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What is the Science of Learning?

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Despite billions of additional dollars and concerted efforts at reforming several pillars of the Australian education ecosystem, students' results continue to plateau. While the focus on teaching quality and effective, evidence-based practices is welcome, it is incomplete. Australian education needs to position the science of learning as the foundation for policy and practice.

The establishment of the Australian Education Research Organisation (AERO) — in particular its recent work How students learn best — and the *Strong Beginnings* report into initial teacher education reforms are important because they create space for shifting focus towards the science of learning.

Unfortunately, key pillars of Australian education policy do not reflect the science of learning, due to the far-reaching impacts of progressive educational beliefs dating back to the eighteenth century. These beliefs include that:

- Students learn best when they guide their own learning and it aligns with their interest;
- Rote learning is harmful;
- Learning should be based on projects or experiences, and that doing this will result in critical and creative thinkers.

But these beliefs are contradicted by the science of learning, which is the connection between: 1) insights from cognitive science and educational psychology; and 2) the teaching practices supported (and not supported) by those insights. Key concepts include:

- Biologically primary knowledge (BPK) and biologically secondary knowledge (BSK): These concepts are not about stages of schooling. Rather, BPK includes things like basic social relations and problem-solving skills

we have evolved to learn and do not need to be taught. In contrast, BSK includes foundational skills — like reading, writing, maths as well as coding, Cubism and how to kick a football (what schools are for) — we can only learn through instruction;
- Domain-specific and domain-general skills: domain-general skills overlap with biologically-primary knowledge but critical thinking and analysis are specific to domains such as maths, history etc;
- Working memory and long-term memory: working memory is severely limited and can only handle small amounts of new information; making it a funnel to long-term memory. A strong long-term memory can help strengthen working memory; and
- Cognitive load theory: given these models of human cognition, teachers should design instruction to optimise the burden on working memory in a way that best helps learning.

The teaching approach best supported by the evidence is explicit instruction of a well-sequenced, knowledge-focused curriculum. Some key features of explicit instruction include:

- Careful ordering of curriculum content so that new information and concepts are built sequentially;
- Explanation of new information in small steps, taught through modelling and worked examples, with student practice after each step;
- Asking questions and checking for all students' understanding of what has been taught before gradual release of students for independent work and more complex tasks; and
- Regular review of previous content to ensure retention.

There are many implications for the science of learning:

- For teachers, it is an opportunity to design instruction in a way that is likely to lead to most students' success with learning;
- Parents can become more informed about how their child will learn best and more empowered when selecting or having conversations with their child's school; and
- For policymakers, it provides a foundation for future reform of policy at all levels.

Introduction

In recent years, the debate around school effectiveness and school improvement has evolved, from structural elements of education policy (such as funding, class sizes, school sectors and autonomy) to a more intensive focus on the quality of teaching and learning — particularly through the language of evidence-based practice.

However, despite this increased policy attention — combined with significant injections of funding for education — educational outcomes have not shifted in the desired direction, with the most recent NAPLAN results showing roughly a third of students are not at the expected standard. There are many reasons for this, but an important contributor is the long legacy of progressive educational philosophy and continuing vagueness embedded in the policy landscape regarding the most effective practices and how to implement them. This is not for lack of knowledge about what practices are most effective. The past few decades of academic research into cognitive science and educational psychology have yielded many insights into how humans learn new information, with valuable insights for education practice — what is called 'the science of learning'. Unfortunately, this 'science of learning' has informed policy and practice in only very limited ways.

The assertion that education should be underpinned by a scientific understanding of how students learn seems commonsense to a layperson. However, this scientific understanding is ignored in the underpinnings of several aspects of the current policy architecture regarding teacher training, standards, curriculum content and teaching guidance.

In an attempt to cut through the woolliness of this messaging, grassroots efforts from segments of the education profession have attempted to do the work themselves; through running their own conferences and creating their own learning networks, both formal and informal. Grassroots initiatives to advance and promote science of learning knowledge and practice are the subject of future CIS research. Rather than representing a return to 'traditional' education that de-individualises teachers and students, the science of learning emphasises contemporary scientific knowledge as the basis for teacher professionalism and for student learning.

Concurrently, recent policy developments have also helped to shift the trajectory of the debate. One is the 2020 establishment of the Australian Education Research Organisation. Intended to help improve education outcomes by empowering educators with research and evidence, in September 2023 they released the report How students learn best: an overview of the evidence, which explores effective teaching practices through the lens of how students learn.

A more concrete policy development is the Strong Beginnings report, which (among other things) recommended that initial teacher education degree courses include mandated core content such as what effective teaching practices are and why they align with scientific insights. By stating explicitly what pre-service teachers need to know about the brain and learning and effective pedagogical practices, the report endorsed a conception of teaching that aligns with the principles of the science of learning.

Research suggests that evidence plays a significant role in how teachers think about their work, but 'evidence' is a broad term and without a proper grounding in cognitive science foundations, many practices can be believed to be evidence-based while contradicting fundamental elements of cognitive science. So, despite a relatively positive finding from AERO that two-thirds of teachers they surveyed use some form of evidence, such figures should be interpreted with caution. Fortunately, the existence and work of AERO and the Teacher Education Expert Panel's Strong Beginnings report suggests a policy appetite for moving beyond the status quo in education.

But despite growing enthusiasm for the science of learning, there is no clear consensus about what the science of learning is and how its principles can be adopted in both education policy and education practice. This paper is the first in a series that aims to fill this gap. This paper will outline a history of educational philosophy and approaches in Australia before elaborating on the science of learning and practices that are supported — or are not supported — by this body of knowledge. The current policy architecture is analysed with respect to what assumptions about teaching and learning are being made therein, before outlining the implications of the science of learning for teachers, parents and policymakers. The paper concludes with discussion of areas for future research.

Politics, philosophy and education

To adequately construct a case for why a new set of first principles for education is needed, it is first important to briefly survey past attitudes and approaches, both in the Western world more broadly and in Australia specifically. This section will show the old roots of several contemporary beliefs about education, such as the notion that education must be tailored to the child and driven by his or her interests, and that a truly educated person is one who has discovered knowledge for themselves, rather than being taught by a tutor or teacher.

It is a truism that the modern classroom, with its emphasis on a set curriculum, physical classrooms and timetables — often derided as the 'factory model' of schooling — had its origins in the Industrial Revolution to prepare children for a lifetime working in tightly controlled and directed environments of the era. However, what is now termed 'progressive education', the dominant philosophy of education in the twentieth century, had its origins as early as the eighteenth century in philosophy, particularly as it related to new ideas about democratic theory and practice (Box 1).

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Box 1: A new, democratic education

In the 18th and 19th centuries, the growth of democratic ideas brought to the fore the need for better education for the common man. The earliest text in this vein was political philosopher Jean-Jacques Rousseau's Emile, published in 1762. Here, Rousseau advocates a naturalistic approach to education for 'Emile', under the watchful guise of his tutor. Rousseau's other work was also on this theme, advocating physical training ("To learn to think we must exercise the limbs, senses and organs, which are the instruments of intellect") and play-based — that is, driven by the child and their interest — learning for students up to the age of 12, eschewing traditional subject teaching.[4]

Even for students older than this, Rousseau argues their education in traditional subject areas or disciplines should be guided by the student's desire to learn it, rather than giving the student knowledge ("He is not to learn science: he is to find it out for himself").[5] Rousseau's ideas were further built upon by Pestalozzi, who believed education was about guiding children's natural impressions: "the business of instruction is to remove the confusion of [the child's] first sense impressions."[6]

The 19th century saw the further development of these ideas, with German philosopher and political reformer Johann Gottlieb Fichte who posited that education should be about shaping a pupil's character for his own good and that of the nation, and his 'new education' about fostering the love of learning for its own sake, where the 'old education' instead "aimed… at purely passive reception by means of the power of memory" and "mechanical rote-learning."[7] The antipathy towards rote-learning is a common theme and addressed further in Box 2.

