Impact

Chartered College of Teaching @5

Our 5 most read Impact articles

CHARTERED COLLEGE OF TEACHING

RECOGNISING
Teaching expertise

GAIN
Formal recognition

BECOME
Chartered

Register for Chartered Teacher Status and start your journey today

chartered.college/chartered-teacher/

Skilful questioning: The beating heart of good pedagogy

JONATHAN DOHERTY
SENIOR LECTURER, PRIMARY EDUCATION, LEEDS TRINITY UNIVERSITY, UK

The issue that teachers face

Questions are an integral part of classroom life and essential to every teacher's pedagogical repertoire. They are also one of the elements of effective formative assessment (Black et al., 2003). Questioning serves many purposes: it engages students in the learning process and provides opportunities for students to ask questions themselves. It challenges levels of thinking and informs whether students are ready to progress with their learning. Questions that probe for deeper meaning foster critical thinking skills and higher-order capabilities such as problem solving, and encourage the types of flexible learners and critical thinkers needed in the 21st century.

Questioning is a crucial pedagogical skill, but one that requires practised knowledge (Cavanaugh and Warwick, 2001). Paramore (2017) identifies an imbalance of questions often found in teaching, saying there is a dominance of teacher talk and an over-reliance on closed questions, providing only limited assessment for learning (AfL) information for a teacher. The issue then is how classroom questioning strategies can become more effective, as evidence suggests that teachers ask too many questions and too many of these questions are low level.

What the research says

The value of classroom questioning is well documented. Research tends to focus on the relationship between teachers' questions and student achievement; here are some of the important messages.

Types of questions used

Too often, questions from teachers are organisational, such as 'What do we always put at the top of our page to begin with?' or instructional in nature, such as 'Who can tell me what an adjective is?' and fail to develop deep learning. Wragg's early study (1993) found teachers commonly use three types of question:

1. Management-related, e.g. 'Has everyone finished this piece of work now?'
2. Information recall-related, e.g. 'How many sides does a quadrilateral have?'
3. Higher-order questions, e.g. 'What evidence do you have for saying that?'

Questioning is a crucial pedagogical skill, but one that requires practised knowledge

In Wragg's study, 57 per cent of questions were management related, 37 per cent required information recall and only 8 per cent challenged higher-order thinking.

Closed or convergent questions have low cognitive involvement and result in limited answers such as 'Yes' or 'No'. Open or divergent questions encourage greater expansion in answers and promote better classroom dialogue (Tofade, Elsner and Haines, 2013). Closed questions are still important, however, and help assist in knowledge retrieval; but proceed with caution here, as the inevitable one-word student answers limit classroom dialogue resulting in what Alexander called 'cognitively restricting rituals' (2006: p.14). Lower-attaining students benefit from closed questions, allowing them greater accuracy of response which in turn breeds encouragement, while higher-attaining students respond better to more challenging questions (Woolfolk, 2008). In order to maximise AfL in lessons, use different types of questions but limit the procedural and emphasise questions that centre on learning, and differentiate them to maximise AfL.

Timing

Student wait time (giving a brief period of time for students to think or reflect before answering) has a positive effect on learning. Brooks and Brooks (2001) found that a rapid-fire questioning approach fails to provide teachers with accurate information about student understanding. Typically, the time between asking a question and a student's response is about one second. Cohen et al. (2004) recommend wait times of three to five seconds for closed questions and up to 15 seconds for open-ended questions.

Cognitive levels

Complex questions promote complex thinking, argue researchers Degener ›

ISTOCK

and Berne (2016). But is it really that simple? There is a lack of consensus in the literature. Some researchers have found higher-cognitive questions superior to lower ones while others have not. In general, the level of teachers' questions is low. Around 60 per cent of questions expect only factual information from students (Lee and Kinzie, 2012). Samson et al. (1987) found that higher-cognitive questioning strategies have a positive effect on learning, but this was not as large as has been previously suggested. Simply asking higher-cognitive questions does not necessarily produce higher-cognitive responses from students.

