Teach First

Teaching and Learning

Research review 2022-23

Contents

Introduction

We know that improving the quality of teaching is key to improving the outcomes of all learners. There has been a lot of research that has sought to understand and explain the process of learning, and a lot of research that has sought to identify the components of effective teaching. The results are not definitive – we remain unclear on how we most effectively judge great teaching whilst learning remains essentially invisible – but we can build on the 'best bets' that the evidence presents. What works in one context may not work in another, so we must be constantly striving for improvement rather than perfection.

Great teaching

> *Our best bet for learning to be a better teacher is to work on specific, underpinning competencies, one at a time.*
>
> (Coe *et al.*, 2020)

Research-based models of teaching have identified varying numbers of dimensions, e.g. Rosenshine's 10 principles (Rosenshine, 2012) and the Early Career Framework's 8 standards (DfE, 2019a), though they have considerable compatibility with the 3-dimensional model (Praetorius *et al.*, 2018), to which Coe *et al*. have added content knowledge as a prerequisite of the required classroom actions (Coe *et al.*, 2020).

According to the evidence toolkit (Coe *et al.*, 2020), great teachers:

1. understand the content they are teaching and how it is learnt
2. create a supportive environment for learning
3. manage the classroom to maximise opportunity to learn
4. present content, activities and interactions that activate their students' thinking.

The individual elements of these dimensions inevitably overlap and are broad in scope. Great teaching will look different in practice across ages, contexts and subjects.

This builds on previous work identifying the elements of teaching that lead to improved student progress:

1. pedagogical content knowledge (strong evidence of impact)
2. quality of instruction (strong evidence of impact)
3. classroom climate (moderate evidence of impact)
4. classroom management (moderate evidence of impact)
5. teacher beliefs (some evidence of impact)
6. professional behaviours (some evidence)

(Coe *et al.*, 2014)

Content knowledge

Teachers need a deep and fluent knowledge of the content they are teaching (content knowledge) and how it's learnt (pedagogical content knowledge). This includes understanding curriculum sequencing and relevant explanations, tasks and activities for the ideas you are teaching (Coe *et al.*, 2020).

Ofsted sees well-trained and experienced teachers who have strong subject and pedagogical knowledge as a common characteristic of outstanding schools. High quality professional development is essential to develop subject knowledge, particularly in primary schools, where teachers teach across a wide curriculum, but also in secondaries where some teachers are teaching out of subject specialism due to shortages (Ofsted, 2020).

The ITT Core Content Framework and Early Career Framework present the core generic content that teachers should learn but both emphasise the importance of training being subject and phase specific (DfE, 2019b) (DfE, 2019a).

The Teachers' Standards further indicate the importance of good subject and curriculum

knowledge (TS3). They also require understanding of and responsibility for literacy, regardless of specialist subject, and of synthetic phonics for those teaching early reading (DfE, 2013).

Skills teaching

The debate continues around skills vs knowledge: which is more important, or how best to teach them. For most teachers, there is a recognition that it is not a binary choice, with both being important.

A further element in this debate has been the notion of twenty-first century skills as a prerequisite for students today in order to prepare them for the world of work.

The variation in prioritising skills in the curriculum has led to increasing divergence in the curriculum across the UK, with Scotland's Curriculum for Excellent focusing on 'soft skills' and Wales using this as a model for their new curriculum. There is also an increasing international variance, with Australia, New Zealand, Estonia and Japan all taking a similar approach to Scotland.

Procedural/declarative knowledge

Declarative knowledge is knowing 'that' something is the case, e.g. that London is the capital of England. Procedural knowledge is knowing 'how' to do something, e.g. how to ride a bike, although we may not be able to explain how we do it. This distinction is central to understanding memory systems, and particularly long-term memory. Short-term memory is considered to be a feature of declarative knowledge. Long-term declarative memory is often not necessary for performance (ten Berge and Van Hezewijk, 1999).

Critical thinking

Whatever the debates around the content of what is taught in schools, there is little disagreement about the importance of the ability to think critically. The benefit of critical thinking is clear, however it is a difficult skill to teach students in a way that they can transfer to new problems.

Willingham points out that it is not useful to think of critical thinking skills as broadly applicable, but as skills that mean different things in different disciplines. Whilst there are principles that carry across domains of study, it is very hard to for people to apply these in new situations (Willingham, 2019).

Willingham argues for a four-step plan to teach specific critical thinking skills to students:

1. Identify what is meant by critical thinking in each domain, e.g. mathematics, history, and teach it explicitly and then practise.
2. Identify the domain content they need to know as this is a crucial driver of thinking skills.
3. Select the best sequence in which to learn the skills – we interpret new information in light of what we already know.
4. Decide which skills should be revisited across years – plan on 3 to 5 years of practice (Willingham, 2019).

Critical thinking, problem solving and creative thinking are closely linked ideas. Whilst critical thinking focuses on assessing and evaluating information and situations, creative thinking can be seen as novel thinking that is useful. Sweller places these firmly within human cognitive architecture as biologically secondary knowledge. He emphasises that successful problem solving relies on previous knowledge and that learning novel information is easier when building on existing knowledge, rather than using a random generate-and-test approach (Sweller, 2022).

Whole child development

There is significant and increasing evidence that shows the importance of a whole child approach to improving outcomes for children at school and beyond. The links between physical wellbeing and good mental health are well known, and this is also linked to improved academic outcomes. Emotional development is a central component of self-regulation, linked to self-esteem, and a child's ability to learn and thrive. Social development dictates our ability to form relationships with others, both teachers and peers. This has been linked to the likelihood of health-risk behaviours. Cognitive development is not synonymous with academic skills, but is about approaches to thinking, problem solving and memory. Metacognition contributes to an individual's ability to make decisions and think critically about situations.

Additional impetus for this approach is an increasing governmental focus on the importance of character development and relationship education in schools. Reports of heightened anxiety within a high-stakes assessment system are increasing and in the aftermath of the COVID-19 pandemic there is increased concern about the impact on pupil wellbeing as well as on an increasing attainment gap between the most and least disadvantaged pupils.

Cognitive development

Vygotsky stressed the fundamental importance of social interaction in the development of cognition, with the community central in the process of 'making meaning'. He argued that children acquired their cultural values, beliefs and problem-solving strategies through collaborative dialogue with more knowledgeable members of society. This led to the development of concepts such as the 'zone of proximal development'. He argued that social learning tends to precede development (Vygotsky, 1929). In contrast, Piaget believed that development must precede learning.

Piaget's theory of cognitive development suggested four different stages through which children moved, focusing on how they acquire knowledge. Children's interaction with the world, as active participants in the learning process, supports them to develop through learning new knowledge, building upon existing knowledge and adapting ideas. The four stages he identified:

- sensorimotor – birth to 2 years
- preoperational – ages 2 to 7
- concrete operational – ages 7 to 11
- formal operational stage – ages 12 and up

The important distinction Piaget made was in understanding that children think in different ways from adults. Early development is based primarily upon actions, but progresses to changes in mental operations. Crucially, intellectual development was not seen as a quantitative process by which children simply acquired more knowledge, but that there are qualitative changes in the ways of thinking (Piaget, 1964).

The most recent iteration of *Development Matters* (2020, revised July 2021) outlines the DfE's non-statutory curriculum guidance for the early years foundation stage, offering a 'top-level view of how children develop and learn'. They suggest that effective pedagogy recognises that children learn through play, through adults modelling, by observing each other, as well as through guided learning and direct teaching. They further suggest that older children need more guided learning (DfE, 2021a).

Willingham challenges the notion of 'developmentally appropriate practice' as a guide for instruction. He argues that children's cognitive development does not happen in discrete stages, but also that the effects of cognitive development do not affect all tasks consistently. Development should be considered more continuous and variable – it depends on the child, the task, even the day. This means that in the classroom we need to use information about principles, but not expect absolutes. We should consider the effectiveness of tasks and why students do not understand. He goes further and says that we need to recognise that no content is inherently developmentally inappropriate (Willingham, 2008).

Social and emotional development

The importance of social and emotional learning in schools has been long recognised as influencing both academic and non-academic outcomes, as well as lifelong learning. Empirical evidence links social and emotional learning (SEL) to improved school attitudes, behaviour and performance, recognising that schools are social places and that learning is a social process (Zins *et al.*, 2007).

Development Matters (DfE, 2021a) includes the importance of persona, social and emotional development for children in the EYFS. The importance of attachment and supportive relationships with adults form the basis of the ability of children to understand their own feelings and develop empathy with others. Supported interaction with other children enables them to learn about good friendships, co-operation and resolving conflicts. These attributes are seen as providing a secure platform for success at school and beyond.

Donnelly *et al*. considered education policy and practice in the UK in relation to the development of social and emotional skills. They found that policy privileges certain social and emotional skills, largely seen as 'competencies' such as building relationships, resilience, teamwork and being creative. Schools generally adopt this approach, focusing on individual capacities such as self-regulation and interaction with others. Changes to the curricula in Wales and Scotland means that England increasingly relies on a disparate set of 'stand-alone' policies. Whole-school approaches were identified but mainly activities occurred outside the curriculum, such as mentoring, behaviour interventions, careers and sometimes sport participation (Donnelly *et al.*, 2020).

One meta-analytic review examined the relationships between students' sense of school belonging and their motivational, social-emotional, behavioural and academic functioning in secondary education. They found a small, positive correlation with academic achievement, small to moderate positive correlations with motivational outcomes, and behavioural outcomes. Also a small negative correlation with absence and dropout rates (Korpershoek *et al.*, 2019).

A national scoping survey of mental health provision in English schools found that although 2/3 of school approaches focused on all pupils, they were primarily reactive rather than preventative interventions. They were also not evidence-based, suggesting that more work needs/needed to be done in order to generate more systematic preventative interventions and frameworks (Vostanis *et al.*, 2013).

The Educational Endowment Foundation presents six recommendations for improving social and emotional learning in primary schools:

1. Teach SEL skills explicitly.
2. Integrate and model skills through everyday teaching.
3. Plan carefully for adopting a SEL programme.
4. Use a 'SAFE' curriculum: sequential, active, focused and explicit.
5. Reinforce SEL skills through whole-school ethos and activities.
6. Plan, support and monitor SEL implementation (EEF, no date).

Physical development

The development of gross motor skills is crucial in the foundation of healthy bodies and social and emotional wellbeing. They also support the development of the fine motor control and hand-eye coordination required for early literacy (DfE, 2021a).

Fenesi *et al*. studied the impact of taking exercise breaks during university lectures and found that they promoted attention and resulted in superior learning. Exercise breaks in children reduce off-task physical behaviours (e.g. fidgeting) whilst improving academic performance (Fenesi *et al.*, 2018).

Aerobic exercise can affect the brain and cognition (Stillman *et al.*, 2020).

Inclusive teaching

Inclusive education means that all children are together in mainstream classrooms for the majority of the day. Whilst traditionally the focus has been primarily on children with special educational needs or disabilities, the evidence shows that successful inclusive practices benefit all children with different characteristics relating to ethnicity, language, gender or socio-economic status (Schuelka, 2018).

The Committee on the Rights of Persons with Disabilities (UN 2016), defines inclusive education as:

- a fundamental right to education
- a principle that values students' wellbeing, dignity, autonomy and contribution to society
- a continuing process to eliminate barriers to education and promote reform in the culture, policy and practice in schools to include all students.

(in Schuelka, 2018, p.3)

Teachers need the knowledge and skills to create inclusive classrooms, within an environment that enables teachers themselves to flourish. Sustainable delivery of inclusive education emphasises inclusive pedagogy in pre-service training, as well as within ongoing professional development. This helps to maintain a positive attitude towards inclusion as part of a teacher's professional role (Schuelka, 2018).

Eight indicators can help teachers review how inclusive their classrooms are:

1. Teaching is planned with all students in mind.
2. Lessons encourage the participation of all students.
3. Students are actively involved in their own learning.
4. Students are encouraged to support one another's learning.
5. Support is provided when students experience difficulties.
6. Classroom discipline is based on mutual respect and healthy living.
7. Students feel that they have somebody to speak to when they are worried or upset.
8. Assessment contributes to the achievement of all students.

UNESCO-IBE 2016, p.109 (in Schuelka, 2018, p. 8–9).

Gender

Gender stereotypes and assumptions have long been an issue in education, with high-achieving boys seen as challenging gender norms, whilst high-achieving girls as confirming them. As a result, there has been a tendency to overlook underachieving girls. These stereotypes can affect teachers' perceptions and expectations, leading to the focus on underachievement being primarily about the underachievement of boys (Jones and Myhill, 2004). There has been a significant focus on the gender gap, considering the reasons for, and solutions to, boys' underachieving (Pinkett and Roberts, 2019; Baars, Mulcahy and Bernardes, 2016). There is now greater recognition of the wider drivers of underachievement, particularly socio-economic disadvantage (House of Commons Education Committee, 2021).

InnerDrive highlights research that demonstrates how gender differences might be played out in a classroom. This suggests that teachers are more likely to use positive comments for girls than boys, and that under-achieving boys are the most likely to be called upon to answer questions whilst under-achieving girls are the least likely (InnerDrive, 2021).

Why STEMinism Matters (Sundorph, 2020) and *STEMinism One Year On* (Teach First, 2021b) highlight the continued gender imbalance in STEM subjects specifically, and explore its links to teacher shortages across these subjects. Whilst girls, on average, do as well as boys in science GCSE, they are less likely to pursue STEM subjects at A-level. This pattern continues in higher education.