Given the span of individuals across centuries and countries of its advocates, it is difficult to argue that there is one simple unified theory of educational progressivism. Nevertheless, some key principles can be said to unify them, according to William Reese on the origins of progressive education:

… something fascinating had emerged in educational thought by the nineteenth century. Critics of traditional forms of child rearing and classroom instruction condemned what they saw as insidious notions about the nature of children and the antediluvian practices of the emerging public school system… They proclaimed that children were active, not passive, learners; that children were innocent and good, not fallen; that women, not men, best reared and educated the young; that early education, without question, made all the difference; that nature, and not books alone, was perhaps the best teacher; that kindness and benevolence, not stern discipline or harsh rebukes, should reign in the home and classroom; and, finally, that the curriculum needed serious reform, to remove the vestiges of medievalism. All agreed that what usually passed for education was mind-numbing, unnatural, and pernicious, a sin against childhood.[8]

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The origins of modern progressive education lie in the work of John Dewey, who is often referred to as the 'father' of progressive education. The irony of this is that Dewey (though his conclusions are wrong by the standards of twenty-first century science) and his predecessor Johann Friedrich Herbart, did important work in pioneering educational science.[9]

Both Herbart and Dewey developed theories about education, put them into practice (Herbart taught students in a demonstration school and ran a training college;[10] Dewey ran a 'Laboratory School' at the University of Chicago) and attempted to measure impact to refine the theory. This is rudimentary educational science. Indeed, Dewey described his approach thus:

> *If there is a science of education it is an experimental science, not a purely deductive one. All well-ordered experiment presupposes two things: a working hypothesis, an idea to be put to the test, and adequate facilities for making the test. There must be a continual union of theory and practice; of reaction of one into the other. The leading idea must direct and clarify the work; the work must serve to criticise, to modify, to build up the theory.*[11]

Despite this important development, Dewey's theories about education were not substantially different from his predecessors all the way back to Rousseau and Pestalozzi: in particular his Pestalozzi-like view that the ideal home was a model for school — where students engaged in learning by doing, related to home life, and formal instruction in reading and writing came as late as 8 years old.[12]

Dewey's educational philosophy inspired others to apply it into the context of twentieth century public education. W. H. Kilpatrick's 'Project Method' of teaching (1918) emphasises student learning through their own activity. Kilpatrick notes that there would be changes needed in schools in terms of furniture, architecture, textbooks, curricula and programs and 'grading and promotion'.[13] Another example was Helen Parkhurst's Dalton Method (1920), which is still used in at least one Australian school today.

In the latter part of the twentieth century, progressive education was subject to further offshoots and evolutions. Debates remained between those who had an overly romantic and individualistic understanding of a child's education (sometimes laden with religiosity in language and theme), and the criticism of this by those who saw progressive education in the context of broader social philosophy and viewed education as a way to remediate social problems related to race and poverty.[14] A key figure here is Paulo Freire, who criticised what he called the 'banking' concept of education as "an instrument of oppression". Freire described 'banking' as:

> *Narration (with the teacher as narrator) leads the students to memorize mechanically the narrated content. Worse yet, it turns them into "containers," into "receptacles" to be "filled" by the teacher. The more completely she fills the receptacles, the better a teacher she is. The more meekly the receptacles permit themselves to be filled, the better students they are. Education thus becomes an act of depositing, in which the students are the depositories and the teacher is the depositor…*[15]

Freire accepted what was by his time an old tradition of critiquing memorisation and suppression of a child's natural instincts (see Boxes 1 and 2) and added a political dimension. His 'critical pedagogy' advocated that teacher-driven models of instruction are inherently oppressive because they created a hierarchy in which the teacher 'knows' and is therefore valuable, whereas a student lacks knowledge and is thus valued less:

> *… knowledge is a gift bestowed by those who consider themselves knowledgeable upon those whom they consider to know nothing. Projecting an absolute ignorance onto others, a characteristic of the ideology of oppression, negates education and knowledge as processes of inquiry… [Instead], education must begin with*

the resolution of the teacher-student contradiction, by reconciling the poles of the contradiction so that both are simultaneously teachers and students (emphasis original).[16]

A critical pedagogy positions student-led learning as good for students but also argues that teacher-led learning is oppressive. Given Freire's philosophy is taught to pre-service teachers in initial teacher education,[17] it is easy to see how it could potentially create hostility towards methods in which the teacher explicitly teaches.

Progressive education in Australia

Contemporary scholarship on progressive education maintains some of the same language observed in its historical iterations, such as emphasis on the "whole" person or child, learning by doing/active learning/learning through experience, democratic and community engagement, and real-world application.[18] However, it is one thing to observe the penetration of these ideas across Europe and the United States and another to demonstrate their influence in Australia (though arguably, neither case can be made comprehensively for reasons of sheer scale of schools, teachers and classrooms).

Echoing the criticisms of the US education system's over-emphasis on memorisation (see Box 2), Australian professor Francis Anderson gave a speech in 1901 at the University of Sydney in which he decried Australian students being taught to parrot, like "New Guinea—North of Australia—birds of Paradise—gold".[19]

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Box 2: Rote learning and memorisation

Progressive educationalists of the 19th and early 20th century were united in a desire to see the end of certain methods of teaching perceived as dominant, such as 'memorisation of various facts'. This has continued to this day, with 'Gradgrindian' (after Dickens' school superintendent in 1854's Hard Times) still used by modern commentators on education as a byword for what they see as mindless rote learning and parroting of meaningless facts.[20]

In Dewey's time, observations of US classrooms saw students memorise and recite information such as "the boundaries and capitals, and principal towns and rivers of States and nation" (Charles F. Adams in 1879) and "the names, dates, and chief performances of the eighteen presidents of the United States" (an unnamed visitor as quoted in J.G. Fitch, 1890).[21]

It is difficult to say with any certainty why this was a favoured approach to teaching in some quarters, through Roediger states that this emphasis on memorisation was part of a theory of formal discipline — that if someone was able to memorise a large volume of content, they would be able to memorise other things more easily.[22]

This is interesting for two reasons. First, progressive educationalists were right in their critique of memorisation, to the extent that this represented the be-all and end-all of education. A return to this narrow view is not desirable. However, this also shows that the reason for this obsession with memorisation — that memorisation would generate 'transferable' or 'generalisable' skills in students — is still with us today.

Rather than rejecting memorisation and the importance of memory, a better path for modern education is to understand how memory works and to draw implications for teaching practice from this knowledge, rather than the other way around.

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Crittenden, in his essay on the philosophy of education in Australia, notes the influence of Herbart and Dewey in the early part of the twentieth century, particularly Dewey's focus on problem-solving and inquiry skills.[23]

However, Crittenden also states that the best-known application of Dewey's idea was Kilpatrick's 'project method', which he states "over-played individual interest in decisions on learning activities at the expense of the place Dewey gave to the systematic disciplines."[24] He also notes that influential texts on teacher training, such as Australian educationalist Margaret Mackie's Educative Teaching (1968), see the practice as "training in critical and creative thinking."[25]

In general, the trend in educational philosophy in Australia in the middle of the twentieth century mirrored that of elsewhere, with debates around the social role of education taking place between those that advocated strong education for an informed citizen in a democracy, and those who believed education should be at the vanguard of broader 'social reconstruction'.

While the full extremes of the social reconstruction view have not been felt in Australia, Crittenden (writing in the mid-1980s) observed that education as a vehicle to "ensure equal opportunity for positions of economic and other advantage" had become an article of faith in recent reports and policy thinking of the past two decades.[26] In parallel, he notes the trend for 'interpretive' research in education abroad which drew on ethnographic methods and in Australia was rebutted in favour of 'action research' based in critical theory. 'Action research' is where teachers devise a problem and carry out their own research, typically on their own practice.[27]

It is important to state that this form of research is very much current in twenty-first century Australian education, notably forming the foundation of mandatory pre-service teacher assessment at universities, as well as the certification for graduate teachers moving to proficient in Victoria to attain full teacher registration.[28] That the theoretical origins of action research are critical of empiricism and 'positivism' suggests that the devaluation of scientific evidence has been well embedded as part of teacher education scholarship and practice for many decades now.