On balance, low-level questioning aimed at recall and fundamental-level comprehension will plateau classroom learning quickly. Higher-level questions can produce deeper learning and thinking, but a balance needs to be struck. Both have a place and a mixture of questions is recommended.

Effective approaches

Over the years, classification taxonomies have been developed to guide teacher questioning (see Krathwohl (1964); Wilen (1986) and Morgan and Saxton (1991) as early examples). Hannel and Hannel's 'highly effective questioning method' (2005) shows how teacher questions promote student engagement, and an interesting approach is the 'sequences of teacher and student questions' (Dekker-Groen, 2015). In literacy, Degener and Berne (2016) devised their six-level 'continuum of questioning complexity' to offer increased challenge at each cognitive level. Shirley Clarke's website (www.shirleyclarke-education.org) has a wide range of practical resources on AfL and proven questioning strategies.

Perhaps the most well-known questioning framework is Bloom's cognitive taxonomy (1956), later revised by Anderson and Krathwohl (2001). In this six-level hierarchy, lower-order questions gauge comprehension; medium-level gauge knowledge application, and higher-order questioning elicits synthesis, analysis and evaluation.

Knowledge
'Can you remember…?'
Comprehension
'Tell me how this works…'
Application
'Where else have you seen this pattern?
Analysis
'Explain to me what is happening here?'
Synthesis
'What conclusions can you draw from this?'
Evaluation
'Can you measure how effective this is?'

Trigger words are an effective way to formulate questions, as shown in **Table 1**.

TABLE 1:
TRIGGER WORDS LINKED TO BLOOM'S TAXONOMY

LEVEL	TRIGGER WORDS
Knowledge	what, who, when, name, list, define, show, identify
Comprehension	compare, distinguish, illustrate, tell, predict, explain
Application	apply, select, solve, choose, consider, connect, plan
Analysis	analyse, classify, relate, support, compare/contrast
Synthesis	propose, formulate, draw together, invent
Evaluation	judge, measure, defend, evaluate, decide, assess

Ideas to try in the classroom

There are many questioning tactics to choose from to promote learning and provide excellent formative assessment information:

1. **No hands up.** Anyone can answer, which avoids the same few students answering questions.
2. **In the hot seat.** Students take it in turns to sit in the 'hot seat' and answer questions.
3. **Ask the expert.** The teacher puts questions to a student on a given topic, extending this to encourage

other students to ask questions.

4. Ask the classroom. The teacher displays a number of written questions to stimulate thinking about pictures or objects in the classroom.

5. Think-pair-share. Allows time to share ideas with a partner and respond to a posed question.

6. Phone a friend. A useful strategy in which a student nominates another to answer the teacher's question. The first student also provides an answer.

7. Eavesdropping. When groups are working, the teacher circulates around the classroom and poses questions to groups based on what is heard in their discussions.

8. Question box. An actual box has a series of questions in it devised by the teacher. Time is set aside at the end of a week to choose some to discuss as a class.

9. Here is the answer, what is the question? Deliberately back to front to encourage out-of-the-box thinking.

10. More than me. The teacher asks a student a question and deliberately cuts short the answer to involve another student to build on this answer.

Questions are among the most powerful teaching tools we have

Things to take into account

'It is better to have a classroom full of unanswered questions than unanswered answers' (Morgan and Saxton, 1991).

Good questions develop discussion and invite exploration. Poor questions can stifle and put undue pressure on students. Using a variety of question types to inform your assessment can transform your classroom into a 'questioning classroom'. A classroom ethos and organisation with enquiry at its heart is an effective one, where purposeful talk dominates and teachers ask fewer questions. Dialogic teaching (Alexander, 2017) uses skilled questions to extend thinking where answers to teachers' questions are built on rather than merely received. Dialogue allows a teacher to respond to students' answers and if necessary re-orientate them. Exchanges chain together, feedback from questions leads thinking forward and students' answers are extended. Questions are among the most powerful teaching tools we have and adopting best practices will significantly enhance the quality of teaching and learning.

