) more")	79%	Not surveyed
Ferrero, M., Garaizar, P. and Vadillo, M. A. (2016). Neuromyths in Education: Prevalence among Spanish Teachers and an Exploration of Cross-Cultural Variation. Frontiers in Human Neuroscience 10:496. https://doi.org/10.3389/fnhum.2016.00496	Spain	284 teachers	91.1%	67.2%	77.1%	44%
Lethaby, C. and Harries, P. (2016). Learning styles and teacher training: are we perpetuating neuromyths? ELT Journal, 70:1. Available from: https://doi.org/10.1093/elt/ccv051	USA and Canada	128 TESOL teachers	88.3%	65.6%	61.7%	30.5%
Canbulat, T., & Kiriktas, H. (2017). Assessment of educational neuromyths among teachers and teacher candidates. *Journal of Education and Learning*, *6*(2), 326-333. https://doi.org/10.5539/jel.v6n2p326	Turkey	752 educators (241 in-service and 511 pre-service)	20%	97%	Not surveyed	75%
Kim, M & Sankey, D (2017). Philosophy, neuroscience and pre-service teachers' beliefs in neuromyths: A call for remedial action, Educational Philosophy and Theory, 50:13, pp. 1214-1227 DOI: https://doi.org/10.1080/00131857.2017.1395736	Australia	1,144 first-year pre-service teachers	97.1%	86%	86.9%	Not surveyed

Van Dijk, W., & Lane, H. B. (2018). The brain and the US education system: Perpetuation of neuromyths. Exceptionality, 28(1), 16—29. https://doi.org/10.1080/09362835.2018.1480954	USA	169 educators	76%	84%	96%	58%
Grospietsch, F. and Mayer, J. (2019). Pre-service Science Teachers' Neuroscience Literacy: Neuromyths and a Professional Understanding of Learning and Memory. Frontiers in Human Neuroscience, 13:20. https://doi.org/10.3389/fnhum.2019.00020	Germany	550 science pre-service teachers	93%	82%	92%	57%
Carter, M., Van Bergen, P., Stephenson, J., Newall, C., & Sweller, N. (2020). Prevalence, Predictors and Sources of Information Regarding Neuromyths in an Australian Cohort of Preservice Teachers. *Australian Journal of Teacher Education*, 45(10). https://doi.org/10.14221/ajte.2020v45n10.6	Australia	1,359 pre-service teachers	77.4%	45.9%	56.6%	27%
Hughes, B, Sullivan, K. A., and Gilmore, L (2020), Why do teachers believe educational neuromyths? Trends in Neuroscience and Education, Vol. 21, 100145. Available from: https://doi.org/10.1016/j.tine.2020.100145	Australia	228 practising teachers	79%	56% (Phrased as "Some of us are left-brained" and some are "right-brained" and this helps explain differences in how we learn")	94%	38%
Ramic, A., Cehic, I., Rustempasic, S., Malec, D., and Memisevic, H. (2022). "We only use 10% of our brains and other neuromyths - A survey of teachers in Bosnia and Herzegovina", Acta Neuropsychologia, 20:3, pp. 305-314	Bosnia and Herzegovina	300 teachers	82%	43%	63%	42%
Khramova, M.V., Bukina, T.V., Smirnov, N.M. et al.. (2023). "Prevalence of neuromyths among students and pre-service teachers." Humanities and Social Science Communication, 10:950. https://doi.org/10.1057/s41599-023-02412-4	Russia	382 pre-service teachers	92%	80%	77%	39%

Appendix B: Questionnaire from Dekker et al. 2012

Neuromyth assertions are presented in italic; C = correct; I = incorrect. Bold type denotes results discussed in this report.

1. We use our brains 24 h a day (C).

2. Children must acquire their native language before a second language is learned. If they do not do so neither language will be fully acquired (I).

3. Boys have bigger brains than girls (C).

4. If pupils do not drink sufficient amounts of water (=6—8 glasses a day) their brains shrink (I).

5. It has been scientifically proven that fatty acid supplements (omega-3 and omega-6) have a positive effect on academic achievement (I).

6. When a brain region is damaged other parts of the brain can take up its function (C).

7. We only use 10% of our brain (I).

8. The left and right hemisphere of the brain always work together (C).

9. Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners (I).

10. The brains of boys and girls develop at the same rate (I).

11. Brain development has finished by the time children reach secondary school (I).

12. There are critical periods in childhood after which certain things can no longer be learned (I).

13. Information is stored in the brain in a network of cells distributed throughout the brain.

14. Learning is not due to the addition of new cells to the brain (C).

15. Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinaesthetic) (I).

16. Learning occurs through modification of the brains' neural connections (C).

17. Academic achievement can be affected by skipping breakfast (C).

18. Normal development of the human brain involves the birth and death of brain cells (C).

19. Mental capacity is hereditary and cannot be changed by the environment or experience (I).

20. Vigorous exercise can improve mental function (C).

21. Environments that are rich in stimulus improve the brains of pre-school children (I).

22. Children are less attentive after consuming sugary drinks and/or snacks (I).

23. Circadian rhythms ("body-clock") shift during adolescence, causing pupils to be tired during the first lessons of the school day (C).

24. Regular drinking of caffeinated drinks reduces alertness (C).

25. Exercises that rehearse co-ordination of motor-perception skills can improve literacy skills (I).

26. Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain (C).

27. Individual learners show preferences for the mode in which they receive information (e.g., visual, auditory, kinaesthetic) (C).

28. Learning problems associated with developmental differences in brain function cannot be remediated by education (I).

29. Production of new connections in the brain can continue into old age (C).

30. Short bouts of co-ordination exercises can improve integration of left and right hemispheric brain function (I).

31. There are sensitive periods in childhood when it's easier to learn things (C).

32. When we sleep, the brain shuts down (I).

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What teachers know and believe about teaching – their mental models – can act as a filter for instruction. This report presents findings from literature about what teachers believe about how students learn. It finds a high prevalence of myths about learning among teachers, but less clarity to what extent these beliefs lead to ineffective education practices. It also finds limited research on teachers' science of learning-related knowledge, with what evidence there is suggesting a great deal of variation across teachers.

Policymakers must therefore engage in concerted efforts to build up coherent mental models among Australian teachers, ensuring learning myths are rejected and teacher knowledge is consistently based on evidence about how students learn. Importantly, policymakers looking to lead system-wide changes in how teachers approach teaching and learning should investigate ways to measure, monitor and develop teacher knowledge about the science of learning.

About the Author

Trisha Jha is a Research Fellow in the Education program, where she leads a stream of work on the science of learning, as well as projects on school improvement and educational policy.

Trisha has previously had roles as a secondary teacher, including through the Teach for Australia program, in state and independent schools in regional Victoria. She has also worked as a senior policy adviser to opposition leaders in Victoria.

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