There are more explicit ways in which strands of Dewey's work — though, notably, less so his attempts at building educational science — influence Australian education theory and practice. Dewey's influence can arguably be seen in formal government advice as to how to teach. The 2003 government-commissioned report *Making History: A Guide for the Teaching and Learning of History in Australian Schools*, said the proper teaching of history should emphasise inquiry and critical thinking[29] and that students' informal knowledge must be acknowledged and built upon.[30] It has also been argued that the Australian Curriculum's 'Ethical Understanding', which is one of the cross-domain 'general capabilities' (i.e. intended to be embedded across all subjects and domains for Foundation to Year 10) is an example of Dewey's influence.[31]

Dewey's work continues to frame the work of Australian education researchers. For instance, Dewey's thinking is used as a challenge to 'best practice' and 'standards-driven reform' in the Australian context, with claims that Dewey rejected "recipes and models to be followed in teaching".[32] Other research has emphasised the democratic strand of Dewey's thinking; focusing on the extent to which teachers are able to truly 'educate' if they are unable to function democratically: "For Dewey (1977a, p. 233) democracy means that persons are "to have a share in determining the conditions and the aims of [their] work".[33]

One 2021 paper examined to what extent Dewey's four principles of experiential learning, interdisciplinary and progressive education, democratic learning and interactive learning are reflected in the education system in NSW.[34] The Australian Association for Research in Education (AARE) hosted an online conference in 2022 with the title 'The legacy of John Dewey on Contemporary Pedagogy'.[35] While far from exhaustive, this shows that Dewey and his brand of progressive education have been highly influential in the Australian educational context.

Progressive education, in believing that education should be about more than memorisation of information and about developing children and young people who are capable of thriving in modern liberal democracies, has undoubtedly won the day in the sense that this is now the bedrock philosophy about the purpose of education.

However, desired ends do not always translate to appropriate means. As progressive education has become more influential, beginning in the latter part of the twentieth century, it has become increasingly clear that modern education needs to be informed by science if it is to achieve its noble goals.

Progressive education versus modern evidence

The problem that has emerged in more recent decades is that as the pedagogies inspired by progressive educational philosophy have spread and become mainstream, education research — particularly in the fields of psychology and cognitive science — has developed in a way that casts doubt on the effectiveness of these methods in the context of contemporary mass scale public education.

At the same time, the translation of that educational science, first into knowledge held by teachers, and then into their practice, has occurred unevenly. Washington University psychology researcher Henry L. Roediger III observed over a decade ago that "once an idea takes hold, it is hard to root out", writing:

> *The field of education seems particularly susceptible to the allure of plausible but untested ideas and fads (especially ones that are lucrative for their inventors). One could write an interesting history of ideas based on either plausible theory or somewhat flimsy research—the various methods of teaching math, reading, foreign languages, and on and on—that have come and gone over the years… [I]n an ideal world, cognitive and educational psychologists would have created a translational educational science that would be eagerly adopted by education schools and educators who would want to improve education on the basis of the latest research findings.*[36]

This is not for lack of cumulative evidence that some teaching methods were more effective than others. For instance, Project Follow Through was a large-scale educational experiment that took place in the United States beginning in 1968. Over 700,000 school-age children in 170 disadvantaged communities were assigned to different educational programs with different foci (affective: promoting self-esteem; cognitive: generalised thinking; and basic skills: foundational literacy and numeracy, including through the Engelmann Direct Instruction program).

Of the nine programs across these foci, the only programs to show consistent growth in student achievement across foundational skills were Direct Instruction and another basic skills program called Behaviour Analysis. However, Direct Instruction also showed positive impacts on the cognitive skill and self-esteem scores of students even though they were not directly targeted by the program.[37] In other words, well-sequenced and explicit teaching of academic knowledge and skills not only developed student ability in those areas, but arguably helped to develop the 'whole child' more effectively than other methods.

Perhaps because of the long history of progressive educational philosophy, according to which programs such as DI would be considered insufficiently student-directed and democratic, the findings of Project Follow Through were not seen for the watershed in education research that they represented.

Subsequent research, termed 'process-product research', focused on the relationship between observed teaching actions and behaviours and student outcomes to gain further clarity about what will help students learn.[38]

However, while Project Follow Through provides evidence — now half a century old — about what methods are likely to be effective, neither it nor process-product research on their own can explain why these instructional methods result in better student outcomes.

Neuromyths

By the beginnings of the twenty-first century, a new emphasis on neuroscience and the brain was impacting public policy, with the US government declaring the 1990s 'the decade of the brain'.[39] However, a consequence of policy enthusiasm untempered by scientific scepticism saw the emergence of myths and misconceptions about the brain, particularly as it pertained to learning.

As early as 2002, the OECD published the book Understanding the Brain: Towards a New Learning Science, which dedicated a section to 'neuromyths': what they are, how they are mistakenly applied in real life and what the evidence from neuroscience and cognitive psychology truly is.

One such neuromyth is 'hemisphere dominance' or specialisation (i.e., that some people are right- or left-brained as a way to explain their traits, talents and interests). Instead, the truth is that while some tasks are dominant in one hemisphere, both hemispheres of the brain have some role to play in most mental processes.[40]

Other neuromyths include visual, auditory, and kinaesthetic (VAK) learning styles and Gardner's multiple intelligences theory. Cognitive psychology does not support these theories and nor is their efficacy as a basis for teaching and learning demonstrated in laboratory or observational studies. While people may have preferences or styles, that is not the same thing as a student learning better if taught in a certain way. Instead, methods of teaching should be based on the nature of what is being taught. For example, many parts of mathematics require visual representation and it would be difficult to learn a new language without ever hearing or speaking it.[41]

This discussion of neuromyths is far from exhaustive. Others include Piagetian conceptions of fixed age-related stages of cognitive development (if a child is outside their age-stage then they cannot learn),[42] students remember a small percentage of what they read or hear but a large percentage of what they do (therefore teachers should minimise reading and explanations and students should learn through experience) and the belief that people retain new information better if it is 'discovered' for oneself (therefore teachers should not simply tell students what they need to know but facilitate them to discover it themselves). As this paper will show, on this latter point especially, the evidence is quite plainly in the opposite direction.

In more recent decades, the newer developments in cognitive science and educational psychology have helped to explain how learning truly happens in the brain — and why some instructional practices are more effective than others.

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Box 3: Where have neuromyths come from?

An interesting question is why these neuromyths emerged and why it has been so difficult to eliminate them from how teachers are trained and how individuals perceive themselves — after all, endorsement of teaching to students' learning styles can be found in contemporary teacher training textbooks.[43] A frequent observation is the research to practice gap — where practices in education continue to be based on unfounded theories — which puts the onus on to scientists to accurately communicate with relevant professionals about their findings and 'translating' this into practice.[44]

Another theory comes from American educationalist E.D. Hirsch, who links modern neuromyths to a culture of 'hyper-individualism' in American education and argues it is rooted in child-centred progressive education, quoting Dewey to support: "Education, therefore, must begin with a psychological insight into the child's capacities, interests and habits. It must be controlled at every point by reference to these same considerations." Hirsch also cautions that the idea of inborn interests or inborn capabilities such as those suggested by VAK learning styles or multiple intelligences can metastasise into notions of inborn ability, which is the opposite of progressive education.[45]

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What is the science of learning?

Put simply, the science of learning is the cognitive science of how students learn, connected with the instructional implications of that science. This two-part formulation of the science of learning also aligns with the distinction proposed in the Strong Beginnings report, where 'effective pedagogical practices' corresponds with what the evidence suggests about the best way to teach, and 'the brain and learning' provides the 'why'; the facts about human cognition which form the foundation of effective practice.