Questions to reflect on/discuss

1. Is my classroom a 'questioning classroom'?
2. Does talk permeate my teaching and learning approach?
3. What types of questions and how many questions do I typically ask in my teaching?
4. Do the questions I ask target higher-order thinking and raise the cognitive stakes? Is this true of my teaching across all subjects?

FURTHER READING

Excellent website with many resources to embed AfL and effective questioning in classrooms: Available at www.shirleyclarke-education.org.

Chapter 2, Questioning to learn, is very readable: Fisher R (2005) *Teaching Children to Learn*. Cheltenham: Nelson Thornes.

Practical and clear overview of Bloom's taxonomy: West Lothian Council Educational Psychology Service. Questioning. Raising Attainment sheet 1. Available at: www.westlothian.gov.uk/education.

REFERENCES

Alexander RJ (2006) *Towards Dialogic teaching: rethinking classroom talk*. 3rd ed. Cambridge: Dialogos.

Alexander RJ (2017) *Towards Dialogic Teaching: rethinking classroom talk*. 5th ed. Cambridge: Dialogos.

Anderson LW, Krathwohl DR, Airasian PW, Cruikshank KA, et al. (2001) *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York: Longman.

Black P, Harrison C, Lee C, Marshall B and Wiliam D (2003) *Assessment for Learning: Putting it into Practice*. Maidenhead: Open University Press.

Bloom BS (ed.) (1956) *Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook I: Cognitive Domain*. New York: David McKay Company, Inc.

Brooks, JG and Brooks MG (2001) Becoming a constructivist teacher. In: Costa: AL (ed.), *Developing Minds: A Resource Book for Teaching Thinking* (pp.150–157). Alexandria, VA: Association for Supervision and Curriculum Development.

Cavanaugh MP and Warwick C (2001) Questioning is an art. *Language Arts Journal of Michigan* 17 (2): 35–38.

Cohen L, Manion L, and Morrison K (2004) *A Guide to Teaching Practice*. London: Routledge.

Degener S and Berne J (2016) Complex questions promote complex thinking. *The Reading Teacher* 70 (5): 595–599. International Literacy Association.

Dekker-Groen A, Van der Schaaf M and Stokking K (2015) Teachers' questions and responses during teacher-student feedback dialogues. *Scandinavian Journal of Educational Research* 59(2).

Hannel GI and Hannel L (2005) *Highly effective questioning* 4th ed. Phoenix AZ: Hannel Educational Consulting.

Krathwohl DR, Bloom BS and Masia BB (eds) (1964) *Taxonomy of educational objectives: Handbook II: The affective domain*. New York: McKay.

Lee Y and Kinzie MB (2012) Teacher question and student response with regard to cognition and language use. *Instructional Science: An International Journal of the Learning Sciences* 40(6): 857–874.

Morgan N and Saxton J (1991) *Teaching Questioning and Learning*. New York: Routledge.

Paramore J (2017) Questioning to stimulate dialogue. In: Paige R, Lambert S and Geeson R (eds) *Building skills for Effective Primary Teaching*. London: Learning Matters.

Samson GK, Strykowski B, Weinstein T and Walberg HJ (1987) The effects of teacher questioning levels on student achievement. *The Journal of Educational Research* 80(5): 290–295.

Tofade TS, Elsner JL and Haines ST (2013) Best practice strategies for effective use of questions as a teaching tool. *American Journal of Pharmaceutical Education* 77 (7) Article 155.

Wilen WW (1986) *Questioning skills, for teachers*. Washington DC: National Education Association.

Woolfolk A, Hughes M and Walkup V (2008) *Psychology in Education*. Harlow: Pearson.

Wragg EC (1993) *Questioning in the Primary Classroom*. London: Routledge.

What is the best way to motivate students in your subject?