Social class

The concept of meritocracy has long been central in education, but we know that socio-economic status remains a key determinant of educational

outcomes and beyond (Shaw *et al.*, 2016). It is unclear that any particular teaching strategies address these inequalities beyond high quality teaching. Wider pastoral interventions, or particular support related to individual needs (for example digital connectivity), may be of value. Polling suggests that the digital divide remains significant; only 2% of teachers working in schools serving the most disadvantaged communities say that all their students have adequate devices and internet to work from home (Teach First, 2021a).

Ethnicity

In the academic year 2019/20 there were 8.89 million pupils in England, an increase of 71,000 from the previous year. The proportion of pupils from minority ethnic backgrounds[1] has been rising steadily over recent years. Approximately a third of pupils in primary and secondary are from ethnic minority backgrounds (33.9% of primary, 32.3% of secondary). However, in London's secondary schools, 72% of pupils belong to an ethnic group other than White British (Mayor of London, 2021).

The BAME acronym has been found increasingly unhelpful in understanding variation in educational outcomes among different ethnic groups. The picture is a complex combination of social, economic and cultural factors (Commission on Race and Ethnic Disparities, 2021).

Patterns in education and social attainment by ethnic groups varies throughout their schooling journey:

- Attainment is highest for Chinese and Indian ethnic groups up to A Level; it is lowest for White Gypsy and Roma and Irish Traveller groups
- White British groups are ranked 10th at GCSE, and 8th at A-level.

One study of attainment argues that there is evidence that some ethnic groups are systematically 'under-assessed' relative to their white peers, whilst some are 'over-assessed'. This may be linked to a teacher's local experience of particular groups (Burgess and Greaves, 2009).

Table 1: Percentage reaching attainment thresholds by ethnic group, 2018 to 2019 school year

	4 to 5 year olds meeting expected development standards (%)	10 to 11 year olds meeting expected standard, reading, writing, and maths (%)	16 year olds getting a strong pass (grade 5 or higher) in GCSE English and maths (%)	18 year olds getting at least 3 As at A level (%)
Chinese	76 (3)	80 (3)	76.3 (2)	25.7 (1)
Indian	78 (20)	77 (19)	64.1 (15)	15.5 (8)
Asian Other	69 (11)	71 (12)	60.1 (9)	11.8 (5)
Mixed White and Asian	75 (10)	73 (9)	55.5 (6)	15.3 (3)
White Irish	74 (2)	73 (2)	54.9 (2)	13.8 (1)
Bangladeshi	67 (10)	70 (11)	50.3 (10)	7.8 (4)
Mixed Other	73 (16)	68 (14)	47 (10)	11.8 (4)
Other	63 (12)	61 (13)	43.4 (10)	10.2 (4)
All	71 (639)	65 (644)	43.2 (543)	13 (218)
Black African	68 (21)	67 (26)	42.9 (20)	6.1 (8)
White British	73 (410)	65 (426)	42.5 (375)	11 (122)
Mixed White and Black African	71 (6)	67 (5)	41.5 (3)	8.3 (1)
White Other	66 (45)	63 (43)	41.5 (28)	11.5 (10)
Pakistani	64 (27)	62 (29)	41.3 (24)	7.3 (8)
Black Other	66 (4)	60 (5)	33.7 (4)	5.4 (1)
Mixed White and Black Caribbean	69 (10)	59 (10)	31 (8)	6.2 (2)
Black Caribbean	68 (5)	56 (7)	26.5 (7)	3.4 (2)
Irish Traveller	39 (0.7)	26 (0.5)	13.9 (0.2)	0 (<0.1)
Gypsy and Roma	34 (2)	19 (2)	6 (1)	0 (<0.1)

Note: Publication of GCSE attainment in the 2019 to 2020 school year was cancelled due to COVID-19. Table ranked by GCSE attainment (number in cohort, thousands). Source: Ethnicity facts and figures.

(Source: Commission on Race and Ethnic Disparities, 2021)

SEND

One review of research about the effects of inclusive education found that inclusion for pupils with SEND generally demonstrated positive gains in literacy and numeracy. Most students with disabilities had better academic outcomes in inclusive settings. Socio-economic context could

[1] Minority ethnic background: those pupils of all school age who have been classified according to their ethnic group and are of any origin other than White British are defined as being of minority ethnic background. https://explore-education-statistics.service.gov.uk/find-statistics/school-pupils-and-their-characteristics

make a difference, with more economically advantaged classes leading to more positive effects for students with SEN. Overall, few studies indicated negative effects for non-SEN pupils from inclusive settings (Gray, Norwich and Webster, 2021).

The EEF guide for supporting students with special needs in mainstream schools (EEF, 2020) makes five recommendations:

1. Create a positive and supportive environment for all pupils, without exception.
2. Build an ongoing, holistic understanding of your pupils and their needs.
3. Ensure all pupils have access to high quality teaching.
4. Complement high quality teaching with carefully selected small-group and one-to-one interventions.
5. Work effectively with teaching assistants.

Preparing teachers to teach children with SEND is difficult as children and young people show a huge variety of individual needs and need very different types of support. A large repertoire of strategies is therefore beneficial, linked to knowledge of the needs of individual students (Carroll *et al.*, 2017).

A rapid evidence assessment suggests that approaches such as collaborative learning or peer tutoring in support of mixed ability teaching can be very helpful for students with SEND, as well as for typical students (Carroll *et al.*, 2017).

(ASK Research, 2017) has collated some of the evidence of effective practices. There is good evidence to support: teaching planning, monitoring and evaluation of pupils' own work; encouraging the use of memory strategies; providing regular practice of taught information interleaved with new material; encouraging regular physical activity in the school routine; promoting language awareness and communication strategies in the classroom; systematic phonics-based reading instruction; explicit teaching of reading comprehension strategies.

The government published a new five-year strategy for autistic children, young people and adults in July 2021. The report has aspirational vision for 'better and more inclusive support' to autistic children and young people, to sustain school placements, ensure positive experiences in education and a better transition into adulthood. Its approach includes key commitments in the first year:

- Improve understanding of autism amongst educational professionals by continuing to provide funding for autism training and professional development in schools and colleges in 2021 to 2022.
- Publish and consult on the SEND review as soon as possible.
- Carry out a new anti-bullying programme in schools, to improve the wellbeing of children and young people in schools, including those who are autistic.
- Provide a further £8.6 million funding in 2021 to strengthen the participation of parents and young people – including those who are autistic in the design of SEND policies and services and ensure that they are able to access high quality information, advice and support.
- Take action to strengthen and promote pathways to employment, such as supported internships, traineeships and apprenticeships, and work to support all local areas to develop supported employment forums.

(HM Government, 2021, p. 20).

Setting vs mixed ability groups

The aim of setting or streaming, or within-class grouping, is to make teaching more efficient and effective by narrowing the attainment range in a given group of students. Whilst the term 'ability' is often used, usually this is determined by prior attainment as reflected by performance data such as SATs or other tests. The prevalence of setting in secondary schools, and within-class grouping in primaries in the UK, is despite the weakness of the evidence for its benefits. A wide range of studies indicates that on average pupils in attainment groups make the same progress as mixed attainment classes (EEF 2018a).

The evidence is mixed but suggests that only a small positive impact of sets for higher attaining

learners is countered by a negative impact for lower attaining learners. There is evidence to support the view that achievement is not compromised by mixed-ability setting and that achievements of average and less able students proved significantly higher compared to their peers in same-ability classes. Highly able students performed about the same. The achievement for those students who were on the cut-off points was largely dependent on being arbitrarily assigned to the lower or higher group (Linchevski and Kutscher, 1998).

Alongside this lack of effect on academic attainment, there is evidence that it may negatively affect wider outcomes such as confidence. There may be longer-term negative effects on the attitudes and engagement of lower attaining students. There is also a concern that students from disadvantaged backgrounds are more likely to be misallocated to groups, with them being overrepresented in lower sets (EEF, 2018a).

Boaler draws links to Dweck's mindset research and how schools can unintentionally promote messages that communicate the idea of fixed abilities. This can affect both higher and lower attaining pupils, with high-achieving girls suffering from the concept of needing to maintain a 'smart' image so becoming resistant to challenge and unable to cope with failure. She notes that studies in the US and the UK show that de-tracking, or mixed-attainment teaching, led to higher pass rates whereas setting actively hindered progress (Boaler, 2013).

Another study of within-class ability groups found that children in lower groups showed more hyperactivity and emotional problems compared to non-grouped children. They also drew attention to the importance of teacher influence on children's self-concept. They concluded that within-class ability-grouping might in fact be limiting rather than facilitating learning and emotional and behavioural development. Being placed in a bottom group within class is apparently the most damaging context emotionally and behaviourally as the more proximal the unfavourable comparison is, the more powerful its impact (Papachristou *et al.*, 2022).

One study suggests that teaching Years 7 and 8 in mixed attainment classes for all subjects is associated with higher progress for all students, but particularly for pupil premium students though the data is not highly reliable. Survey data suggests a negative impact of even limited setting (e.g. in core subjects) on pupil premium students across all subjects (Social Mobility Commission, 2021).

A UCL study of 9,000 Year 8 mathematics students (age 12–13 years), showed that ability groupings widened gaps in self-confidence as learners. Those in top sets had significantly higher and those in bottom sets, significantly lower self-confidence in their learning, and that this impact extended beyond the set subject to other classes. Their findings echo those of Boaler that setting creates or reinforces a view of fixed ability despite the lack of evidence that attainment grouping benefits attainment. Attainment grouping illuminates existing social inequalities but also further exacerbates them. The limited evidence on mixed attainment grouping suggests it is more equitable and can improve both academic outcomes and self-confidence, and that lower attaining pupils do better when taught with higher attaining pupils (Francis, Taylor and Tereshchenko, 2020).

Other studies have looked more specifically at within-class grouping as an alternative to setting or streaming. An EEF study looking at primary maths that compared whole-class teaching and teaching in same- or mixed-attainment groups found no evidence of an association between whole-class attainment grouping and maths scores in Year 2, or that the frequency or using different approaches (whole-class or within-class same or mixed-attainment grouping) was associated with higher attainment in Year 5 or Year 9, or that it was associated with self-confidence levels. In other words, no approach demonstrated superiority to the others (Jerrim, 2021).

The EEF and Sutton Trust toolkit draws on this extensive body of research to conclude that setting is disadvantageous to lower achieving

students in most cases, and no clear advantage to higher attaining pupils (EEF, 2021b).
Given that there is no discernible evidence that any grouping approach benefits student achievement significantly, other criteria must be considered to understand why it is so frequently used (Slavin, 1990). A team from UCL recognised the under-developed support for good practice in student grouping and what effective pedagogy looks like. They start from the principle that every student from every social background and prior attainment level is entitled to equality of access to high quality pedagogy and curriculum. The document supports this by providing evidence-based guidance on dos and don'ts (Francis *et al.*, 2018).

Pupil premium

Whilst there have been suggestions relating to supporting pupils in receipt of pupil premium through, for example, marking their work first, there is no evidence that such strategies have any impact.

The EEF guidance for pupil premium strategies (EEF, 2021c) has 4 steps:

1. Diagnose pupils' needs.
2. Use strong evidence to support your strategy.
3. Implement.
4. Monitor and evaluate.

A tiered approach starts with high quality teaching, which may include investing in professional development to ensure an effective teacher in front of every class. This can be followed with targeted academic support, including use of teaching assistants and linking structured small group interventions to classroom teaching. Then wider strategies relating to non-academic challenges such as behaviour and attendance should be considered (EEF, 2021c).

Differentiation/scaffolding

Differentiation has become a problematic term in many ways, reflecting a tendency for it to become associated with strategies that involve producing multiple resources for each class to address pupil needs and perceived abilities. Teacher standard 5 refers to adaptive teaching, including knowing: 'when and how to differentiate appropriately – using approaches which enable pupils to be taught effectively' (DfE, 2013).

Bjork and Bjork talk about desirable difficulties as part of the learning process. These desirable difficulties are linked to encoding and retrieval processes. However, without the requisite background knowledge or skills to respond to these difficulties, they become 'undesirable'. The optimal level of difficulty therefore varies according to the prior learning of each individual student. The difficulty must present a challenge but not be too hard to overcome and therefore teaching needs to be 'adaptive' in the sense that it can be tailored to an individual's past achievement. It should be noted that motivation to embrace desirable difficulties is an important element in the long-term benefits available in the face of short-term consequences which typically involve error and poorer performance (Bjork and Bjork, 2020).

Students are less likely to employ effective learning strategies that involve desirable difficulties because they lack metacognitive knowledge and believe they are too effortful. The Study Smart programme explored this issue further, noting that whilst teachers often assumed students knew how to prepare for assessments, in fact they often employed ineffective techniques such as rereading notes rather than self-testing. It is important to challenge these misconceptions about learning strategies in order to improve performance. Deliberate teaching of desirably difficult learning strategies is important to support students. This involves a shift from knowledge transfer to learning strategy support even though it may result in uncertainty about students' knowledge level (Biwer *et al.*, 2020).

Using scaffolds provides students with support to access higher-level thinking strategies. This introduces students to cognitive strategies such as generating questions about their reading to improve comprehension (Rosenshine and Meister, 1992). As with Bjork and Bjork's work, the use of such scaffolding requires students to have a sufficient background ability and knowledge to

tackle new learning. Vygotsky describes this as the student's 'zone of proximal development'.[2]

Adaptive/responsive teaching

Adaptive teaching is about being able to respond to the individual needs of pupils, understanding that they learn at different rates and will require different levels and types of support at different times (DfE, 2019).