For the science of learning to become the basis of teaching and learning practice across the education ecosystem, practitioners at all levels require a sound understanding of both how students learn best and what teaching practices are — and are not — likely to lead to effective learning for students.

It is important to note that while there is a degree of academic debate concerning founding principles and models of human cognition, the implications for teaching and learning within classroom settings are generally consistent. Science is never 'settled' and refinements to theory will always occur as the volume of relevant knowledge grows, but this is not a reason to reject the science of learning as a foundation for teaching and learning practices.

Defining learning

To explain a 'science of learning', it is necessary to first offer some definitions of 'learning' as it might apply to a school context. One definition comes from cognitive scientists Paul A. Kirschner, John Sweller and Richard E. Clark. In their original 2006 article in the Educational Psychologist journal, the authors state "Learning, in turn, is defined as a change in long-term memory".[46] In their summary of this article for the American Federation of Teachers magazine in 2012, the authors state "the aim of all instruction is to add knowledge and skills to long-term memory. If nothing has been added to long-term memory, nothing has been learned."[47]

The influence of both versions of this definition is visible in the England schools inspectorate Ofsted's current guidance for school inspections, which states: "Learning can be defined as an alteration in long-term memory. If nothing has altered in long-term memory, nothing has been learned."[48] Similarly, AERO states "Learning is a change in long-term memory" as one of four key areas of focus in its overview of how students learn best.[49]

Though influential and advanced by experts in cognitive science, the Kirschner, Sweller and Clark definition is by no means accepted as definitive. Cognitive scientist Daniel Willingham has noted that learning is difficult to define outside specific narrow contexts, and definitions are contestable.[50]

Another definition comes from Nicholas C. Soderstrom and Robert A. Bjork, who offer a definition of learning as "relatively permanent changes in comprehension, understanding, and skills of the types that will support long-term retention and transfer", but also distinguish learning from performance: "learning needs to be distinguished from performance, which refers to the temporary fluctuations in behaviour or knowledge that can be observed and measured during or immediately after the acquisition process."[51]

Both definitions have similarities, notably the emphasis on change and the long-term/permanent nature of that change. The Kirschner, Sweller and Clark definition specifies that memory is the site of that change whereas Soderstrom and Bjork's definition, by using the terms "understanding and skills", implies demonstration; though, of course, one cannot demonstrate something that one does not know.

Therefore, learning — both as a process and an end result — has a strong link to the brain and cognitive procedures. It is knowledge of these that should become an integral part of teacher knowledge and practice.

Key concepts in cognitive science

1) 'Biologically primary' knowledge is distinct from 'biologically secondary' knowledge, and acquired differently

One fundamental concept to the science of learning was developed by University of Missouri evolutionary psychologist David C. Geary: the distinction between biologically primary knowledge (BPK) and biologically secondary knowledge (BSK). The distinction is important because it has implications for how knowledge is acquired — it does not refer to the difference between primary and secondary school in the Australian context.

In short, BPK relates to things humans have evolved to learn how to do through necessity of survival. One example is how humans view themselves and each other in order to interact and negotiate socially with others (folk psychology), which includes using and comprehending verbal language, as well as conveying and interpreting emotions. Because evolution has meant these traits come naturally, children — according to Geary — "are largely motivated to engage in activities that will elaborate folk abilities", such as socialising, exploration and playing with objects.[52]

However, because other knowledge critical to survival in modern life is not something that humans have evolved to acquire in the way BPK is, this learning will be a more effortful and less inherently motivating process. Not only that, the "motivational interest" in, or bias toward, folk abilities can in practice distract from these other, important types of knowledge.[53] It is this category of knowledge that is referred to as 'biologically-secondary knowledge' (BSK).

Geary defines BSK as "competencies acquired through formal or informal training"[54] and "the acquisition of culturally important information and skills needed to live in modern societies."[55] Where biologically primary knowledge is more effortlessly acquired, BSK requires instruction. A simple example is the difference between speaking in one's native language (BPK) and the ability to read in that same language (BSK) as the latter requires the ability to decode (connect written symbols with their sounds).[56]

Though BPK provides the foundation for learning BSK, they are not the same and BSK cannot be acquired through immersive and experiential learning in the same way BPK is. Instead, the purpose of schools and other forms of education and training is to explicitly instruct people in the knowledge and skills that cannot be acquired naturally,[57] which can include fields as diverse as coding, Cubism, or kicking a football.

2) Knowledge and skills are specific to domains, not generally applicable

If the categories of knowledge that can be acquired relatively effortlessly is limited, then other categories of knowledge required to equip a person for modern life are vast and require instruction. How can such a vast array of knowledge be organised and taught in the context of modern schools?

One view, seen in elements of progressive education, as well as formal discipline's emphasis on memory (Box 2), is that by teaching broad skills like inquiry or critical thinking, they can become 'multipurpose muscles' — transferable across domains and contexts. This idea continues to have currency and is evident when people say education should be about 'learning how to learn' or 'how to think, not what to think'.

However, research literature does not support this idea. The Cambridge Handbook of Expertise and Expert Performance states "Research clearly rejects the classical views on human cognition in which general abilities such as learning, reasoning, problem solving, and concept formation correspond to capacities and abilities that can be studied independently of the content domains."[58]

By trying to teach 'transferable' skills, students are being asked to engage in random generation (of a solution to a problem) and test (whether the solution is effective in obtaining the desired result). This process relies upon prior knowledge, such as previous experience with a similar problem, to help in generation — but it does not require specific instruction as it is a form of biologically primary knowledge.[59]

In addition, random generate-and-test is more efficient in gaining the correct solution when performed by those who have a great deal of prior experience and domain-specific expertise[60] compared to those, such as students, who have very little. Instead, these learners can only develop critical thinking and inquiry skills through strong knowledge of individual domains. Nathan R. Kuncel, professor of psychology at the University of Minnesota, argues that "what people call critical thinking is either a class of very specific reasoning skills, or the formation of expertise in a field (e.g. medicine, accounting). In all cases, domain specific knowledge is necessary to make anything more than trivial progress with most problems."[61]

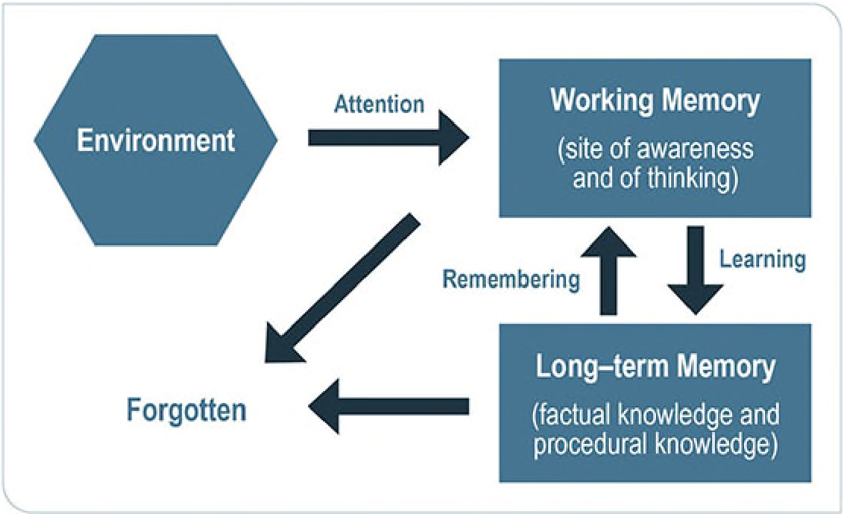
3) Working memory is limited, and long-term memory is the only known way to improve it

Debates continue about how many types of memory there are, and which forms of memory have the most significant impact on learning. In the interests of maintaining accessibility, this section will discuss those elements which have the most relevance to learning.