ADAM BOXER
CHEMISTRY TEACHER, JCOSS, UK

Motivation is a complicated beast. Traditionally broken into intrinsic and extrinsic types, students may be motivated by a whole host of competing and intertwined factors. The academic literature varies widely on these definitional terms and how they are measured (Garon-Carier, 2015; see also Didau and Rose, 2016). This is further confounded by a gap between what people believe and what they actually do. For example, a recent and ongoing study into student attitudes to science education found that many students think that science is important and valuable, but do not wish to study it themselves (DeWitt, 2017).

Schools and teachers insert themselves into this cacophonous mix with often confusing and unpredictable results. For instance, a recent large-scale study of attendance interventions found that in schools where students were awarded for 100 per cent attendance, the attendance actually worsened over time. The researchers posit that social pressures (nobody wants to be 'that' student) can affect student motivation to attend. Furthermore, by rewarding 100 per cent, the schools were potentially signalling to students that actually less than 100 per cent was expected, and 100 per cent was above expected, worsening student motivation to attend (Robinson et al., 2018).

In curricular studies, some urge that content should be tailored to the students'

GETTY

lived experiences in order to boost motivation. However, such a position can betray the 'power' of our subjects, limiting students and failing to open their minds to broader horizons and cultural treasures (Young, 2018). Additionally, such ideas can be difficult to implement – students have a curriculum to follow, and lived experiences aren't always going to be relevant.

An interesting avenue of pursuit relates to the relationship of student ability to long-term motivation. Ryan and Deci's seminal research into Self-Determination Theory (Ryan and Deci, 2000) argues that a vital component of individual motivation is competence. For example, giving people encouraging feedback on their performance increases their motivation: the experience of competence, of being good at something, boosts motivation. Garon-Carier et al. (2015) devised an experiment to test this idea. Defining intrinsic motivation in mathematics as engagement and interest in that subject, they found that motivation at the age of seven was no predictor of performance in mathematics some years later. However, performance at the age of seven *did* predict motivation some years later. Noting dissenting evidence, the researchers concluded that student performance – or competence – strongly affects whether or not they find interest in mathematics in the years to come.

Recently replicated (Nuutila et. al, 2018), this experiment suggests that teachers and schools should be aware that one of the most powerful ways to ensure students become motivated in their subjects is through improving their competence in that subject. As such, it may be more important for teachers to think about the best techniques to improve student performance, rather than techniques to increase their short-term engagement or interest.

An interesting case for discussion could be the role of 'drill', or extensive independent practice. Often derided as 'drill and kill' techniques (see Little, 2016), extensive silent, independent practice can be considered boring and demotivating and substituted for 'engaging' or 'fun' activities. This jars with the evidence base, which generally supports extensive individual practice (Willingham, 2010).

One of the most powerful ways to ensure students become motivated in their subjects is through improving their competence in that subject

Arguing for an appropriation of the phrase 'to drill and thrill', maths teacher Dani Quinn (2017) argues that extensive and carefully designed drill can lead students to feel a sense of success. An interesting comparison here is retrieval practice. It is well known that low-stakes quizzing is a highly effective tool for leveraging long-term memory (Firth et al., 2017), but it is worth noting that in the seminal studies on the topic, participants who undertook retrieval practice actually reported lower confidence in their abilities than those who undertook less effective memory activities, such as rereading or highlighting (Roediger and Butler, 2011). In the short term, challenging activities like retrieval practice can leave students feeling demotivated, or lacking in 'competence'. In the long term, however, such activities are far more likely to bring improved student performance and, with it, a sense of competence and motivation.

The flip side of this is also true. Nuthall's research (2007) revealed that students are most engaged when involved in work that carries minimal cognitive demand. Many activities touted as 'fun and engaging' do not adequately challenge students. As such, activities that appear beneficial in the short term are perhaps less so in the long term, and ones that appear ineffective in the short term may be highly effective in the long term.

In summary, motivation remains a complicated beast. But teachers should know that the day-to-day cycle of expert teaching – explain, practice, review – is a potential winner for building long-term interest and motivation.

REFERENCES

DeWitt J (2017) Inspiring the next generation of scientists. *Education in Chemistry*. Available at: https://eic.rsc.org/feature/inspiring-the-next-generation-of-scientists/3007626.article (accessed 21 November 2018).