The terms adaptive or responsive teaching have largely replaced differentiation in the literature. This is in part due to the increasing connotation of differentiation with providing multiple different levels of work for different levels of prior attainment, resulting in increased workload for teachers whilst potentially limiting the achievement of students by restricting either the scope or depth of the curriculum.

Adaptive teaching is closely linked to assessment, particularly what is usually termed formative assessment or assessment for learning. Understanding where students are in their learning is essential for teachers to be able to respond and support in an appropriate manner (Fletcher-Wood, 2018).

An important facet of adaptive teaching is recognising that teaching must be based around what students know – that prior or existing knowledge is the single greatest factor influencing learning (Ausubel in Wiliam, 2018, p.122). Rather than there being a set of techniques to learn to be responsive, it is about using the evidence available to both identify the problem and effective was to address it (Fletcher-Wood, 2018).

[2] https://www.simplypsychology.org/Zone-of-Proximal-Development.html [accessed 10/12/2021]

Evidence-informed education

Since Ben Goldacre called for a greater use of evidence in education to improve outcomes for children and increase professional independence, there has been a significant shift in the sector. Research networks, conferences and organisations have had their work reinforced in policy with the release of new Initial Teacher Training (DfE, 2019b) and Early Career Teacher (DfE, 2019a) frameworks, and reform of the National Professional Qualifications[3] for leaders.

This approach is variously called evidence-based, research-based, evidence-informed, or other versions. The distinction maybe less important than the purpose and intention.

One study in 2017 found that for more teachers, being evidence-informed meant drawing on research evidence to integrate and trial in their own practice, rather than directly applying research findings. Use of research evidence was prompted by the need to solve a practical problem. There was a lack of confidence in engaging with research directly, though most valued external research. Observational impact or hearing from colleagues was needed to convince teachers, rather than the research evidence alone. Whilst it could challenge existing beliefs about practice, even in the most research-engaged schools, this only lead to sustained change in practice if time was allowed for informed debate and to see the impact in practice (Coldwell *et al.*, 2017)

Research is considered as a structured, rigorous programme of investigation. Evidence can be conceptualised as a broader approach that encompasses the findings from research but also a range of different types of data that may include school-level data and the outcomes of evaluation activity (Griffiths and Stefanini, 2020).

The evidence base is a shifting one that is not always straightforward to understand, and it takes time to implement change in classroom practice. The first challenge is to achieve clarity and purpose around what we mean by evidence-based, evidence-informed or research-led education. The second is to clearly articulate the benefits to teachers. The third is enabling leaders to build the capacity to integrate approaches into the wider school system (Griffiths and Stefanini, 2020).

Pedagogy

Robin Alexander draws a distinction between curriculum and pedagogy, not least in a comparative understanding. Where curriculum is the prominent educational discourse, this is in systems where it is contested. He sees pedagogy as the discourse we engage with in order both to teach and to make sense of teaching. Discourse and action are interdependent. In fact, he goes further in arguing that pedagogy 'relates the act of teaching to the ideas which inform and explain it' (Alexander, 2009, p. 4).

> *Pedagogy is the observable act of teaching together with its attendant discourse of educational theories, values, evidence and justifications. It is what one needs to know, and the skills one needs to command, in order to make and justify the many different kinds of decisions of which teaching is constituted.*
>
> (Alexander, 2009, p. 5)

Dylan Wiliam raises the uniqueness of teaching in comparison with other professions. He points out

[3] https://www.gov.uk/government/publications/national-professional-qualifications-frameworks-from-september-2021

the lack of teachers involved in academic research and therefore what is published is often at a distance from the students that are the focus. He suggests that 'classrooms are just too complicated for research ever to tell teachers what to do' (Wiliam, 2019). What he is seeking to emphasise is the importance of teachers being able to critically evaluate research to determine its relevance. He holds up the ideal of the teacher committed to self-improvement, with a growth mindset that encourages them to constantly seek for new means to reach those students that would otherwise give up.

Robin Alexander considered the lack of a national approach to pedagogy in Britain. In 1997 the strategies for literacy and numeracy were introduced, but he argues whilst offering practicality, they lacked evidential rigour and balance. Political influence over pedagogy compromises the coherence of discourse, countering the transformative possibilities of research with a culture of compliance (Alexander, 2008).

Debates on pedagogy are closely linked to different educational theories of learning, as well as to political policy influence. Student-led approaches are often associated with discovery learning theories such as Vygotsky, whilst more direct instructional pedagogies are linked to current cognitive science and cognitive load theories. These are the ones currently privileged in educational policy through the core Content (DfE, 2019b) and Early Career (DfE, 2019a) Frameworks, as well as the reformed National Professional Qualifications – the specialist NPQ Leading Teacher Development in particular (DfE, 2020b).

> *Pedagogy does not begin and end in the classroom ... [it] reflects the values of the wider society.*

(Alexander, 2009)

Educational theories

Whilst some elements of schools and education seem to have changed little in centuries, some of the fundamental ideas about the principles and theories of education remain greatly debated. There will be those teachers who claim never to have read a single thing on theory but will, nevertheless, reflect the inherent biases of their own experience of education, the way they were taught, and the context in which they have trained and taught. It is sometimes claimed that people can be 'natural teachers', but actually our instincts can be misleading, and it is important to challenge our biases.

ITT has changed significantly in recent years, reflecting changes introduced by the DfE and Ofsted, but many teachers and senior leaders trained under different conditions and when different ideas held sway. It can be helpful to be aware of how theoretical understanding has changed over time and the implications for classroom teaching.

Ultimately, teachers will combine different elements of different theories in ways that best suit their own teaching style and the context in which they teach. The debate between 'trad' and 'prog' that you may experience on twitter, suggests a dichotomy that doesn't necessarily exist in practice, where it is often wise to maintain an element of adaptability – what works in one place won't necessarily work in another. Other areas of apparent conflict (e.g. teacher talk vs student-led learning; edutainment; twenty-first-century skills) are often linked to the dominant trends in educational practice and the available research that has underpinned training.

A summary of key educational theories can be found here, along with a timeline.

What is learning?

Knowledge, memory, understanding and the skills to apply them, lie at the centre of debates around what constitutes learning. Politically charged debates around knowledge vs skills in the curriculum continue, though cognitive science is

giving greater weight to the focus on a knowledge-rich curriculum, where the importance of knowledge and memory in order to develop domain-specific skills is recognised.

The Ofsted definition focuses on 'an alteration in long-term memory' (Ofsted, 2019, p. 45), with reference to the rich processes of teaching that enable this transfer. They also reference the importance of connecting new knowledge to existing or prior knowledge and develop fluency and unconscious application of this knowledge as skills. They are explicit that this does not equate to rote learning of facts. The DfE, in the ITT and Early Career Frameworks and across the reformed NPQs, describes learning as involving 'a lasting change in pupils' capabilities or understanding' (DfE, 2019b) (DfE, 2019a). This emphasis on the long term is a welcome change for many who remember the need to show students making progress in 20 minutes of a lesson, but brings its own challenges in terms of measurement.

Willingham and others place 'thinking' at the heart of learning, both to ensure that we remember and retrieve the knowledge we learn, but also to enable us to apply that to new problems.

> *People are naturally curious, but we are not naturally good thinkers; unless the cognitive conditions are right, we will avoid thinking.*
> (Willingham, 2009)

Fiorella and Mayer argue that learning is a generative activity; learners actively seek to make sense of material – generative learning. They identify eight strategies that they argue have been shown to improve student learning: summarising, mapping, drawing, imagining, self-testing, self-explaining, teaching and enacting (Fiorella and Mayer, 2015). Some of these can be seen to align with instructional methods designed to support, for example, retrieval of prior knowledge and integrating new knowledge with existing.

Soderstrom and Bjork's definition encompasses a slightly wider definition than that of Ofsted. They draw attention to the importance of separating learning from performance, 'to create relatively permanent changes in comprehension, understanding, and skills of the types that will support long-term retention and transfer' (Soderstrom and Bjork, 2015).

Shimamura offers MARGE, a whole-brain learning approach based on five principles:

- motivate
- attend
- relate
- generate
- evaluate

Shimamura conceptualises learning as 'our ability to acquire knowledge from sensory experiences' (Shimamura, 2018, p. 1). He identifies perceptual learning (e.g. reading an x-ray), conceptual learning (e.g. a historian or scientist linking facts and ideas) and skill learning (e.g. a musician learning a new piece).

Learning in early years

The DfE Inspection Handbook for early years refers to 'what children know, remember and can do' (DfE, 2021b). The statutory framework references the EYFS standards and requirements for learning and development covering: the seven areas of learning and development, the early learning goals, assessment arrangements and safeguarding and welfare requirements (DfE, 2020c).

The three prime areas for building a foundation for curiosity and enthusiasm for learning, and forming relationships are:

- communication and language
- physical development
- personal, social and emotional development

And four specific areas:

- literacy
- mathematics
- understanding the world
- expressive arts and design

The three effective characteristics of teaching and learning in the early years are:

- playing and exploring
- active learning
- creating and thinking critically (DfE, 2020c)

Development Matters explores the learning of young children further, emphasising the individuality of the learning pathway of each child and the importance of accurate assessment, 'to make informed decisions about what a child needs to learn and be able to do next' (DfE, 2020a).

The domains of agency, literacy and numeracy are interdependent in young learners who will be better able to persist in maths and literacy as they develop stronger self-regulation abilities. Likewise, growing confidence in maths and literacy will strengthen their sense of agency (Deans for Impact, 2019).

Evolutionary education psychology

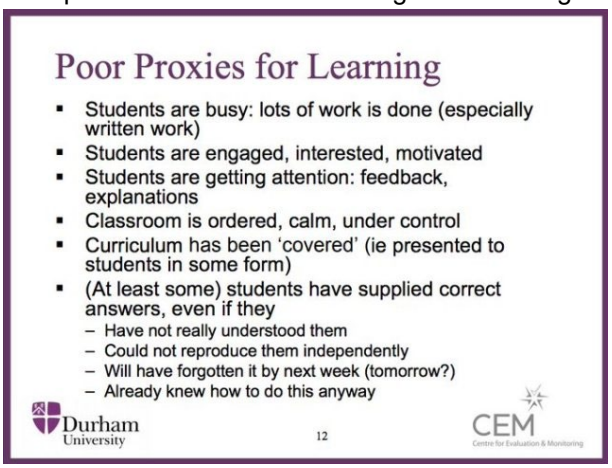
The aim of evolutionary education psychology is to build a theoretical framework for understanding the relationship between universal social and cognitive adaptations and academic learning. Of particular interest is the relationship between evolved social and cognitive biases and motivation and ability to learn in school. Geary makes a distinction between biologically primary knowledge that we have evolved to acquire, and biologically secondary knowledge that is culturally important (Geary, 2002).

Geary's theoretical framework and its distinction between biological primary and secondary knowledge has implications for our approaches to instruction and our understanding of learning. The rationale that we can learn without explicit instruction has been highly influential in terms of supporting discovery learning/constructivist approaches. However, the evidence points that when dealing with novices in a domain learners perform better when provided with worked examples rather than being asked to discover something for themselves. Geary's thesis supports the importance of explicit instruction and motivational encouragement when learning biologically secondary knowledge. This also has implications for cognitive load theory with 'problem solving' seeming only to apply to secondary knowledge. This understand can help to explain why learning at school, where we encounter primarily secondary knowledge that is culturally important to learn, can be difficult for many people (Sweller, 2008).

(Paas and Sweller, 2012) used Geary's theories of human cognitive architecture to amend cognitive load theory. They suggest that biologically primary knowledge, the acquisition of which has fewer demands on working memory, may be used to advantage to facilitate the learning of secondary knowledge.

Learning vs performance

A lot of the time that we think we are seeing learning, we are actually seeing performance. Assessing what students remember immediately after a lesson means we are likely seeing short-term performance rather than long-term learning.



(Coe, 2013)

What we can observe and measure during lessons is performance; an unreliable index of whether those long-term changes that equate to learning have taken place. Soderstrom and Bjork argue that the distinction between performance and learning is crucial because of evidence that considerable learning can occur without any performance gains, but also conversely, that performance gains can occur without lasting changes in learning. They also looked at research in metacognition that suggests that individuals often mistakenly interpret their performance as a

reliable guide to long-term learning (Soderstrom and Bjork, 2015).

Memory and understanding

Cognitive science relies on an understanding of memory that is predicated upon differences in long-term, short-term and working memory. However, there remains confusion about these types across the literature and ultimately the distinction between short-term memory and working memory depends at least in part on the definition accepted. They conclude that an attentional system used both for processing and for storage explains why some tests of short-term memory serve as the best correlates of cognitive aptitudes. This rests upon the belief that short-term memory demonstrates both temporal decay and chunk capacity limits and that some of these measures correlate with what we term working memory (Cowan, Brain and Author, 2008).