The oldest scientific theories concerning memory are well over a century old. The earliest models of memory acknowledged two types, a limited-capacity primary memory and an unlimited-capacity secondary memory, and date back to as early as 1890.[62]

Contemporary scholarship affirms the limited nature of working memory, and long-term memory is "now viewed as the central, dominant structure of human cognition. Everything we see, hear, and think about is critically dependent on and influenced by our long-term memory.[63]

Cognitive scientist Daniel Willingham describes memory as "the residue of thought" and explains his idea further: "Given that you can't store everything away, how should you pick what to store and what to drop? Your brain lays its bets this way: If you don't think about something very much, then you probably won't want to think about it again, so it need not be stored. If you do think about something, then it's likely that you'll want to think about it in the same way in the future."[64] Willingham created this simple model of memory for his book:



Source: Daniel T. Willingham, *Why Don't Students Like School?*

This shows the crucial relationship between working memory which is the access point to long-term memory and that long-term memory, in turn, can be used in working memory.

Not shown in this diagram is that working memory is limited both in its capacity (quantity of units of information) and duration (how long these units can be stored without rehearsal).[65] Earlier theories of working memory posited that it could hold about seven (plus or minus two) separate 'chunks' of information in working memory. More recent scholarship has revised that figure down to about four.[66] Duration is estimated to be around 20 seconds.[67] There is no consensus, as some people may display a working memory capacity greater than this and some smaller, but there is agreement that working memory is very limited.

Novel information can only enter long-term memory through the bottleneck of working memory. In addition to the significant limitations of working memory, there is no way of 'training' working memory to improve or increase its capacity, meaning that instruction or activity on popular working memory tasks or training is not time well-spent from a teaching perspective.[68]

However, there are two ways to improve the effectiveness of working memory: by increasing the store of information in long-term memory, and by achieving greater automaticity of learned processes.[69]

Greater automaticity is achieved through overlearning, where a person's ability to do that task does not improve past mastery. Information is more strongly embedded in long-term memory with reduced chance of forgetting[70] and the ensuing process can become so automatised it requires little to no working memory capacity.[71]

Long-term memory can be defined as a "vast store of knowledge and a record of prior events"[72] or "that big mental warehouse of things (be they words, people, grand philosophical ideas, or skateboard tricks) we know."[73]

In contrast to the limitations of working memory, there are no known capacity limits of long-term memory.[74] In fact, the information from unlimited store of long-term memory can be retrieved (moved into working memory) when novel information is being encountered.

Willingham argues that "[e]very new idea must build on ideas that the student already knows. To get a student to understand, a teacher… must ensure that the right ideas from the student's long-term memory are pulled up and put into working memory."[75]

Consequently, for novices such as school students, well-learned and well-organised units of information ('chunks' or schemas*) retrieved from long-term memory can be used to help ease processing of new information and thus enable learning. However, information in long-term memory is also organised differently in the minds of domain experts compared to novices.

Analysis of experts completing tasks in their field suggests that their domain knowledge is broader and more interconnected, and procedural knowledge is characterised by greater automaticity.[76]

* A **schema** is a way of grouping and organizing information that is stored in long-term memory. A useful analogy is being asked to remember a random numerical sequence of 10, versus remembering your own mobile number. Remembering 10 random numbers is taxing on working memory and very few individuals will be able to remember them in order, but your own mobile number is no less random – the difference is that your mobile number is stored as one 'chunk' in your long-term memory due to overlearning, and can be brought into working memory if needed as only one unique piece of information.

4) Cognitive load theory uses these models to inform instruction

Cognitive load theory draws on these findings from evolutionary psychology and cognitive science to inform how to teach. In this term, 'load' refers to the burden on working memory. 'Load' is not inherently bad – some burden on working memory is, after all, necessary for any type of learning. Cognitive load can be divided into three types:[77]

- Intrinsic load (sometimes combined with germane load[78]), which is the necessary load of learning new information;
- Germane load, which is the load that comes from transferring information into long-term memory; and
- Extraneous load, which is load not necessary for what is being taught – therefore, good instruction will aim to reduce extraneous load as much as possible.

The application of cognitive load theory is to find ways of teaching students that maximise intrinsic and(/or) germane load and minimises extraneous load, while ensuring there is no overload of students' working memory.

The goal is to design instruction such that it enables students to process new information, store it in long-term memory and retrieve it when needed, either for further learning or independent practice and application.

Cognitive load 'effects' have been derived from the depth of literature on cognitive load theory, and these effects are used to inform instruction. The five main ones from Ashman and Sweller (2023) are:[79]

The worked example effect: showing learners example problems that have been worked out means they learn more than students who must solve equivalent problems on their own using the random generate-and-test method;

The element interactivity effect: When tasks and problems set for students rely on a combination of new and existing knowledge, element interactivity is high if the new knowledge is high and their existing knowledge is low, with the reverse also being true. Element interactivity informs the level of guidance required for students to learn;

The expertise reversal effect: While using worked examples for teaching that involves high element interactivity is an effective strategy with novice learners, this advantage decreases as expertise increases and the student may be better off with independent problem-solving;

The redundancy effect: If information is provided that is redundant (unnecessary) for the learner, it can contribute to extraneous cognitive load and reduce learning; and

The guidance fading effect: The level of guidance from the teacher fades from highly guided practice in the form of worked examples, to partly completed problems where students complete the remainder and then to independent practice by the student.

Explicit teaching: connecting cognitive science insights to effective practice

On its own, an understanding of different categories of knowledge, models of memory and cognitive load is not enough to be considered a 'science of learning'. These insights must be connected to practice — that is, used to identify both ineffective and effective practices.

The NSW Department of Education's Centre for Education Statistics and Evaluation, in its 2017 literature review of cognitive load theory, concluded that it provides support for explicit models of instruction.[80]

First, however, we will consider what instructional methods are not supported by the evidence, particularly regarding the question of what students must be taught and what knowledge students can figure out for themselves.

There are a range of terms for what can be grouped together as 'partial or minimal instruction-based approaches', such as problem-based learning, experiential learning, the project method (which is over a century old) or a general focus on inquiry driven by student interest that dates to the eighteenth century. A basic summary of what this looks like in the modern classroom is:

> *Teachers whose lessons are designed to offer partial or minimal instructional guidance expect students to discover on their own some or all of the concepts and skills they are supposed to learn. The partially guided approach has been given various names, including discovery learning, problem-based learning, inquiry learning, experiential learning and constructivist learning… [S]tudents receiving partial instructional guidance may be given a new type of problem and asked to brainstorm possible solutions in small groups without prompts or hints (emphasis added)… Through the process of trying to solve the problem and*

discussing different students' solutions, each student is supposed to discover the relevant mathematics. In some minimal guidance classrooms, teachers use explicit instruction of the solution as a backup method (emphasis added) for those students who did not make the necessary discoveries and who were confused during the class discussion.)[81]

This description makes clear the ways this does not align with what cognitive science suggests about the best way to provide novel information to novice learners, who learn and solve problems differently from experts.

The inquiry learning approach does not acknowledge, for instance, that mathematics (or any other domain taught in schools) is biologically secondary knowledge that therefore requires explicit instruction with concepts and procedures specifically related to that domain. Inquiry learning also does not account for the limitations of working memory and the burden on a student's cognitive load in trying to solve a complex problem without a pre-existing understanding of the necessary concepts and procedures.[82]

There is also an educational equity aspect to the use of these methods of teaching. While students must use prior and background knowledge to solve problems in the classroom regardless of the domain, in the absence of a knowledge-focused curriculum at school, the knowledge students possess is going to be more strongly a function of their upbringing and family environment. E.D. Hirsch states "the early knowledge advantage that has been gained by fortunate students is like Velcro; it is a base to which further knowledge sticks more readily."[83]

Similarly, Keith Stanovich has observed 'Matthew effects'* in reading, one where vocabulary knowledge facilitates reading comprehension but reading comprehension also facilitates vocabulary growth, leading to students who already have advantages gaining more.[84]

* The **'Matthew effect'** is a generic principle in social science where advantages and benefits accrue more greatly to those who already have some. It is named for the 'parable of the talents' in the gospels of Matthew and Luke.