Didau D and Rose N (2016) *What Every Teacher Needs to Know About … Psychology*. Woodbridge: John Catt.

Firth B, Smith M, Harvard B et al. (2017) Assessment as learning: The role of retrieval practice in the classroom. *Impact* 1: 18–21.

Garon-Carrier G, Boivin M, Guay F et al. (2015) Intrinsic motivation and achievement in mathematics in elementary school: A longitudinal investigation of their association. *Child Development* 87(1): 165–175.

Little G (2016) The drill and kill routine of improving test scores in exam factories hangs like dark, oppressive cloud over primary schools. *TES News*. Available at: https://www.tes.com/news/drill-and-kill-routine-improving-test-scores-exam-factories-hangs-dark-oppressive-cloud-over (accessed 21 November 2018).

Nuthall G (2007) *The Hidden Lives of Learners*. Wellington, New Zealand: NZCER Press.

Nuutila K, Tuominen H, Tapola A et al. (2018) Consistency, longitudinal stability, and predictions of elementary school students' task interest, success expectancy, and performance in mathematics. *Learning and Instruction* 56: 73–83.

Quinn D (2017) Drill and Thrill. In: Until I know better. Available at: https://missquinnmaths.wordpress.com/2017/03/16/drill-and-thrill/ (accessed 21 November 2018).

Robinson CD, Gallus J, Lee MG et al. (2018) The demotivating effect (and unintended message) of retrospective awards. HKS Faculty Research Working Paper Series. Available at: https://scholar.harvard.edu/files/todd_rogers/files/the_demotivating.pdf (accessed 14 January 2019).

Roediger H and Butler A (2011) The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences* 15(1): 20–27.

Ryan R and Deci E (2000) Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist* 55(1): 68–78.

Willingham D (2010) *Why Don't Students Like School?* San Francisco, CA: Jossey-Bass.

Young M (2018) A knowledge-led curriculum: Pitfalls and possibilities. *Impact* 4: 1–4.

Cognitive Load Theory and its application in the classroom

DOMINIC SHIBLI
SENIOR LECTURER IN SECONDARY SCIENCE, UNIVERSITY OF HERTFORDSHIRE, UK

RACHEL WEST
HEAD OF PSYCHOLOGY, THE NOBEL SCHOOL, HERTFORDSHIRE, UK

Cognitive Load Theory (CLT) has recently become 'The Next Big Thing' in teaching. Dylan Wiliam tweeted on 26 January 2017 that he had 'come to the conclusion Sweller's Cognitive Load Theory is the single most important thing for teachers to know'. This is an emphatic statement and it is important to consider the implications. As teachers, there are huge demands on our time, so when considering a new strategy it is essential to evaluate the evidence.

CLT, first researched by Sweller in the late 1980s, is based around the idea that our working memory – the part of our mind that processes what we are currently doing – can only deal with a limited amount of information at one time. Reif's (2010, p. 361) description of cognitive load is extremely useful: 'The cognitive load involved in a task is the cognitive effort (or amount of information processing) required by a person to perform this task.' There are a number of excellent resources freely available online that explain CLT (see Paas et al. (2003) for a useful overview), so we will only touch on the foundations of the theory here that will be useful for the rest of the article.

The theory identifies three different forms of cognitive load:

- **Intrinsic cognitive load:** the inherent difficulty of the material itself, which can be influenced by prior knowledge of the topic.
- **Extraneous cognitive load:** the load generated by the way the material is presented, and which does not aid learning.
- **Germane cognitive load:** the elements that aid information processing and contribute to the development of 'schemas'.

CLT suggests that if the cognitive load exceeds our processing capacity, we will struggle to complete the activity successfully. In summarising CLT, De Jong (2010, p. 105) states that 'Cognitive Load Theory asserts that learning is hampered when working memory capacity is exceeded in a learning task'.