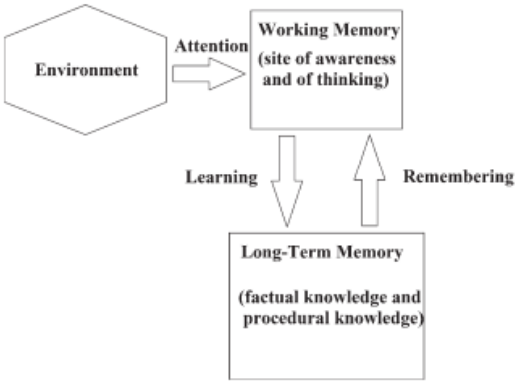
Gathercole and Alloway provide an introduction to working memory and the role it can play to support learning in school. They outline the limits to working memory and the importance of 'attention' to avoid loss of information as a result of: distraction, trying to hold too much information in mind, engaging in a demanding task. They point out that working memory capacity varies between individuals as well as increasing with age during childhood, reaching adult capacity in the teenage years at around double that of a 4-year-old child. Those with poor working memory capacity in childhood will see a capacity increase with age but at a lower rate, leading to a gap with others. One area where working memory is crucial is in following a set of instructions, particularly in complicated mental activity (Gathercole, E. S. and Alloway, 2007).

The causes of low working memory capacity are not well understood. They are not strongly related to factors relating to background, such as inadequacies in pre-school experiences or education, or to the quality of social or intellectual stimulation in the home. It is likely that genes play an important role. Children with poor working memory typically may seem not to have paid attention, frequently lose their place in tasks, make poor academic progress and seem easily distracted (Gathercole, E. S. and Alloway, 2007).

The principles of the **forgetting curve** as derived by Ebbing-Haus tell us that:

- You begin forgetting things you have learnt almost immediately.
- The rate of forgetting is high – often a matter of hours.
- Each time you practice recalling information, you reduce the rate and amount of forgetting.
- Retrieving something back into working memory slows the rate of forgetting – but the how and when of the retrieval is important.

What the forgetting curve cannot tell us is what the curve will look like for individual students, or for a specific taught topic. There are too many factors at play in the learning environment and individual context. It therefore remains an imperfect but useful tool to consider (Lemov, 2021).

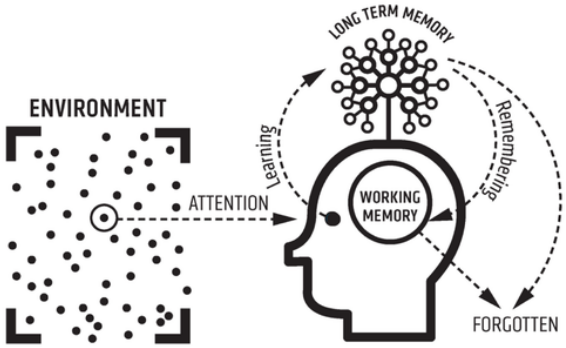


(Source: Willingham, 2017; diagram from 2009)

Schema and mental models

Schema are a theoretical construct that helps us to understand how we form and retrieve long-term memories. We organise ideas, knowledge and the things we learn, in patterns of connected information – called schema. Retrieving items in memory relies on environmental cues and prompts which provide connected information helping us to retrieve the relevant memories. Somewhat counter-intuitively, the more items in a schema and the greater the number of

connections, the easier it becomes to draw the information or entire schema into working memory. Fluency as a concept (for example in a language), is our ability to draw vast schemas into working memory effortlessly and automatically.



(Source: Oliver Caviglioli in Sherrington, 2020)

The understanding of schemas and how they relate to retrieval of specific episodes has been developed further through experiments. These show that memory for specific episodes was more precise when consistent with a learned schema. The benefit is greater when memories were weaker overall. However, whilst the schema become more influential in the retrieval of these memories, the schema themselves also decay over time. As memories decay, retrieval becomes increasingly reliant on schematic rather than episodic memory (Tompary, Zhou and Davachi, 2020).

Mental models can be seen as a form of schemata in which our minds learn from experiences to create models that can guide us in future decision making. As a result, expertise and experience can increase the number of models on which an individual can draw. Much of the process is automatic, seemingly instinctive, but an awareness of these models and how they underpin the analysis of our problems can be helpful. It enables us to be aware of gaps in our knowledge or experience or highlight bias in our decision making processes (Evans, no date).

Research on learning, memory and metacognition, suggests that people often have a faulty mental model of how they learn and remember things. Assessment of our own learning is affected by current performance but also subjective sense of fluency (Bjork, Dunlosky and Kornell, 2013).

Willingham talks of the mental model of the learner held by teachers. He therefore argues that teacher education should aim to make this mental model more accurate and internally consistent, in order to benefit students (Willingham, 2017).

Episodic and semantic learning

Episodic memory is our autobiographical memory, the stories of our life. We don't have to consciously remember these events, the memories happen automatically. Semantic memory requires effort, and this is the memory we need to use for consciously studying things we need to remember. Episodic memory is highly contextual, bounded with sensory experiences and emotions, and these are the things we remember most clearly. The problem is that we often remember the contextual tags of a lesson but not the actual learning. Once we have stored information in the semantic memory, it can be transferred to different contexts, in a more flexible way. The implication for teaching is that we should avoid the episodic lessons in favour of lessons that focus on what children will be thinking about in order to ensure they create the semantic memories intended and necessary for long-term learning (Sealy, 2019).

Memorisation

Willingham talks about memorising 'meaningless' material, commonly called rote memorisation. Memory tricks such as mnemonics can be a useful way of learning this sort of material that doesn't lend itself to the story structure. Common mnemonic methods include:

- peg words – using a rhyme, and associating new materials visually with the pegs
- method of loci – associating material by visualising it at a part of a familiar location or walk
- link method – visualising the items connected to each other in some way
- acronym – create an acronym of the words to be remembered and then remember the acronym

The acronym approach is more flexible because you can create a unique mnemonic for each thing

you need to learn. It does require some familiarity with the material. Setting material to music or rhythm can also work well (for example the alphabet). The different methods work primarily by providing cues to the information you need to remember, e.g. the first letter (Willingham, 2009).

Willingham goes on to argue that more common than rote knowledge is shallow knowledge. He conceptualises this as when a student has some understanding of the material, but this understanding is limited. If the knowledge is shallow, then this makes it harder for the student to connect this knowledge to new information (Willingham, 2009)

The hidden learner

Nuthall's work sought to reveal the intricacies of the learning processes that occurred during the lesson, often independent of the intentions and perceptions of those involved. He found that students needed to encounter new information three times in order for them to grasp it meaningfully, but rather than this providing a neatly defined approach, he emphasised the variety of experiences in the classroom and contradictions (Nuthall, 2007). Whatever the current debates about learning, he saw classroom teaching as structured by ritualised routines and widely held myths about learning and ability. These routines are necessary to enable the management of a class of 20–30 students simultaneously, but also explain why individual experience and learning remain largely invisible to teachers. To understand learning, the teacher needs to find ways to stand outside of these ritualised routines and myths (Nuthall, 2005).

Misconceptions

Feedback is part of correcting common misconceptions, but one study found that in order for corrective feedback to be effective it needs to be believed. In practical terms, this suggests that correction should be accompanied by a supporting explanation in order to achieve knowledge revision (Rich *et al.*, 2016).

Metcalfe and Miele also consider the correction of misconceptions and mistakes, particularly those held with high levels of confidence. Whilst it might be expected that these are the most difficult to correct, they suggest that the 'hypercorrection effect' actually means these are easier to correct than low confidence errors. Their study suggests that testing immediately after corrective feedback enhanced memory for the correct answers as well as blocking the return of the errors (Metcalfe and Miele, 2014).

Worked examples have been shown to support learning through developing understanding of the concepts that support correct problem solving, whilst recognising that cognition capacity is limited. Solving practice problems on their own may lead students to make guesses about which procedures are appropriate, leading to misconceptions. A study of using incorrect problem solutions, e.g. demonstrating a common mistake, can help students to identify and understand the error. Studying incorrect worked examples in algebraic equations has been shown to reduce student misconceptions about instructional content, leading to a greater conceptual understanding (Booth *et al.*, 2015).

The science of learning

Relying on intuition rather than science can lead us to choose the wrong learning strategies: we may feel confident in our approach but we risk seeking out supporting evidence (confirmation bias) and using strategies that feel good and are less effective than ones that feel hard and give us less confidence (Weinstein and Sumeracki, 2019).

Cognitive research has evaluated many easy-to-use learning techniques to consider their effectiveness for students. The findings show that some of the techniques frequently used by students, e.g. re-reading and highlighting, are of limited effectiveness in terms of improving performance (Dunlosky *et al.*, 2013).

Cognitive load is concerned with the relative demands of a task and the mental resources we have available to meet those demands. This has implications for instructional design. Different perspectives, however, lead to different emphasis particularly in the notion of separate short and long-term memory stores (Smith, 2021).

Embodied cognition

Embodied cognition is an example of how the use of biologically primary knowledge can be used in service of acquiring biologically secondary knowledge (Geary, 2002). Embodied cognition grounds cognitive processes in perception and action, rather than abstract symbols. Research demonstrates the use of visual and motor processes in cognitive tasks such as reading, comprehension and mental arithmetic. Gesture and object manipulation – biologically primary information – can reduce cognitive load for the acquisition of biologically secondary information (Paas and Sweller, 2012).

Proponents of embodied cognition emphasise the importance of the body as part of thinking, not just the mind. It is linked closely to situated and distributed cognition, but covers a large range of areas. One of the key elements of embodied cognition in the classroom is exploring how movement can help us to learn concepts. However, results of research are difficult to replicate, so should be viewed with caution (InnerDrive, 2022).

Situated cognition

Situated cognition has been described as learning by doing, but more specifically it is about learning that takes place within socially organised practices, developing specialised skills. In a classroom context, this is best articulated as learning disciplinary approaches, e.g. the nature of scientific experiments, or literary analysis. This enables students to participate in communities of practice. Context therefore becomes an important component of the learning process.[4]

Distributed cognition

Kirschner first described the collective working memory effect, suggesting that collaborative learners can be considered as a single information processing system. They can share knowledge through communication and coordination to divide the cognitive load, albeit with a transactional cost from additional cognitive effort to support this collaboration (Sweller, Van Merriënboer and Paas, 2019).

Cognitive Load Theory

> *I've come to the conclusion that Sweller's Cognitive Load Theory is the single most important thing for teachers to know.*
>
> (Dylan Wiliam[5])

Cognitive Load Theory (CLT) is based on the principle that working memory capacity is limited. Research has identified and demonstrated a

[4] https://www.sciencedirect.com/topics/neuroscience/situated-cognition [02/08/2021]

[5] https://twitter.com/dylanwiliam/status/824682504602943489

number of different elements that contribute to cognitive load and can interfere with learning by overwhelming working memory.

Three categories of cognitive load are considered: intrinsic, extraneous and germane:
Intrinsic – the complexity of information being processed (determining the complexity of information is difficult as it depends on both the information itself and the knowledge of the person processing that information).
Extraneous – relates to how the information is presented and what the learner is required to do as a result of the instructional process and can therefore be changed in order to change the instructional effect.
Germane – refers to the cognitive load required to learn, i.e. the working memory resources devoted to dealing with the intrinsic cognitive load rather than extraneous. Therefore, the more resources that must be devoted to dealing with extraneous cognitive load, the less will be available to deal with intrinsic cognitive load with the effect that less will be learned (Sweller, Van Merriënboer and Paas, 2019).

The **goal-free effect**, eliminating the means–end approach to problem solving, enables greater learning by freeing up working memory resources, e.g. instead of 'find angle x', 'find the values of as many angles as you can' (Sweller, 2016) (Sweller, Van Merriënboer and Paas, 2019).

The **worked examples effect**, learners who study worked examples perform better than learners who solve the same problem themselves, also derives from the reasoning that learning is weakened by conventional problem solving because it isn't based on transferring knowledge to long-term memory, but on reaching a problem goal (ibid.).

The **split-attention effect** also affects the level of working memory load, for example when students have to mentally integrate information from different sources, such as a diagram (ibid.).

The **modality effect**, using both auditory and visual channels for input, increases working memory capacity. However, auditory material is transient, with new information replacing old whereas written information is permanent. The modality effect can be reversed by the transient information effect (ibid.).

The **redundancy effect** is where unnecessary information can overload working memory, e.g. providing pictures to beginning readers can interfere with learning to read. Providing unnecessary information can be a major reason for instructional failure (ibid.).

Intrinsic cognitive load arises from the **element interactivity effect** – the composition of a task and the working memory resources it requires. CLT therefore applies to complex material that is difficult to understand (ibid.).

Collective working memory, recognises that learners with different knowledge bases can collaborate, essentially pooling their working memories (ibid.). See also distributed cognition (above).

The **expertise reversal effect** relies on an understanding of how novices and experts relate to information and whether or not the element interactivity is low or high as a result. For example, studying worked examples is better for novices, whereas problem-solving mechanisms work for experts as they require fewer memory resources (ibid.).

Transfer of learning

Successful transfer can be considered the ability to apply learning in a new situation. Critically, this is more than simple recall of information, and involves using that knowledge in new and different ways. A minor change in context is 'near transfer', e.g. using Pythagorean calculations in a new problem. Where the change in context is greater, this is 'far transfer' – this may relate to a very different context, or could happen at a later date, e.g. using something from school in everyday life (Agarwal and Pan, 2018).