Fortunately, the insights from cognitive science suggest a better way to teach and points us in the direction of practices that might be effective. If working memory is limited, information should be encountered in small steps and practised, and clear, explicit, teacher-directed instruction will make this process easier. It suggests that independent student work should be carefully placed within a larger instructional sequence to limit the chances of overloading working memory.

If working memory relies strongly on long-term memory and novel information is more likely to 'stick' when it can be connected to existing knowledge, teaching and learning should involve the same content and be practised over an extended period of time to ensure it is retained.

The set of pedagogical practices best supported by cognitive science is explicit instruction, sometimes called 'direct instruction' (DI) or 'explicit and direct instruction' (EDI).* which involves the explicit teaching of specific skills and knowledge by the teacher.

* ***Direct Instruction*** is the brand name for a series of educational programs based on the work of Siegfried Engelmann which, though grounded in the same principles, do not represent the only way of implementing explicit instruction/EDI in schools.

The rationale behind explicit instruction is rooted in research indicating that clear, step-by-step instruction of a well-sequenced curriculum that carefully builds understanding, accompanied by clear explanations that teach through modelling that guide practice through worked examples, can effectively support students in learning. By breaking down complex concepts into manageable parts, providing explicit instruction on each component and checking for understanding before gradually releasing responsibility to students, they are more likely to develop a solid foundation of understanding.[85]

One description of explicit instruction is from Anita Archer and Charles A. Hughes, who clearly link explicit instruction with the insights of cognitive science:

> *Effective and explicit instruction can be viewed as providing a series of instructional supports or scaffolds—first through the logical selection and sequencing of content, and then by breaking down that content into manageable instructional units based on students' cognitive capabilities (e.g., working memory capacity, attention, and prior knowledge). Instructional delivery is characterized by clear descriptions and demonstrations of a skill, followed by supported practice and timely feedback. Initial practice is carried out with high levels of teacher involvement; however, once student success is evident, the teacher's support is systematically withdrawn, and the students move toward independent performance.*[86]

The same process is described slightly differently from a teacher point of view, published in 2012:[87]

> *Teachers providing explicit instructional guidance fully explain (emphasis original) the concepts and skills that students are required to learn… In a math class, for example, when teaching students how to solve a new type of problem, the teacher may begin by showing students how to solve the problem and fully explaining the how and why of the mathematics involved. Often, in following problems, step-by-step explanations may gradually be faded or withdrawn until, through practice and feedback, the students can solve the problem themselves. In this way, before trying to solve the problem on their own, students would have already been walked through both the procedure and the concepts behind the procedure (emphasis added).*

In both examples, a general 'I do, we do, you do' framework is being followed. The teacher first provides instruction to the students ('I do'), followed by students practising step-by-step with guidance ('we do'), before gradually releasing students for independent practice ('you do').

Along the way, feedback — from the students to the teacher about what has been learned and what may require further practice — helps inform the teacher's decisions about when and how to release the students for independent practice. Further implications for teacher practice are discussed later in this paper.

The policy architecture of teaching and learning

This paper has explored the history of progressive educational approaches and how they are still commonly used in the classroom, as well as made the case for the insufficiency of these approaches on the basis of the science of learning. It is now worth critically examining Australia's current policy framework to see what the bedrock assumptions are and identify potential areas for reform.

Policymakers have historically been agnostic about how teachers should teach. While teachers, education researchers and cognitive scientists have been asking and answering questions about how students learn best, government was focused on the policy architecture required to improve the overall capacity of Australian education to deliver a quality education to all students.

Equality of educational opportunity has been a fundamental pillar of Australian schools policy since at least the release of 1973's Karmel report into Australian schools.[88] In that context, the purpose of education policy reform has been to focus on policy settings in the expectation that this will deliver on the desired goal. Only recently have policymakers begun to pay closer attention to teaching (rather than teachers) as a key determinant of educational outcomes.

As this section will show, this policy agnosticism about teaching has meant the system has gravitated towards reflecting the progressive view of education and, paradoxically, led the nation further away from the long-held objective of excellence and equity.

Key areas of policy attention include school funding, teacher training, teacher professional standards and — though least subject to effortful policy coordination — attempts to build consensus on evidence-based practice.

While school funding, teacher training and professional development were considered in the Karmel report, the growing policy attention in the intervening period on teacher professional standards and evidence-based practice has arguably been influenced by education research (as discussed previously) but also concern around student achievement, as measured by national and international testing.

It has been more than a decade since the Review of Funding for Schooling, more widely known as the 'Gonski review', proposed an overhaul to how federal and state governments fund the nation's schools — resulting in annual public funding reaching $72.2 billion in the 2020-21 financial year; a figure that will continue to increase in real per student terms until the end of the decade.[89]

Despite a significant injection of funding and other reform efforts, the educational achievement of Australian students has largely trended towards either decline or stagnation against national and international standardised testing measures (see Box 4).[90]

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Box 4: Australian performance in national and international testing

NAPLAN (National Assessment Plan for Literacy And Numeracy): The test has taken place each year since 2008 (except 2020 during the COVID-19 pandemic). Comparing the first year of testing to the last comparative year (2022) shows little improvement in most domains and year levels, and achievement gaps between disadvantaged and more advantaged students have continued. In 2023, the reporting of NAPLAN results changed and showed that about a third of students, at all year levels, failed to meet a proficient standard in reading, numeracy and writing.[91]

PISA (Programme for International Student Assessment): PISA 2022 data for Australia showed little change when compared to recent cycles but confirmed that from the first round of testing, Australia 's 15-year-old students have lost the equivalent of a year of schooling in science, two years in maths and a year and a half in reading. In addition, a lower proportion of students are meeting the proficient standard, with a lower proportion of high performers and an increasing proportion of low performers.[92]

PIRLS (Progress in International Reading Literacy Study): This tests Year 4 students and Australia first participated in 2011. PIRLS 2021 data for Australia showed that 20% did not meet international benchmarks for reading, down from 24% in 2011. Average scores were flat from PIRLS 2016 but higher than in 2011.

TIMSS (Trends in International Maths and Science Study): This tests students on Maths and Science in Year 4 and Year 8, for the first time in 1995. TIMSS 2019 showed:

- Year 4 Mathematics achievement has improved relative to 1995 but is unchanged since 2007
- Year 8 Mathematics achievement declined between 1995 and 2007 before improving to 2019
- Year 4 and Year 8 Science achievement has improved, declined and improved to 2019

………………………………………………………

The Alice Springs (Mparntwe) Declaration

Australian education ministers met in Melbourne in 2008 and Alice Springs (Mparntwe) in 2019 to affirm educational goals for all Australians.[93] The latter (henceforth 'the Declaration', "sets out a vision for a world class education system that encourages and supports every student to be the very best they can be, no matter where they live or what kind of learning challenges they may face" and "places students at the centre of their education by emphasising the importance of meeting the individual needs of all learners".[94]

The document contains two goals: 1) The Australian education system promotes excellence and equity and 2) All young Australians become confident and creative individuals, successful lifelong learners, and active and informed members of the community. While Goal 2 refers to the desired end state for the education system, the first relates to what education should look like in Australia. It uses phrases such as "promot[ing] personalised learning", "individual capabilities", "enabl[ing] all learners to explore" and learners' "individual abilities, interests, and experiences." This aligns strongly with progressive educational philosophy as explored earlier.

In addition, the emphasis on the individualisation of learning and student exploration does not necessarily align with key science of learning principles (such as the cognitive architecture shared by all humans that means the way students learn is more fundamentally similar that it is different) and practices (that the most effective way to ensure students learn is not through students exploring and pursuing their own interests, but through carefully teacher-designed and -directed learning).

Initial teacher education

Federal government reform in the last decade has largely focused on ITE. A cursory glance of the recent history of ITE reform (see Box 5) shows that successive reviews of the sector have steadily driven in the direction of more external prescription of ITE course content; perhaps in part due to limited evidence the sector has been responsive to the expectations of policymakers.