Working memory should be seen as short term and finite, whereas long-term memory can be seen as infinite. The aim should be to move knowledge to long-term memory because when a student is exposed to new material, they can

GETTY

If subject knowledge is incomplete, the student is unable to fall back on the long-term memory and the working memory becomes overloaded

draw on this previous knowledge and the cognitive load is reduced. However, if subject knowledge is incomplete, the student is unable to fall back on the long-term memory and the working memory becomes overloaded, leading to working memory failures. According to Gathercole and Alloway (2007), indications of working memory failures include:

- incomplete recall
- failing to follow instructions
- place-keeping errors
- task abandonment.

Of course, there are many other reasons for these that are not related to CLT; however, if teachers understand how this theory applies to their classroom, they can plan their lessons in a way that takes into account cognitive load.

Reducing cognitive load

Intrinsic cognitive load can be reduced by breaking down the subject content, sequencing the delivery so that sub-tasks are taught individually before being explained together as a whole. The idea is to not overwhelm a student too early on in the introduction of new work.

Extraneous cognitive load can be reduced by the way in which instructions are presented. We make sense of new material by referencing schemas, or mental models, of pre-existing knowledge. Lack of clarity in instruction puts too high a load on the working memory, and so too much time is spent problem-solving the instructions as opposed to new schema formation. For example, lessons that use PowerPoint, with excessive writing and the teacher talking at the same time, can inadvertently generate excessive cognitive load and lead to working memory failures. Chandler and Sweller (1991) write that 'Cognitive Load Theory suggests that effective instructional material facilitates learning by directing cognitive resources towards activities that are relevant to learning.'

Introducing ideas within a topic

Van Merriënboer et al. (2003) recommend using simple-to-complex sequencing to try to reduce cognitive load. They advise starting with worked-out examples (where a full solution is shown, which students then have to apply to a new question), then moving into completion assignments (where a partial solution is given and they have to complete it themselves), and then moving to conventional tasks, where they are simply given the question. This acts as a form of scaffolding, which helps students to learn independently, without necessarily needing the help of their teacher for each stage.

Renkl and Atkinson (2003) further investigated this fading form of scaffolding. They suggested that moving through activities sequentially could reduce intrinsic load, as learners will have already mastered some of the knowledge they need to work out a solution in an earlier skill stage. Therefore, their ›

› research recommends beginning with a model (a complete example), gradually removing completed steps, which the learner will have to complete independently, and finally leaving just the to-be-solved problem.

These principles can be readily applied in the classroom by beginning with a model answer, then providing a writing frame/structure with a lot of information, followed by a writing frame/structure with less information, then finally a question that learners must complete independently without a writing frame. It is worth, though, being aware of the 'expertise reversal effect' suggested by Kalyuga et al. (2003), whereby if you continue to provide worked-out examples for experts, their usefulness is significantly reduced. Cognitive load theorists suggest this is because worked-out examples contain information that an expert could work out for themselves, making it redundant and therefore extraneous cognitive load rather than useful germane cognitive load.

Presenting information to minimise cognitive load

Chandler and Sweller (1992) found evidence of the split-attention effect. This occurs when different sources of information discussing the same topic are separated by time or space, such as a diagram with a key that corresponds to separate text next to it. When information is presented in this way, it is left to the learner to attempt to amalgamate it, which generates extraneous cognitive load. Therefore, it is recommended that if one of the sources adds nothing new, it should be eliminated. However, if it is essential to include both sources, they should ideally be physically integrated (e.g. texts and diagrams combined). This way, extraneous cognitive load is reduced and working memory capacity can be used for intrinsic and germane cognitive load instead.

A word of caution

There are, of course, issues with CLT. Reif (2010, p. 361) writes that if cognitive load is reduced too much, 'the entire learning process would consist of too many small steps – and would thus become unduly fragmented and long'. There are also issues to do with the hypothesis being unfalsifiable. Doug Holton (2009) points out that it is difficult to measure cognitive load, and therefore difficult to generate evidence to prove the theory.