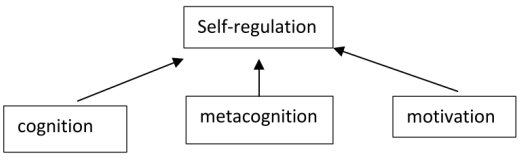
It has long been an urban myth that we can transfer the knowledge and skills learned in one domain to another context, e.g. learn Latin to improve your ability to learn other languages, or

learn music so that you can improve in maths. This is known as transfer of learning. Whilst near transfer is helpful across situations that are relatively similar, such as driving a car or bus – the examples above (such as learning languages) are often considered to be 'far transfer'. Essentially, transferring skills or knowledge across different domains can be very difficult. A point of contention is the assumption that learning a particular skill can influence the development of personality traits such as creativity. However, such traits cannot be taught and many positive effects are temporary. Where we see a positive correlation between a skill in one area and performance in another, we are usually seeing the result of elements related to personality and background. There is also the risk of devaluing the intrinsic value of the original study by seeking to link it to the development of other knowledge or skills (De Bruyckere, Kirschner and Hulshof, 2020).

Metacognition and self-regulation

Self-regulated learning has three essential components: cognition (the mental process of knowing and understanding), metacognition (learning to learn); and motivation (willingness to engage these two skills). It requires an understanding of your own strengths and weaknesses. Metacognition is about thinking more explicitly about your own learning, and knowing which specific strategies might be appropriate for a given task. It is linked to being a self-regulated (or independent) learner with the ability to select appropriate strategies for planning, monitoring and evaluating your own learning. Recent studies see metacognition as a part of self-regulation (Muijs and Bokhove, 2020).

Figure 1. Components of self-regulated learning



(Source: Components of self-regulated learning, Muijs and Bokhove, 2020, p.5)

There is widespread assumption that metacognition and self-regulated learning are important to learning and raising attainment, however they are quite context-dependent. Students who demonstrate strong metacognitive or self-regulation in one task or domain, may be weak in another. Strong foundational subject knowledge is important for strong self-regulation and metacognition. It is also a social rather than purely individual and internal process so modelling by adults is important (Muijs and Bokhove, 2020).

Metacognitive knowledge is what a learner knows about the way they learn. It can be seen as having three subcomponents:

- declarative knowledge – about oneself as a learner and the factors that influence performance
- procedural knowledge – strategies and procedures such as organisation elaboration strategies
- conditional knowledge – why and when to use a particular strategy. (Muijs and Bokhove, 2020)

Metacognitive skills relate to the ability to apply metacognitive knowledge, for example for students to evaluate their progress in a cognitive task. (Muijs and Bokhove, 2020) make the important point that metacognitive knowledge can be wrong (e.g., we underestimate the time we need to memorise something) and metacognitive skills we use can be suboptimal in terms of efficiency or effectiveness (e.g., highlighting or re-reading text for revision).

Effective metacognitive strategies in the classroom include getting learners to think about their own learning more explicitly, by setting goals, and then monitoring and evaluating their progress against those goals. The EEF summary identifies seven recommendations:

1. Teachers should acquire the professional understanding and skills to develop their pupils' metacognitive knowledge.
2. Explicitly teach pupils metacognitive strategies, including how to plan, monitor and evaluate their learning.
3. Model your own thinking to help pupils develop their metacognitive and cognitive skills.

4. Set an appropriate level of challenge to develop pupils' self-regulation and metacognition.
5. Promote and develop metacognitive talk in the classroom.
6. Explicitly teach pupils how to organise and effectively manage their learning independently.
7. Schools should support teachers to develop knowledge of these approaches and expect them to be applied appropriately.

(Quigley, Muijs and Stringer, 2018)

Studies indicate that Theory of Mind (ToM), the pre-cursor to metacognition, can develop as early as 3 years old. In at least one study, the extent of development of ToM at 3 has been to be a predictor of reading comprehension at age 6, though further studies have not all shown similar effects. Co-regulation is an important part of early metacognitive development, where children develop their self-regulation by sharing practices and thinking with a parent or other more knowledgeable person (Muijs and Bokhove, 2020).

In the early years self-regulation focuses particularly on the ability to improve self-control and reduce impulsivity. The development of self-regulation and executive function is consistently linked with successful learning. Children from disadvantaged backgrounds may be more likely to start school with weaker self-regulation skills than their peers and therefore especially benefit from self-regulation strategies. However, the evidence is currently limited, particularly in relation to specific programmes or curricula; the evidence is strongest in terms of behavioural outcomes (EEF, 2021a).

Metacognition is important because as learners we tend not to know how best to assess and manage our own learning (cf Dunlosky, 2013), instead it is something we need to be taught. To become truly effective as a learner, according to (Bjork, Dunlosky and Kornell, 2013), entails:

1. understanding how humans learn and the nature of memory
2. knowing storage and retrieval activities and techniques
3. learning how to monitor and evaluate one's own learning
4. understanding certain biases that impair judgement of whether learning for future recall has been achieved.

Motivation

Motivation is an important element in learning. Motivation leads to greater attention and greater effort, persistence and more independent working. When motivation is lacking, students are distracted more easily, require constant monitoring to stay on task, and retain less of what they learn. Motivation matters, however it is not yet clear how to achieve greater levels of motivation in the classroom. Like learning, motivation is complex and largely invisible. Its connection with engagement, the notion that the more engaging a lesson, the more motivated a student is to perform, is problematic.

According to Ryan and Deci, intrinsic (self-driven) motivation is better than extrinsic motivation, i.e. response to reward. However, they also argue that the distinction is crude and often motivation is a mix of intrinsic and extrinsic factors (Ryan and Deci, 2000). Discovery learning has long been seen as an important element in generating motivation through curiosity. Other approaches include greater uses of ICT and other technology. However, studies suggest that even where engagement was higher with this discovery approach, this did not equate to greater learning. In fact, 'boring' lessons proved more effective (Kirschner and Neelen, 2016).

There continues to be debate about the role of success in motivation. Some studies suggest that success leads to motivation, rather than motivation leading to success (Kirschner and Neelen, 2016). Muijs and Bokhove link delayed gratification to the effective use of cognitive and metacognitive strategies. Self-efficacy, the belief in our own ability to affect our learning, is also important. As a result, motivation may need to be regulated with strategies developed to sustain or raise it where at risk (Muijs and Bokhove, 2020).

Engagement

Teachers need to design lessons that ensure students are thinking about the meaning of the content they are studying. Trying to make the subject matter ‘relevant’ to the students’ interests doesn’t work as it can become artificial and lead to attention being diverted away from the intended content. Willingham argues that it’s about style rather than content, how the teacher interacts with students and makes ‘boring material’ interesting and gets the students to think about meaning. In fact, he argues that effective teachers have two things in common: they are able to connect personally with students (in their own style), and they organise the material in a way that makes it interesting and easy to understand (Willingham, 2009).

Teaching and learning

The EEF has also produced a toolkit, exploring the evidence base around different teaching strategies and interventions. It indicates both the strength of the evidence, the cost and the potential impact in terms of learning (EEF, 2018a).

Explicit instruction

At different points in time, varying educational theories have held sway in teacher training. For a long time social constructivist thinking dominated, propounding the belief that students learned better when they discovered information for themselves. However, work done by Professor Coe among others, has demonstrated the ineffectiveness of such 'discovery' learning approaches (Coe *et al.*, 2014). Further, research supports the view that direct or explicit instruction leads to greater learning (Kirschner, Sweller and Clark, 2006).

There is tension between many early years practitioners and proponents of direct instruction, seeing it as contradictory to play-based learning approaches. One resolution to this conflict is to consider Geary's differentiation between biological and secondary learning, with the former best discovered by a child (e.g. walking and speaking), but the latter needing instruction (Geary, 2007).

A key article by Kirschner, Sweller and Clark outlined their belief in the importance of explicit instruction in opposition to constructivist, inquiry-based teaching. They emphasise the need for students to have sufficiently high prior knowledge to enable self or internal guidance, so in most instances guided instruction is more effective and more efficient (Kirschner, Sweller and Clark, 2006).

Engelmann's programme of Direct Instruction sits at one extreme of this approach, consisting of scripts, focused resources and teaching sequences planned in detail. But it seems clear that the overwhelming weight of evidence now supports guided instruction where the teacher directs the learning process – often called explicit or direct instruction (Boxer, 2019).

> *The aim of all instruction is to alter long-term memory. If nothing has changed in long-term memory, nothing has been learned. (Kirschner, Sweller and Clark, 2021, p.77)*

Teaching and learning strategies

Dunlosky *et al*. looked carefully at a number of traditional teaching and learning strategies and explored their effectiveness for achieving student outcomes. The findings were instrumental in questioning some habitual practices, and identifying which ones actually worked – often counter-intuitively.

Table 1 Effectiveness of Techniques Reviewed

Technique	Extent and Conditions of Effectiveness
Practice testing	Very effective under a wide array of situations
Distributed practice	Very effective under a wide array of situations
Interleaved practice	Promising for math and concept learning, but needs more research
Elaborative interrogation	Promising, but needs more research
Self-explanation	Promising, but needs more research
Rereading	Distributed rereading can be helpful, but time could be better spent using another strategy
Highlighting and underlining	Not particularly helpful, but can be used as a first step toward further study
Summarization	Helpful only with training on how to summarize
Keyword mnemonic	Somewhat helpful for learning languages, but benefits are short-lived
Imagery for text	Benefits limited to imagery-friendly text, and needs more research

(Source: Dunlosky *et al*., 2013, p. 20)

Further research has identified six key strategies for effective learning which have decades of support from cognitive psychology (Weinstein and Sumeracki, 2019):

1. spaced practice
2. retrieval practice
3. elaboration
4. interleaving
5. concrete examples
6. dual coding

Additional variations on these strategies are included for illustration purposes below.

Spaced practice

Rather than cramming before a test, spaced or distributed practice involves spreading retrieval activities over a longer period of time before an exam or test. This enables multiple opportunities to revisit material and aids long-term learning (Weinstein and Sumeracki, 2019).

The research dates back to the 1800s and the German researcher Ebbinghaus who counted the number of attempts it took him to recite a list of nonsense syllables perfectly and developed what is known as the 'forgetting curve'. Spaced practice has been investigated in many different subjects and learning contexts. Its effectiveness may be in part due to 'storage strength', a measure of deep learning, rather than our current ability to produce information, 'retrieval strength'. Forgetting a little before we restudy enables us to boost the storage strength of the information when we encounter it again (Yan, 2016).

Cepeda *et al*. sought to expand existing research into the efficient spacing of retrieval practice to uncover more about the optimal gap where test delay was up to one year. They found that initially the interstudy gap increased with the test delay, but then gradually reduced. So as a proportion of test delay, the optimal gap declined from about 20–40% of a one-week test delay, to about 5–10% of a one-year test delay. The main conclusion for practical application in the classroom is that the optimal gap between study sessions is not an absolute quantity but depends a great deal on how long you wish to remember something (Cepeda *et al.*, 2008).

If a person wishes to retain information for several years, a delayed review of at least several months seems likely to produce a highly favorable return on the time investment.
(Cepeda et al., 2008, p.1101)

Retrieval practice

Bringing information to mind from memory is a more effective technique for promoting long-term learning than more traditional approaches to study such as re-reading materials (Roediger and Karpicke, 2006). When we retrieve information from our memory we actually change the memory, often making it more durable and flexible for future use (Smith, Roediger and Karpicke, 2013).

Frequent low- or no-stakes quizzing is a good way to practise retrieval practice without increasing stress which can damage performance (Weinstein and Sumeracki, 2019). This is often referred to as the testing effect. This informs Dunlosky's work which challenges traditional approaches to studying involving re-reading or highlighting texts in favour of practise testing.

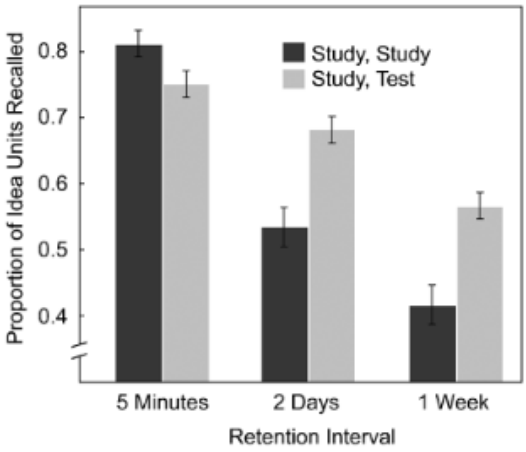


Fig. 1. Mean proportion of idea units recalled on the final test after a 5-min, 2-day, or 1-week retention interval as a function of learning condition (additional studying vs. initial testing) in Experiment 1. Error bars represent standard errors of the means.

(Source: Roediger and Karpicke, 2006, p.250)

Feedback is not always necessary for retrieval practice to have a direct impact on learning, but it can make it even more effective. Research on the optimal timing of feedback is mixed with some suggesting that delaying is most beneficial, and others that instant is best (Weinstein and Sumeracki, 2019).

Interleaving

Switching between ideas or types of problems can support spaced retrieval, or retrieval practice. Interleaving promotes better discrimination between ideas and procedures (Rohrer, Agarwal and Dedrick, 2017). A student might switch

between ideas during a study session, not studying one thing for too long. They should revisit topics in a different order in order to strengthen understanding, and make links between different ideas as they switch between them (Weinstein and Sumeracki, 2019).

The efficacy of this approach has been explored particularly in mathematics teaching with students performing better on a *later* test after interleaved practice, despite better performance on the blocked task *during* learning (Rohrer, Agarwal and Dedrick, 2017).

Whilst there have been some striking results with interleaving, there remains a lot unknown about what type of material should be interleaved or what level of similarity helps rather than hinders attention. As a result, the recommendation is to focus on spaced practice and mixing up some of the ideas of types of problems (Weinstein and Sumeracki, 2019).