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Box 5: Recent history of ITE reform

The Teacher Education Ministerial Advisory Group (TEMAG), formed in 2014, was established to provide advice to government on the nature and quality of ITE courses and how graduates from those courses could be more effective. The final report, Action Now: Classroom Ready Teachers, was released in late 2014 and the federal government formally responded in early 2015.[95] The report focused on stronger quality assurance of ITE, more rigorous selection of students for ITE courses, improved practicum for ITE students, proper assessment of graduates to ensure classroom readiness.[96]

The most notable changes due to this review process were the introduction of a literacy and numeracy test for teacher graduates (LANTITE) and Teaching Performance Assessments (TPAs), a university-based assessment of teacher performance that purportedly aligns with the Australian Professional Standards for Teachers.[97] With the exception of one area of attention on selection of ITE students, the report primarily focused on what candidates are learning in teacher education.

A subsequent review, the Quality Initial Teacher Education Review, was announced March 2021 and a final report in February 2022. It canvassed many of the same issues as its predecessor report, with a more specific focus on ensuring teacher preparation is "evidence-based and practical."[98] The report endorsed the need to "strengthen ITE programs to 'equip graduate teachers with a strong understanding of what works best to improve student learning based on the best evidence'."[99] In particular, it clearly stated that ITE programs should inform graduates of "how students learn to provide teachers with a foundational understanding of why specific teaching practices work. This includes understanding how students process new information, how they retain that information and how they apply that knowledge to new situations." The content of the report suggests that these questions are, in fact, a matter of some consensus as opposed to highly individual to the student and which therefore cannot be the subject of teacher training — the latter a cornerstone of progressive beliefs about education.

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The most recent development was the 2023 release of Strong Beginnings, the report of the Teacher Education Expert Panel led by Mark Scott, current Vice-Chancellor of the University of Sydney and former secretary of the NSW Department of Education. Reports into ITE are nothing new (Box 5), but the contents of this report are instructive about what the expert panel saw as the solution (at least as far as ITE is concerned). The Panel established four areas of core content,[100] of which the first two are most relevant to this report:

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

The *Strong Beginnings* report makes the case that pre-service teachers must be taught key knowledge about how people learn, that this knowledge should inform how teachers teach, and which pedagogical practices are best supported by this knowledge.

In particular, it specifies that for Core Content Area 1 (the brain and learning), pre-service teachers must learn about distinctions between novice and expert learners, short and long-term memory and cognitive load, mastery of knowledge including retrieval and application across contexts and neuromyths.

This is significant because it is the first time cognitive science insights have been explicitly positioned as vital knowledge for pre-service teachers — and therefore for teachers more generally.

Further, it recommends that 'core content' be present in any course seeking accreditation for producing graduate teachers; in other words, without adequately offering the prescribed core content, programmes will not meet accreditation standards.

The nation's education ministers met twice in 2023 to discuss the report; in July when they provided in-principle support to progress its recommendations, and in December when they agreed AITSL will require the teaching of core content (as outlined in Strong Beginnings), with ITE providers to have until the end of 2025 to make the necessary changes to their programs.

While the endorsement of the Strong Beginnings report shows the broad level of support for science of learning principles in reforming ITE, delivering quality education is a much more significant task than fixing ITE alone. For instance, over the past 15 years between 16,500 and 19,000 students graduated from ITE programs every year, but those who go into teaching join a total school full-time-equivalent teacher workforce of over 300,000. More must be done at all parts of the education ecosystem to inform these teachers and get good practice into their classrooms as well.

Professional standards, accreditation and registration

A nationally consistent approach to teacher standards — now known as the Australian Professional Standards for Teachers (APST)[101] — was finalised in 2011.[102] The APST has four stages (Graduate, Proficient, Highly Accomplished and Lead) and is used for three purposes:

For pre-service teachers: the Graduate level is used to inform core content in initial teacher education (ITE), with pre-service teachers required to complete some form of teacher performance assessment that aligns with the Graduate level of the standards;

For graduate teachers (generally 1-2 years in teaching): the Proficient level is used to inform state-based registration/accreditation with the relevant teacher regulatory authority (for example, NESA in NSW or VIT in Victoria) and the teacher must demonstrate that their practice aligns with the Proficient level of the standards; and

For mid-career and senior teachers: the Highly Accomplished and Lead levels are used to inform a national certification program* to identify and recognise quality teachers, with the certification process involving external assessors.

* HALT certification is not used in Victorian, WA and Tasmanian state schools. It is also not used in the Catholic sector in WA and Tasmania and the independent sector in Queensland and Tasmania.

At best, the APST can be described as vague; at worst, the standards can be said to encourage practices that contradict the science of learning and the recommendations for core content mandates in the Strong Beginnings report. For instance, Standard 1 — Know students and how they learn — does not contain references to cognitive psychology, the science of memory, cognitive load theory or any similar concepts; therefore, it is vague about what the knowledge of the students is and how they learn. Is it about cognitive science, or is it about individual learning styles and interests (as implied by the Alice Springs Mparntwe Declaration)?

AITSL provides some guidance as to what the standards look like in practice through their standards-linked 'illustration of practice' resources. One such video resource for Standard 1.2 Understand how students learn is of "a teacher of mathematics us[ing] an inquiry approach to learning with her Prep students",[103] and this is intended as an illustration of the 'Proficient' level for that standard. This plainly contradicts cognitive science principles about how best to instruct novice learners, which Foundation (Prep/Kindergarten) students certainly are.

Given that ITE providers will now be required to provide more specifics around this standard in particular, it makes sense for the Standards themselves — which apply to all teachers, not just pre-service and graduate teachers — to be reviewed to align with the new core content requirements.

The policy push for 'evidence-based practice'

The fact that discussions around teaching practice now utilise the language of evidence is a significant improvement on historical methods of teaching. However, unless the term 'evidence' has clear meanings, its use in practice can create an illusion of progress among the teaching profession.

Teachers and leaders know, to varying degrees, that evidence should be a central part of their work. AERO's 2022 survey of evidence use found 67% of Australian teachers use teacher-generated evidence (defined as evidence generated through daily practice such as observations, non-standardised formative or summative assessments or insights from student feedback) 'often' or 'very often', but this compares to only 41% for research evidence.[104] This suggests that while most practitioners will engage with evidence, the conceptual understanding of what constitutes evidence is fluid.

'Evidence-based practice' arguably entered the Australian education lexicon in 2008, when education professor John Hattie published Visible Learning, which synthesised over 800 meta-analyses to find out what influences achievement in school-age students. While Hattie's work was the first popular example to criticise learning styles, its method of collapsing the effect sizes of hundreds of studies of varying qualities on different instructional practices has been subject to criticism.[105]

Nevertheless, the method has been influential: the Victorian Department of Education uses Hattie's effect size method to identify 10 'High Impact Teaching Strategies' as part of its pedagogical guidance to schools.[106] The general approach of synthesising studies and presenting information in an accessible format is also used by the Education Endowment Foundation and its Australian offshoot, Evidence for Learning, in the 'Teaching and Learning Toolkit'.[107]

At first glance, the pursuit of 'evidence-based practice' or 'what works' seems entirely in keeping with the science of learning. But the science of learning, as outlined in this paper, is more particular than the general desire for evidence-based practices in teaching. It is fundamentally based in a belief that teaching should be about what students learn; where 'learning' is couched primarily in terms of change in long-term memory.

This is not a view that is shared by all theorists and practitioners of education. As the previous section on the history of educational approaches has shown, there are different philosophical views about what learning is; going so far as to question the idea that there is an accepted body of knowledge that students should know.

Furthermore, 'evidence' and 'research' are broad terms, and many practices can claim the mantle of being 'evidence-based' — even if that evidence is derived from a limited number of studies, studies that use poor methodology, studies with limited generalisability, or that evidence has been seriously challenged by subsequent scholarship. If it is to be effective, 'what works' practices cannot be presented independently of research into cognitive science and what approaches might be implied by that base of knowledge.