An important question, though, is whether it is useful in the classroom. Ashman (2017) has explained that an understanding of CLT changed his maths teaching, and offers the following four examples:

1. **I don't read out my slides** – avoid simultaneous oral and text presentation.
2. **Break it down further** – pause for practice between individual problem types (this leads directly into number 3).
3. **Example-problem pairs** – give a worked example alongside an almost identical question.
4. **Stop after five minutes** – advise students never to spend more than five minutes trying to solve a problem or question. Go on to the next question then go back to it or ask for help.

So is CLT the single most important thing for a teacher to know? Perhaps not – it is a bold claim. But, if used correctly, it can improve teacher instruction, which is an important variable in the complex classroom environment.

REFERENCES

Ashman G (2017) Four ways cognitive load theory has changed my teaching. Available at: https://gregashman.wordpress.com/2017/05/13/four-ways-cognitive-load-theory-has-changed-my-teaching%EF%BB%BF/ (accessed 25 July 2017).

Chandler P and Sweller J (1991) Cognitive load theory and the format of instruction. *Cognition and Instruction* 8(4): 293–332.

Chandler P and Sweller J (1992) The split-attention effect as a factor in the design of instruction. *British Journal of Educational Psychology* 62: 233–246.

De Jong T (2010) Cognitive load theory, educational research, and instructional design: Some food for thought. *Instructional Science* 38(2): 105–134.

Gathercole S and Alloway T (2007) Understanding working memory. A classroom guide. Harcourt Assessment. Available at: https://www.mrc-cbu.cam.ac.uk/wp-content/uploads/2013/01/WM-classroom-guide.pdf (accessed 11 July 2017).

Holton D (2009) Cognitive load theory: Failure? Available at: https://edtechdev.wordpress.com/2009/11/16/cognitive-load-theory-failure/ (accessed 25 July 2017).

Kalyuga S, Ayres P, Chandler P et al. (2003) The expertise reversal effect. *Educational Psychologist* 38(1): 23–31.

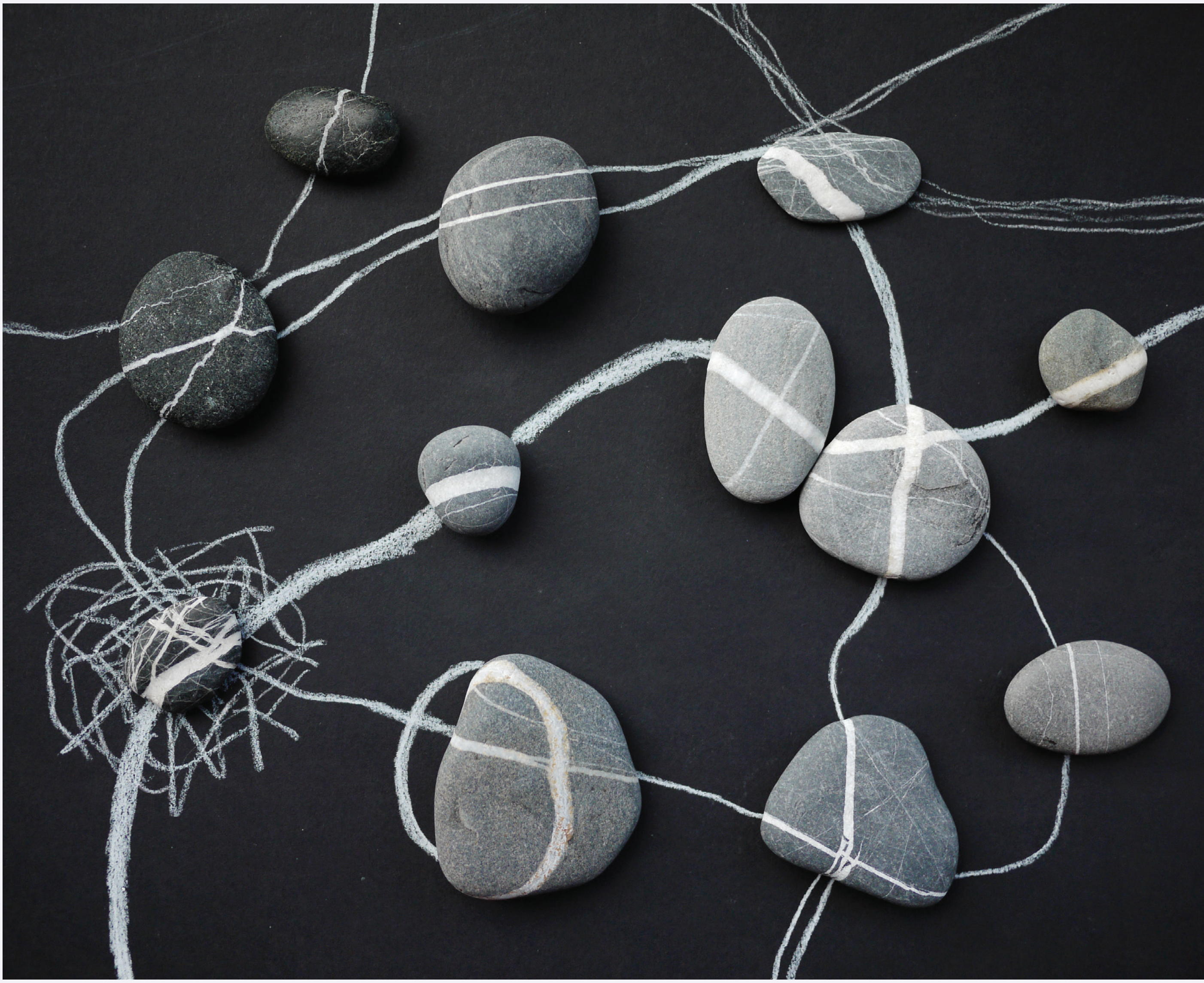
Paas F, Renkl A and Sweller J (2003) Cognitive load theory and instructional design: Recent developments. *Educational Psychologist* 38(1): 1–4.