Spacing and interleaving can lead to slower initial learning, but more durable retention, which is why they are often used together. Research on interleaving suggests that it leads to enhanced performance on delayed tests in comparison with blocked practice. By interleaving problem types, students learn to practice the skills of discriminating between different problem types, an opportunity not offered by block practice. Again, this is has primarily been tested in mathematics and it remains unclear whether or not the same benefits would be found from mixing topics in subjects such as biology or history (Roediger III and Pyc, 2012).

Elaboration

Elaboration encourages organising and connecting ideas which makes it easier to remember the new information later on. Three specific techniques show promise in improving student learning and understanding: elaborative interrogation, concrete examples and dual coding (Weinstein and Sumeracki, 2019).

Elaborative interrogation is about asking yourself how and why and then producing the answers to those questions. The elaboration comes from making connections between old and new knowledge, making the memories easier to retrieve at a later date. This strategy works both for individuals and groups and works better with high background knowledge (Weinstein and Sumeracki, 2019). Self-explanation is a similar approach, as is the prepare-to-teach method where expecting to have to teach the material being studied actually produces greater learning gains (Nestojko *et al.*, 2014).

Roediger and Pyc see elaborative interrogation and self-explanation as related techniques. The former involves generating plausible explanations to statements – explaining why. Self-explanation involves students self-monitoring learning by describing some features such as what facts they already know whilst reading. Both techniques rely on the student being involved in active learning. One study suggested that self-explanation can help provide the kind of deep learning that supports far transfer of knowledge to different types of problems than those originally studied (Roediger III and Pyc, 2012).

Concrete examples

Concrete examples help students to grasp abstract ideas. The challenge is ensuring students grasp the underlying idea rather than simply remembering the concrete example. Novices are more likely to remember surface features, whilst experts can extract underlying structures from problems (Weinstein and Sumeracki, 2019).

> *We understand new things in the context of things we already know, and most of what we know is concrete. (Willingham, 2009, p.67)*

Andy Tharby outlines what he believes makes a good example:

- It should connect to what a student already knows.
- It should be as simple as possible.
- It should appeal to the senses.
- It should be easy to transfer to new contexts.
- It should be memorable.
- It should come in multiples.

- It should aim to provoke an emotional response (Tharby, 2018, p.81).

The other important strategy Tharby identifies, referencing the work of Wragg and Brown (1993), is the importance of non-examples. These help to illustrate the criteria for inclusion in a concept by demonstrating where the criteria are not met. They can prevent overgeneralisation and encourage discrimination between similar concepts (Tharby, 2018).

Worked examples

Worked examples in instruction provide a problem solution from an expert that a learner can study. Research suggests that multiple examples for each conceptual problem type should be presented in close proximity to matched practice problems. Learning from worked examples may be particularly useful in the initial stages of cognitive skills acquisition, with problem-solving approaches becoming more useful when learners become more expert as a result of practice (Renkl and Atkinson, 2003). Self-explanations are an important learning activity during the study of worked examples; these can be fostered by instructional methods (Atkinson *et al.*, 2000).

Renkl and Atkinson further develop the instructional use of worked examples by proposing a fading procedure. This involves gradually integrating problem-solving elements into examples until learners are able to solve problems independently (Renkl and Atkinson, 2003).

Experimental studies into instructional explanation to support example-based learning suggest three conclusions: first, there are minimal benefits of instructional explanations for example-based learning; second that such instructional explanations are more helpful in acquiring conceptual knowledge rather than procedural; third that instructional explanations are not necessarily more effective than other methods such as self-explaining (Wittwer and Renkl, 2010).

Stories

Daniel Willingham refers to the idea of stories as 'psychologically privileged', meaning they are treated differently in memory to other content. He suggests that organising a lesson plan like a story can be an effective way to help students remember and understand. One such story structure follows four principles:

- causality – events as causally related to each other (the why they are connected)
- conflict – a main character pursuing a goal they can't reach and therefore must struggle
- complications – subproblems arising from the original gaol
- character – strong interesting characters with action as the key to those qualities

He notes that too much information makes a story less interesting. Your memory for stories comes because you think about them, through inference or to understand the meaning. Whilst stories can be useful, he actually suggests that you use this structure to organise your lesson plan – as a story (Willingham, 2009).

Andy Tharby also discusses storytelling, linking it to the evolutionary history of human communication as discussed in Harari's *Sapiens* (2014). Stories in the classroom can help enhance learning because they are interesting, easy to understand and easy to remember (Tharby, 2018).

Dual coding

Combining words and visuals can give students two ways to help them retrieve information later (Weinstein and Sumeracki, 2019). Combining too many words and visuals can create cognitive overload (Moreno and Mayer, 2000). This dual-coding theory suggests that the same information presented properly in two different ways will enable you to access more working memory capacity – double-barrelled learning (Kirschner and Neelen, 2017).

According to Clark and Lyons (2004), cognitive scientists working on the benefits of dual coding, there are six significant benefits to students' learning:

- direct attention
- manage cognitive load
- transfer to working memory
- trigger prior knowledge
- build schema
- motivate

(Caviglioli, 2019, p. 13)

An example of dual coding is the adding of images or pictures to text for education, particularly for younger children with less well-developed reading skills. At least one study suggests that overall pictures enhance learning, but that the text should be spoken rather than written. Reading by themselves and looking at pictures can overload children's cognitive capacities (Herrlinger *et al.*, 2017).

Deliberate practice

Ericsson *et al*. distinguished deliberate practice from work (services rendered for pay) and play (activities with no explicit goal and inherently enjoyable), as activities specifically designed to improve performance. Their study suggested that performance differences could be largely accounted for by different amounts of practice, whilst also recognising the possibility that genes may contribute towards people's willingness to engage in deliberate practice over the prolonged time necessary to achieve expertise (Ericsson, Krampe and Tesch-Römer, 1993).

Other researchers are more sceptical and dispute the claims of Ericsson *et al*., arguing that other factors, including 'talent', must be considered (Ackerman, 2014).

In one review of deliberate practice, looking at findings relating to chess and music, the conclusion was that deliberate practice is not as important in explaining individual differences in performance as Ericsson claimed. Concerns can be raised in relation to both the measurement of correlating factors, and the reliability of retrospective estimates of practice. However, the study did indicate that deliberate practice does explain a considerable amount of variance in performance in the domains studied (Hambrick *et al.*, 2014).

The attraction of deliberate practice as accounting for inter-individual variability in performance is likely connected to the appeal of meritocratic views of ability, the sense that we can all achieve if we work hard. These claims have been questioned, but there is evidence that deliberate practice contributes to intra-individual variability in performance – an individual's improvement within a specific domain. This recognises the importance of training to acquire skills, but also that this process of learning will happen at different rates. In other words, 'deliberate practice is an important piece of the expertise puzzle, but not the only piece' (Macnamara *et al.*, 2018).

Mastery learning

Traditional teaching maintains a constant time on each topic and allows the level of pupils' mastery of each topic to vary. Mastery learning aims for the learning outcomes to be constant by varying the amount of time needed to acquire the proficiency necessary. Learners are expected to demonstrate a high level of success on assessment of each step before progressing to the next. On average, meta-analyses suggest that mastery learning approaches are effective, though there is variation. It appears to be most effective when pupils work in groups and take responsibility for supporting each other's progress, but also when a high bar is set for achievement. It seems to be less effective when pupils work at their own pace. It also seems more effective when used as an occasional or additional teaching strategy, rather than for all sessions (EEF, 2018b).

A study carried out with university students suggests that a mastery approach to assessment, emphasising the educational function or improving learning, rather than the selection function which compares performance, can result in students from a more disadvantaged background performing as well as those from non-disadvantaged backgrounds (Smeding *et al.*, 2013).

Myths and misconceptions

Despite experiments repeatedly demonstrating that there is no learning benefit in matching the form of instruction to a student's preferred learning style, many educators still believe it is important. A simple reason might be that they are unaware of the research evidence. However, many still refused to change their minds even when informed directly that it was a learning 'myth'. Cultural cognition can describe how we interpret facts and evidence through the lens of our existing values. Challenges to beliefs can be perceived as threatening teacher autonomy in the classroom. Fundamentally, we need to change people's mental models in order to change their beliefs (Pershan and Riley, 2017).

In *What Does this Look Like in the Classroom?* David Didau and Pedro de Bruyckere explore some of the persistent myths in education. They start with Bloom's Taxonomy, which was not based on empirical evidence, and emphasise the importance of understanding the importance of foundational knowledge to make higher order thinking possible. The familiar triangle does not appear in Bloom's work and is inappropriate. They also tackle Howard Gardner's theory of multiple intelligences – one which he himself admitted was no longer current in 2016. No experiments were carried out to test his theory. Arguably it is not so much a myth as a misuse of the word intelligences rather than simply recognising that people have differences that might be described as talents (Hendrick and Macpherson, 2017).

Christodoulou's book discusses seven myths of education:

1. Facts prevent understanding.
2. Teacher-led instruction is passive.
3. The 21st century fundamentally changes everything.
4. You can always just look it up.
5. We should teach transferable skills.
6. Projects and activities are the best way to learn.
7. Teaching knowledge is indoctrination (Christodoulou, 2014).

References

Ackerman, P. L. (2014) 'Nonsense, Common Sense, and Science of Expert Performance: Talent and Individual Differences', *Intelligence*. JAI, 45(1), pp. 6–17. doi: 10.1016/J.INTELL.2013.04.009.

Agarwal, P. K. and Pan, S. C. (2018) *Retrieval Practice and Transfer of Learning*. Available at: http://pdf.retrievalpractice.org/TransferGuide.pdf.

Alexander, R. (2008) *Essays on Pedagogy*. Abingdon: Routledge. Available at: https://www.google.co.uk/books/edition/Essays_on_Pedagogy/8dS3AAAAQBAJ?hl=en&gbpv=1&dq=robin+alexander&printsec=frontcover.

Alexander, R. (2009) 'Towards a Comparative Pedagogy', in Cowen, R. and Kazamias, A. M. (eds) *International Handbook of Comparative Education*. Springer, pp. 923–942. Available at: http://robinalexander.org.uk/wp-content/uploads/2019/12/IHCE-chapter-59-Alexander.pdf (Accessed: 7 December 2021).

ASK Research (2017) *SEN Support: Research Evidence on Effective Approaches and Examples of Current Practice in Good and Outstanding Schools and Colleges*. Available at: https://www.sendgateway.org.uk/download.sen-support-research-evidence-on-effective-approaches-and-examples-of-current-practice-in-good-and-outstanding-schools-and-colleges.html.

Atkinson, R. K. *et al.* (2000) 'Learning from Examples: Instructional Principles from the Worked Examples Research', *Review of Educational Research*, 70(2), 181–214. doi: 10.3102/00346543070002181.

Baars, S., Mulcahy, E. and Bernardes, E. (2016) *The underrepresentation of white working class boys in higher education The role of widening participation*, *Kings College London*. Available at: https://cfey.org/wp-content/uploads/2016/07/The-underrepresentation-of-white-working-class-boys-in-higher-education-baars-et-al-2016.pdf.

ten Berge, T. and Van Hezewijk, R. (1999) 'Procedural and Declarative Knowledge', *Theory and Psychology*, 9(5), 605–624. Available at: https://core.ac.uk/download/pdf/55534264.pdf (Accessed: 2 August 2021).

Biwer, F. *et al.* (2020) 'Future Steps in Teaching Desirably Difficult Learning Strategies: Reflections from the Study Smart Program', *Journal of Applied Research in Memory and Cognition*, 9(4), 439–446. doi: 10.1016/J.JARMAC.2020.07.006.

Bjork, R. A. and Bjork, E. L. (2020) 'Desirable Difficulties in Theory and Practice', *Journal of Applied Research in Memory and Cognition*, 9(4), 475–479. Available at: https://bjorklab.psych.ucla.edu/wp-content/uploads/sites/13/2021/01/RABjorkELBjorkJARMAC2020ForPostingSingleSpaced.pdf (Accessed: 21 January 2021).

Bjork, R. A., Dunlosky, J. and Kornell, N. (2013) 'Self-regulated Learning: Beliefs, Techniques, and Illusions', *Annual Review of Psychology*, 64(1), 417–444. doi: 10.1146/annurev-psych-113011-143823.

Boaler, J. (2013) 'Ability and Mathematics: the mindset revolution that is reshaping education', *FORUM*, 55(1). Available at: http://www.youcubed.org/wp-content/uploads/14_Boaler_FORUM_55_1_web.pdf (Accessed: 2 August 2022).

Booth, J. L. *et al.* (2015) 'Worked Examples 1 Simple Practice doesn't Always Make Perfect: Evidence from the Worked Example Effect', *Policy Insights from the Behavioral and Brain Sciences*, 2(1), 24–32. Available at: https://files.eric.ed.gov/fulltext/ED566953.pdf.

Boxer, A. (2019) 'Explicit and Direct Instruction – Introduction', in Boxer, A. and Bennett, T. (eds) *Explicit and Direct Instruction*. Woodbridge: John Catt.

De Bruyckere, P., Kirschner, P. A. and Hulshof, C. (2020) 'If You Learn A, Will You Be Better Able to Learn B?', *American Educator*, Spring. Available at: https://www.aft.org/ae/spring2020/debruyckere_kirschner_hulshof (Accessed: 11 September 2020).