In addition, if teachers are presented only with overly simplified lists of 'what works' that are divorced from learning science evidence that provides a 'why', it poses several problems. Firstly, it becomes difficult for those practices to be implemented with fidelity and in their proper context if teachers do not fully understand the rationale and reasoning behind the practice. Secondly, if the practice has not resulted in the desired impacts, then this can engender scepticism among teachers. Worse, it can contribute more broadly to a deep pessimism or cynicism about the language of 'evidence' that hinders the update of even well-supported methods of teaching.

If teachers and leaders within the education ecosystem are equipped with a sound understanding of 'why', this could instead create a sense of empowerment among teachers. Subsequent research will examine how teachers have developed their practice and professional identity as a result of immersion in the science of learning.

Implications of the science of learning

A combination of government changes in policy as well as an increasingly vocal and active teaching profession mean there is opportunity for a wider public conversation about what Australian schools should be doing to prepare students to not simply participate, but flourish in a modern society.

For teachers

For teachers, the science of learning represents an opportunity to design instruction in a way that is likely to lead to most students' success with learning.[*] The evidence suggests explicit instruction of a well-sequenced knowledge-focused curriculum will lead to that success.

* Some students may have weaker working memory capacity or have other conditions that can inhibit their learning. These students can be identified through universal screening and assessment, followed by small group or individual intervention, in what is called a 'Response to Intervention' or 'Multi-Tiered System of Supports' framework.

Nevertheless, turning the insights explained earlier in the paper into a body of knowledge and set of guiding principles for teachers and leaders at a school or system level is difficult. One example of how it could be done is the work of the Catalyst program in the Catholic Education Archdiocese of Canberra-Goulburn (CEACG). The Catalyst team examined research and evidence from educational experts (many of whom were used in this paper) such as ED Hirsch Jr, Barak Rosenshine, Dylan Wiliam and John Sweller to develop eight 'big ideas' for learning.[108]

The principles show a combination of how to teach, what the curriculum should focus on, and the set of insights from cognitive science that underpin this.

- School is where we learn biologically secondary information;
- Learning is a change in long-term memory;
- Teaching is a profession that should be informed by the evidence;
- Knowledge matters — it's what we think with;
- The most efficient way to teach knowledge is to teach explicitly;
- High quality whole class instruction will help all students learn;
- Reading is essential for students to acquire knowledge; and
- Curriculum should be ambitious, coherent, sequential and cumulative.

At a school level, creating a strong curriculum is complex and labour-intensive. To create a new curriculum or build on the existing curriculum, specialist teachers will need to work together and think carefully about what knowledge is crucial for students and how to best teach that knowledge across a learning sequence. Teachers should also collaborate to develop the most effective ways of creating quality explanations for new concepts and ways of modelling these to students.

Despite not covering every subject and year level, education non-profit Ochre Education is now providing a thorough suite of resources, aligned to relevant curriculum, to teachers free of charge — including demonstrations of teacher practice.[109]

There are several practices to consider embedding across learning sequences and individual lessons, with some being more labour-intensive than others to implement. One well-regarded list is Barak Rosenshine's Principles of Instruction, derived from research in cognitive science, classroom practice of effective teachers and cognitive supports:[110]

- Daily review of previous learning;
- New material in small steps with student practice after each;
- Ask a large number of questions and check all student responses;
- Provide models;
- Guide student practice;
- Check student understanding;
- Obtain high success rate;
- Scaffolds for difficult tasks;
- Require and monitor independent practice; and
- Weekly and monthly review.

There are many other lists of similar practices, including a plausible lesson structure and practice principles in other work, such as Archer and Hughes[111] and Hollingsworth and Ybarra.[112] Further work also exists on how to embed these practices in a subject-specific manner.

For parents

Parents also have an important role to play in the public conversation about the science of learning, as they are heavily invested in the learning of their children.

One factor that may influence parents' perception of how their child is being taught is the 'curse of knowledge' — a cognitive bias that means if you know something, it is difficult to see things from the perspective of someone who doesn't. In this case, it might mean learning activities that appear logical and useful to you as someone with knowledge of multiplication or essay writing may be too difficult for your child. P

arents may also fall into the trap that befalls many teachers: using observed levels of engagement (such as the extent of student focus and interest when they are creating a project, doing a science experiment or an online multimedia task) as a proxy for learning. As Willingham notes, people learn what they think about. If students are thinking about cutting and pasting, science equipment or the many distractions of digital technology, they are unlikely to be learning, or consolidating their learning, to any great degree.[113]

Parents can also engage around the science of learning when selecting a new school or during parent-teacher interviews. Some helpful questions for understanding a school's approach to teaching are "What does student learning mean?" and "How do you teach in a way that makes students most likely to succeed?" Other questions could relate to the curriculum across the whole school, such as "How is the curriculum for one year built upon in subsequent years?"

Looking at students' classwork and homework to see how homework tasks build on what has been taught in class could also be a valuable starting point to ask questions; though it is important to not make hasty judgements on the basis of one or two tasks.

For parents of younger students, it's particularly important to ask about how foundational skills such as reading and mathematics are taught, and how student progress is monitored. For older students, particularly those in secondary school, it could be useful to ask questions about and discuss what independent study techniques are most helpful. For instance, common student study techniques, such as re-reading and highlighting, are not supported by evidence whereas self-testing retrieval practice can be more beneficial.[114]

For policymakers

By committing to change accreditation requirements for initial teacher education in line with the Strong Beginnings report, future cohorts of pre-service teachers will be better equipped with the knowledge and skills to succeed in the classroom. However, there are still questions as to what quality assurance mechanisms will be put in place for the sector.

In addition, ITE is one part of the educational ecosystem. The CEO of AITSL has noted that if ITE is the only focus of improvement within the policy landscape, it will take approximately 28 years for the workforce to achieve what is desired. Policymakers also need to commit to reforming the Professional Standards for Teachers, as well as Principals, to reflect the much more detailed view of teacher capacity that has emerged (and been endorsed) from Strong Beginnings. For this to occur, policymakers need to consider how to upskill and develop the existing teacher workforce, while monitoring the ever-present concern of workload and teacher shortages. Future CIS research will focus on reform of standard and potential models for teacher professional development.

School systems and state governments have other avenues that do not trigger any tricky federal-state relations issues. Systems could review their local syllabus or curriculum to ensure knowledge is emphasised as the object of learning, and is built on sequentially within and across many year levels. Systems can also revise pedagogical guidance and advice to teachers to prioritise cognitive science insights and explicit teaching practices. One example of how this can be communicated is the short guide published in 2015 by US organisation Deans for Impact, which summarises cognitive science principles and connects it to practices for the classroom.[115]

While this paper has sought to explain why the science of learning provides the ideal foundation for teaching and learning practices in Australian schools, the actual extent to which these practices are adopted by schools and teachers is difficult to measure.

Given the inconsistencies and contradictions embedded in the key policy pillars of the Australian education system, it seems safe to assume this practice, to the extent that it exists, has been the fruit of concerted effort by individual teachers and schools rather than the result of school system priorities (the aforementioned Catalyst program from the Catholic Education Archdiocese of Canberra-Goulburn is the sole example of an exception to this).

Nevertheless, teachers and leaders have taken matters into their own hands and used their own budgets to embark upon a significant program of professional development to achieve a science of learning-aligned approach in their schools.

Future CIS research will examine the experiences of some of these teachers and leaders to yield insights for how science of learning can be more widely adopted within the Australian education system, and find ways to measure and track science of learning knowledge within the teaching profession.

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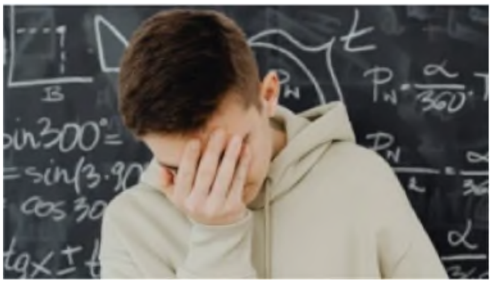

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