Burgess, S. and Greaves, E. (2009) *Test Scores, Subjective Assessment, and Stereotyping of Ethnic Minorities*. Centre for Market and Public Organisation. doi: 10.1086/669340.

Carroll, J. *et al.* (2017) *SEN Support: A Rapid Evidence Assessment*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/628630/DfE_SEN_Support_REA_Report.pdf (Accessed: 20 November 2019).

Caviglioli, O. (2019) *Dual Coding for Teachers*. John Catt.

Cepeda, N. J. *et al.* (2008) 'Spacing Effects in Learning: A Temporal Ridgeline of Optimal Retention', *Psychological Science*, 19(11), 1095–1102. doi: 10.1111/j.1467-9280.2008.02209.x.

Christodoulou, D. (2014) *Seven Myths about Education*. Routledge.

Coe, R. (2013) *Improving Education: A Triumph of Hope over Experience.* Inaugural lecture of professor. Available at: http://www.cem.org/attachments/publications/ImprovingEducation2013.pdf (Accessed: 6 December 2019).

Coe, R. *et al.* (2014) *What Makes Great Teaching? Review of the Underpinning Research*, Project Report, Sutton Trust, London. Available at: http://www.suttontrust.com/researcharchive/great-teaching/.

Coe, R. *et al.* (2020) *Evidence Review Great Teaching Toolkit*. Available at: https://assets.website-files.com/5ee28729f7b4a5fa99bef2b3/5ee9f507021911ae35ac6c4d_EBE_GTT_EVIDENCE REVIEW_DIGITAL.pdf (Accessed: 19 June 2020).

Coldwell, M. *et al.* (2017) *Evidence-informed teaching: an evaluation of progress in England*. Available at: https://www.mendeley.com/reference-manager/reader/086fe652-88d0-3aaf-9e3d-6d47f08b297d/2031b2c6-aca9-715f-704d-9ebb72ebfac1 (Accessed: 28 October 2019).

Commission on Race and Ethnic Disparities (2021) *Education and Training*. Available at: https://www.gov.uk/government/publications/the-report-of-the-commission-on-race-and-ethnic-disparities/education-and-training (Accessed: 8 December 2021).

Cowan, N., Brain, P. and Author, R. (2008) 'What are the Differences between Long-term, Short-term and Working Memory?', *Prog Brain Res*, 169, 323–338. doi: 10.1016/S0079-6123(07)00020-9.

Deans for Impact (2019) *The Science of Early Learning: How Young Children Develop Agency, Numeracy, and Literacy*. Austin, Texas. Available at: https://deansforimpact.org/wp-content/uploads/2017/01/The_Science_of_Early_Learning.pdf (Accessed: 2 February 2021).

DfE (2013) *Teachers' Standards*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/665520/Teachers__Standards.pdf (Accessed: 20 December 2019).

DfE (2019a) *Early Career Framework*. Available at: https://www.gov.uk/government/publications/supporting-early-career-teachers.

DfE (2019b) *ITT Core Content Framework*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/919166/ITT_core_content_framework_.pdf (Accessed: 4 November 2019).

DfE (2020a) *Development Matters*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1007446/

6.7534_DfE_Development_Matters_Report_and_illustrations_web__2_.pdf (Accessed: 3 September 2020).

DfE (2020b) *National Professional Qualification (NPQ): Leading Teacher Development Framework*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/925511/NPQ_Leading_Teacher_Development.pdf (Accessed: 14 October 2020).

DfE (2020c) *Statutory Framework for the Early Years Foundation Stage: Setting the standards for Learning, Development and Care for Children from Birth to Five.* EYFS reforms early adopter version. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/896810/EYFS_Early_Adopter_Framework.pdf (Accessed: 10 September 2020).

DfE (2021a) *Development Matters – Non-statutory Curriculum Guidance for the Early Years Foundation Stage*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1007446/6.7534_DfE_Development_Matters_Report_and_illustrations_web__2_.pdf (Accessed: 2 August 2021).

DfE (2021b) *Early Years Inspection Handbook for Ofsted Registered Provision*. Available at: https://www.gov.uk/government/publications/early-years-inspection-handbook-eif/early-years-inspection-handbook-for-ofsted-registered-provision (Accessed: 24 May 2021).

Donnelly, M. *et al.* (2020) *Developing Social and Emotional Skills: Education Policy and Practice in the UK Home Nations*. Available at: https://media.nesta.org.uk/documents/Developing_Social_and_Emotional_Skills.pdf (Accessed: 5 November 2020).

Dunlosky, J. *et al.* (2013) 'Improving Students' Learning with Effective Learning Techniques: Promising Directions from Cognitive and Educational Psychology', *Psychological Science in the Public Interest, Supplement*, 14(1), 4–58. doi: 10.1177/1529100612453266.

Dunlosky, J. (2013) 'Strengthening the Student Toolbox: Study Strategies to Boost Learning', *American Educator*, 37(3), 12–21. Available at: http://www.aft.org/sites/default/files/periodicals/dunlosky.pdf.

EEF (2018a) *Education Endowment Foundation Teaching and Learning Toolkit*. Available at: https://educationendowmentfoundation.org.uk/public/files/Toolkit/complete/EEF-Teaching-Learning-Toolkit-October-2018.pdf.

EEF (2018b) *Mastery Learning: Toolkit Strand*. Education Endowment Foundation. Available at: https://educationendowmentfoundation.org.uk/evidence-summaries/teaching-learning-toolkit/mastery-learning/ (Accessed: 4 September 2020).

EEF (2020) *Special Educational Needs in Mainstream Schools: Guidance Report*. Available at: https://educationendowmentfoundation.org.uk/public/files/Publications/Send/EEF_Special_Educational_Needs_in_Mainstream_Schools_Guidance_Report.pdf (Accessed: 9 October 2020).

EEF (2021a) *Early Years Toolkit - Self-regulation Strategies*. Available at: https://educationendowmentfoundation.org.uk/pdf/generate/?u=https://educationendowmentfoundation.org.uk/pdf/toolkit/?id=303&t=Teaching and Learning Toolkit&e=303&s= (Accessed: 21 June 2021).

EEF (2021b) *Setting and Streaming*. Available at: https://educationendowmentfoundation.org.uk/education-evidence/teaching-learning-toolkit/setting-and-streaming (Accessed: 9 December 2021).

EEF (2021c) *The EEF Guide to the Pupil Premium-Autumn 2021*. Available at: https://d2tic4wvo1iusb.cloudfront.net/documents/guidance-for-teachers/pupil-premium/EEF-Guide-to-the-Pupil-Premium-Autumn-2021.pdf (Accessed: 12 November 2021).

EEF (no date) *Improving Social and Emotional Learning in Primary Schools Guidance Report*. Available at:

https://educationendowmentfoundation.org.uk/public/files/Publications/SEL/EEF_Social_and_Emotional_Learning.pdf (Accessed: 3 March 2021).

Ericsson, K. A., Krampe, R. T. and Tesch-Römer, C. (1993) 'The Role of Deliberate Practice in the Acquisition of Expert Performance', *Psychological Review*, 100(3), 363–406. doi: 10.1037/0033-295X.100.3.363.

Evans, M. (no date) *The School Leader: Using Mental Models Effectively. Ambition Institute*. Available at: https://www.ambition.org.uk/blog/school-leader-using-mental-models-effectively/ (Accessed: 17 September 2020).

Fenesi, B. *et al.* (2018) 'Sweat so You Don't Forget: Exercise Breaks During a University Lecture Increase On-task Attention and Learning', *Journal of Applied Research in Memory and Cognition*. Society for Applied Research in Memory and Cognition, 7(2), 261–269. doi: 10.1016/j.jarmac.2018.01.012.

Fiorella, L. and Mayer, R. E. (2015) *Learning as a generative activity: Eight learning strategies that promote understanding*. Cambridge: Cambridge University Press. doi: 10.1017/CBO9781107707085.

Fletcher-Wood, H. (2018) *Responsive Teaching*. Abingdon: Routledge.

Francis, B. *et al.* (2018) *Dos and don'ts of attainment grouping*. Available at: https://www.ucl.ac.uk/ioe/sites/ioe/files/dos_and_donts_of_attainment_grouping_-_ucl_institute_of_education.pdf (Accessed: 26 May 2020).

Francis, B., Taylor, B. and Tereshchenko, A. (2020) *Reassessing 'Ability' Grouping: Improving Practice for Equity and Attainment*. Abingdon: Routledge.

Gathercole, E. S. and Alloway, T. P. (2007) 'Understanding Working Memory', *A Classroom Guide*, pp. 1–22. doi: 10.1007/s10648-013-9242-2.

Geary, D. C. (2002) 'Principles of Evolutionary Educational Psychology', *Learning and Individual Differences*, 12(4), 317–345. doi: 10.1016/S1041-6080(02)00046-8.

Geary, D. C. (2007) *Educating the Evolved Mind: Conceptual Foundations for an Evolutionary Educational Psychology*, Information Age Publishing. Available at: http://goo.gl/ZqG4kS.

Gray, P., Norwich, B. and Webster, R. (2021) *Review of Research about the Effects of Inclusive Education: A Summary*. Available at: https://senpolicyresearchforum.co.uk/wp-content/uploads/Review-of-inclusion-effects-research-final-Feb-21-.pdf (Accessed: 18 March 2021).

Griffiths, J. and Stefanini, L. (2020) 'Addressing the Challenges of Using Evidence in Education', *Impact*, 10(September). Available at: https://impact.chartered.college/article/addressing-the-challenges-using-evidence-education/ (Accessed: 28 April 2021).

Hambrick, D. Z. *et al.* (2014) 'Deliberate Practice: Is that all it Takes to become an Expert?', *Intelligence*, 45(1), 34–45. doi: 10.1016/j.intell.2013.04.001.

Hendrick, C. and Macpherson, R. (2017) *What Does this Look Like in the Classroom?* John Catt.

Herrlinger, S. *et al.* (2017) 'When Do Pictures Help Learning from Expository Text? Multimedia and Modality Effects in Primary Schools', *Research in Science Education*. Springer Netherlands, 47(3), pp. 685–704. doi: 10.1007/s11165-016-9525-y.

HM Government (2021) *The National Strategy for Autistic Children, Young People and Adults: 2021 to 2026*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1004528/the-national-strategy-for-autistic-children-young-people-and-adults-2021-to-2026.pdf (Accessed: 17

November 2021).

House of Commons Education Committee (2021) *The Forgotten: How White Working-class Pupils have been Let Down, and How to Change it*. Available at: https://committees.parliament.uk/publications/6364/documents/69838/default/ (Accessed: 22 June 2021).

InnerDrive (2021) *Do We Teach Boys and Girls Differently?* Available at: https://blog.innerdrive.co.uk/teaching-boys-and-girls (Accessed: 30 September 2021).

InnerDrive (2022) *Embodied Cognition: Why We should be both Optimistic and Cautious*, blog.innerdrive.co.uk. Available at: https://blog.innerdrive.co.uk/embodied-cognition-optimistic-and-cautious (Accessed: 21 February 2022).

Jerrim, J. (2021) *The association between within-class grouping and children's achievement in mathematics during Year 2, Year 5, and Year 9*. Available at: https://educationendowmentfoundation.org.uk/public/files/Within_class_grouping_report_-_final.pdf (Accessed: 3 March 2021).

Jones, S. and Myhill, D. (2004) '"Troublesome Boys" And "Compliant Girls": Gender Identity and Perceptions of Achievement and Underachievement', *British Journal of Sociology of Education*, 25(5). doi: 10.1080/0142569042000252044.

Kirschner, P. A. and Neelen, M. (2016) *Close the Stable Doors: Effects of Motivation and Engagement on Learner Achievement?* 3-Star Learning Experiences. Available at: https://3starlearningexperiences.wordpress.com/2016/05/17/close-the-stable-doors-effects-of-motivation-anengagement-on-learner-achievement/ (Accessed: 6 May 2021).

Kirschner, P. A. and Neelen, M. (2017) *Double-Barrelled Learning for Young and Old.* 3-Star Learning experiences. Available at: https://3starlearningexperiences.wordpress.com/2017/05/30/double-barrelled-learning-for-young-old/ (Accessed: 14 January 2020).

Kirschner, P. A., Sweller, J. and Clark, R. E. (2006) 'Why Minimal Guidance During Instruction does not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-based, Experiential, and Inquiry-based Teaching', *Educational Psychologist*, 41(2), 75–86. doi: 10.1207/s15326985ep4102_1.

Korpershoek, H. *et al.* (2020) 'The relationships between school belonging and students' motivational, social-emotional, behavioural, and academic outcomes in secondary education: a meta-analytic review', *Research Papers in Education*. Informa UK Limited, 35(6), pp. 641–680. doi: 10.1080/02671522.2019.1615116.

Lemov, D. (2021) *An Annotated Forgetting Curve.* Teach like a Champion. Available at: https://teachlikeachampion.com/blog/an-annotated-forgetting-curve/ (Accessed: 3 August 2021).

Linchevski, L. and Kutscher, B. (1998) 'Tell Me With Whom You're Learning, and I'll Tell You How Much You've Learned: Mixed-Ability Versus Same-Ability Grouping in Mathematics', *Journal for Research in Mathematics Education*, 29(5), pp. 533–554. Available at: http://math.buffalostate.edu/dwilson/MED595/JRME_AbilityGrouping.pdf (Accessed: 2 August 2022).

Macnamara, B. N. *et al.* (2018) 'The Deliberate Practice View', in Hambrick, D. Z., Campitelli, G., and Macnamara, B. N. (eds) *The Science of Expertise*. Routledge.

Mayor of London (2021) *London Education Report Secondary Education*. Available at: https://www.london.gov.uk/sites/default/files/3.secondary_march2021.pdf (Accessed: 27 April 2021).

Metcalfe, J. and Miele, D. B. (2014) 'Hypercorrection of High Confidence Errors: prior Testing both Enhances Delayed Performance and Blocks the Return of the Errors', *Journal of Applied Research in Memory and Cognition*, 3, 189–197. doi: 10.1016/j.jarmac.2014.04.001.

Moreno, R. and Mayer, R. E. (2000) 'A Coherence Effect in Multimedia Learning: The Case for Minimizing Irrelevant Sounds in the Design of Multimedia Instructional Messages', *Journal of Educational Psychology*, 92(1), 117–125. doi: 10.1037/0022-0663.92.1.117.

Muijs, D. and Bokhove, C. (2020) *Metacognition and Self-Regulation: Evidence Review*. Available at: https://educationendowmentfoundation.org.uk/public/files/Metacognition_and_self-regulation_review.pdf (Accessed: 26 May 2020).

Nestojko, J. F. *et al.* (2014) 'Expecting to Teach Enhances Learning and Organization of Knowledge in Free Recall of Text Passages', *Memory and Cognition*, 42(7), 1038–1048. doi: 10.3758/s13421-014-0416-z.

Nuthall, G. (2005) 'The Cultural Myths and Realities of Classroom Teaching and Learning: A Personal Journey', *Teachers College Record*, 107(5), 895–934. Available at: https://talkinglearningtechnologies.edublogs.org/files/2011/03/2005-Nuthall-Myths-Realities-Teaching-2d6f8lq.pdf (Accessed: 4 May 2021).

Nuthall, G. (2007) *The Hidden Lives of Learners*. NZCER Press.

Ofsted (2019) *School Inspection Handbook*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/843108/School_inspection_handbook_-_section_5.pdf (Accessed: 7 September 2020).

Ofsted (2020) *The Annual Report of Her Majesty's Chief Inspector of Education, Children's Services and Skills 2019/20*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/939834/Ofsted_Annual_Report_2019-2020.pdf (Accessed: 2 December 2020).

Paas, F. and Sweller, J. (2012) 'An evolutionary upgrade of cognitive load theory: using the human motor system and collaboration to support the learning of complex cognitive tasks', *Educational Psychology Review*, 24(1), 27–45. doi: 10.1007/s10648-011-9179-2.

Papachristou, E. *et al.* (2022) 'Ability-grouping and problem behavior trajectories in childhood and adolescence: Results from a U.K. population-based sample', *Child Development*. John Wiley & Sons, Ltd, 93(2), pp. 341–358. doi: 10.1111/CDEV.13674.

Pershan, M. and Riley, B. (2017) *Why Mythbusting Fails: A Guide to Influencing Education with Science.* Deans for Impact. Available at: https://deansforimpact.org/why-mythbusting-fails-a-guide-to-influencing-education-with-science/ (Accessed: 14 January 2020).

Piaget, J. (1964) 'Part I: Cognitive Development in Children: Piaget Development and Learning', *Journal of Research in Science Teaching*, 2(3), 176–186. doi: 10.1002/tea.3660020306.

Pinkett, M. and Roberts, M. (2019) *Boys Don't Try? Rethinking Masculinity in Schools*. Routledge.

Praetorius, A. K. *et al.* (2018) 'Generic Dimensions of Teaching Quality: The German Framework of Three Basic Dimensions', *ZDM – Mathematics Education*, 50(3), 407–426. doi: 10.1007/S11858-018-0918-4.

Quigley, A., Muijs, D. and Stringer, E. (2018) *Metacognition and Self-regulated Learning: Guidance Report*. Available at: https://educationendowmentfoundation.org.uk/public/files/Publications/Metacognition/EEF_Metacognition_and_self-regulated_learning.pdf.

Renkl, A. and Atkinson, R. K. (2003) 'Structuring the Transition from Example Study to Problem Solving in Cognitive Skill Acquisition: A Cognitive Load Perspective', *Educational Psychologist*. 38(1), 15–22. doi: 10.1207/S15326985EP3801_3.

Rich, P. R. *et al.* (2016) 'Belief in CORRECTIVE FEEDBACK for Common Misconceptions: Implications for

Knowledge Revision', *Journal of Experimental Psychology: Learning Memory and Cognition*, 43(3), 492–501. doi: 10.1037/xlm0000322.

Roediger, H. L. and Karpicke, J. D. (2006) 'Test-enhanced Learning: Taking Memory Tests Improves Long-term Retention', *Psychological Science*, 17(3), 249–255. doi: 10.1111/j.1467-9280.2006.01693.x.

Roediger III, H. L. and Pyc, M. A. (2012) 'Inexpensive Techniques to Improve Education: Applying Cognitive Psychology to Enhance Educational Practice', *Journal of Applied Research in Memory and Cognition*, 1(4), 242–248. doi: 10.1016/j.jarmac.2012.09.002.

Rohrer, D., Agarwal, P. K. and Dedrick, R. F. (2017) *Interleaved Mathematics Practice giving Students a Chance to Learn*. Available at: http://uweb.cas.usf.edu/~drohrer/pdfs/Interleaved_Mathematics_Practice_Guide.pdf.

Rosenshine, B. (2012) 'Principles of Instruction: Research-based Strategies that all Teachers Should Know', *American Educator*, 36(1), 12–20. Available at: https://files.eric.ed.gov/fulltext/EJ971753.pdf.

Rosenshine, B. and Meister, C. (1992) 'The use of scaffolds for teaching higher-level cognitive strategies', *Educational Leadership*, 26–33. Available at: http://www.formapex.com/telechargementpublic/rosenshine1992a.pdf (Accessed: 8 October 2020).

Ryan, R. M. and Deci, E. L. (2000) 'Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being Self-Determination Theory', *American Psychologist*. 55(1), 68–78. Available at: https://selfdeterminationtheory.org/SDT/documents/2000_RyanDeci_SDT.pdf (Accessed: 9 December 2021).

Schuelka, M. J. (2018) *Implementing Inclusive Education*. Available at: https://assets.publishing.service.gov.uk/media/5c6eb77340f0b647b214c599/374_Implementing_Inclusive_Education.pdf (Accessed: 4 March 2021).

Sealy, C. (2019) The Best Way to Help Children Remember Things? Not "Memorable Experiences"', - *The ResearchEd Guide to Education Myths – Education Next: Education Next*, *Education Next*. Available at: https://www.educationnext.org/best-way-to-help-children-remember-things-not-memorable-experiences-excerpt/ (Accessed: 14 January 2020).

Shaw, B. *et al.* (2016) 'Ethnicity, Gender, and Social Mobility', *Social Mobility Commission*, (December), 1–60.

Sherrington, T. (2020) *Schema-building: A Blend of Experiences and Retrieval Modes make for Deep Learning.* Teacherhead blog. Available at: https://teacherhead.com/2020/01/05/schema-building-a-blend-of-experiences-and-retrieval-modes-make-for-deep-learning/ (Accessed: 3 August 2021).

Shimamura, A. (2018) *MARGE: A Whole-Brain Learning Approach for Students and Teachers*. Available at: https://shimamurapubs.files.wordpress.com/2018/09/marge_shimamura.pdf (Accessed: 17 July 2020).

Slavin, R. E. (1990) *Achievement Effects of Ability Grouping in Secondary Schools: A Best-Evidence Synthesis*. 143. Available at: https://files.eric.ed.gov/fulltext/ED322565.pdf (Accessed: 2 August 2022).

Smeding, A. *et al.* (2013) 'Reducing the Socio-economic Status Achievement Gap at University by Promoting Mastery-oriented Assessment', *PLoS ONE*, 8(8), 1–6. doi: 10.1371/journal.pone.0071678.

Smith, M. (2021) *What Do We Really Mean by Cognitive Load?* The Emotional Learner, theemotionallearner blog. Available at: https://theemotionallearner.com/2021/07/09/what-do-we-really-mean-by-cognitive-load/ (Accessed: 29 July 2021).

Smith, M. A., Roediger, H. L. I. and Karpicke, J. D. (2013) 'Covert Retrieval Practice Benefits Retention as Much as Overt Retrieval Practice', *Journal of Experimental Psychology: Learning Memory, and Cognition*,

39(6), 1712–1725. doi: 10.1037/a0033569.

Social Mobility Commission (2021) *Against the Odds: Achieving Greater Progress for Secondary Students Facing Socio-Economic Disadvantage.* Research report. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/997897/Against_the_odds_report.pdf (Accessed: 29 July 2021).

Soderstrom, N. C. and Bjork, R. A. (2015) 'Learning Versus Performance: An Integrative Review', *Perspectives on Psychological Science*, 10(2), 176–199. doi: 10.1177/1745691615569000.

Stillman, C. M. *et al.* (2020) 'Effects of Exercise on Brain and Cognition Across Age Groups and Health States', *Trends in Neurosciences*, 43(7), 533–543. doi: 10.1016/j.tins.2020.04.010.

Sundorph, E. (2020) *Missing Elements: Why 'Steminism' Matters in The Classroom and Beyond*. Available at: https://www.teachfirst.org.uk/sites/default/files/2020-02/teach_first_steminism_report_0_2.pdf (Accessed: 30 September 2021).

Sweller, J. (2008) 'Instructional implications of David C. Geary's evolutionary educational psychology', *Educational Psychologist*, 43(4), 214–216. doi: 10.1080/00461520802392208.

Sweller, J. (2016) 'Story of a Research Program', *Education Review*, 23. Available at: http://dx.doi.org/10.14507/.

Sweller, J. (2022) 'Some Critical Thoughts about Critical and Creative Thinking', *The Centre for Independent Studies*, 32. Available at: https://www.cis.org.au/app/uploads/2022/02/ap32.pdf? (Accessed: 8 February 2022).

Sweller, J., Van Merriënboer, J. J. G. and Paas, F. (2019) 'Cognitive Architecture and Instructional Design: 20 Years Later', *Educational Psychology Review*, 31, 261–292. doi: 10.1007/s10648-019-09465-5.

Teach First (2021a) 'Just 2% of Teachers in the Most Disadvantaged Schools say all their Pupils have Adequate Digital Access'. Available at: https://www.teachfirst.org.uk/press-release/digital-access (Accessed: 10 December 2021).

Teach First (2021b) *STEMinism One Year On*. Available at: https://www.teachfirst.org.uk/sites/default/files/2021-06/STEMinism - One year on_0.pdf (Accessed: 30 September 2021).

Tharby, A. (2018) *How to Explain Absolutely Anything to Absolutely Anyone*. Crown House Publishing.

Tompary, A., Zhou, W. and Davachi, L. (2020) 'Schematic Memories Develop Quickly, but are not Expressed unless Necessary'. PsyArXiv. Available at: https://psyarxiv.com/k4fea/.

Vostanis, P. *et al.* (2013) 'How do Schools Promote Emotional Well-being among their Pupils? Findings from a National Scoping Survey of Mental Health Provision in English Schools', *Child and Adolescent Mental Health*, 18(3), 151–157. doi: 10.1111/j.1475-3588.2012.00677.x.

Vygotsky, L. (1929) *Soviet Psychology: The Problem of the Cultural Development of the Child*. Available at: https://www.marxists.org/archive/vygotsky/works/1929/cultural_development.htm (Accessed: 14 January 2020).

Weinstein, Y. and Sumeracki, M. A. (2019) *Understanding How We Learn*. Routledge.

Wiliam, D. (2018) *Embedded formative assessment*. 2nd edn. Bloomington: Solution Tree Press.

Wiliam, D. (2019) 'Teaching is not a Research-based Profession', *TES*. Available at: https://www.tes.com/news/dylan-wiliam-teaching-not-research-based-profession (Accessed: 14 February

2020).

Willingham, D. T. (2008) ‘What is Developmentally Appropriate Practice?’, *American Educator*, 32(2), 34–39. doi: 10.1007/BF02430447.

Willingham, D. T. (2009) *Why Don’t Students Like School?*. JosseyBass, pp. 4–13. Available at: https://www.aft.org/sites/default/files/periodicals/WILLINGHAM%282%29.pdf.

Willingham, D. T. (2017) ‘A Mental Model of the Learner: Teaching the Basic Science of Educational Psychology to Future Teachers’, *Mind, Brain, and Education*, 11(4), 166–175. doi: 10.1111/mbe.12155.

Willingham, D. T. (2019) ‘How to Teach Critical Thinking’, *Education: Future Frontiers*. Available at: http://www.danielwillingham.com/uploads/5/0/0/7/5007325/willingham_2019_nsw_critical_thinking2.pdf (Accessed: 6 November 2019).

Wittwer, J. and Renkl, A. (2010) ‘How Effective are Instructional Explanations in Example-based Learning? A Meta-analytic Review’, *Educational Psychology Review*, 22(4), 393–409. doi: 10.1007/s10648-010-9136-5.

Yan, V. (2016) *Retrieval Strength Vs. Storage Strength.* The Learning Scientists, guest post. Available at: https://www.learningscientists.org/blog/2016/5/10-1 (Accessed: 21 January 2021).

Zins, J. E. *et al.* (2007) ‘The Scientific Base Linking Social and Emotional Learning to School Success’, *Journal of Educational and Psychological Consultation*, 7(2-3) 191–210. doi: 10.1080/10474410701413145.