Reif F (2010) *Applying Cognitive Science to Education. Thinking and Learning in Scientific and Other Complex Domains*. Cambridge, MA: The MIT Press.

Renkl A and Atkinson RK (2003) Structuring the transition from example study to problem solving in cognitive skill acquisition: A cognitive load perspective. *Educational Psychologist* 38(1): 15–22.

Sweller J (1988) Cognitive load during problem solving: Effects on learning. *Cognitive Science* 12: 257–285.

Van Merriënboer JJG, Kirschner PA and Kester L (2003) Taking the load off a learner's mind: Instructional design for complex learning. *Educational Psychologist* 38(1): 5–13.



GETTY

Applying the science of learning in the classroom

PAUL HOWARD-JONES, KONSTANTINA IOANNOU, RUTH BAILEY, JAYNE PRIOR AND SHU HUI YAU
SCHOOL OF EDUCATION, UNIVERSITY OF BRISTOL, UK
TIM JAY
SHEFFIELD INSTITUTE OF EDUCATION, SHEFFIELD HALLAM UNIVERSITY, UK

The US 'decade of the brain' in the 1990s saw the launch of a number of educational programmes that claimed to be 'brain-based'. These were usually unscientific in their approach and motivated by commercial interests. Rather than inform education, these programmes often promoted misunderstandings about the brain: so-called 'neuromyths' (Howard-Jones, 2014). In contrast, the last two decades have seen a blossoming of authentic dialogue between education and neuroscience, aimed at enhancing teaching and learning with insights from the mind and brain. These more recent › initiatives are very different from their predecessors, often including critiques of the myths that the brain-based industry helped to create. These efforts to identify genuine scientific insights that can inform teachers' understanding and practice bear a variety of names, including 'neuroeducation', 'educational neuroscience' and 'mind, brain and education'. Rather than producing brain-based approaches, they converged on the view that neuroscience is one important source of insight into learning to should be considered alongside other scientific and educational sources.

Some critics of these efforts have proposed that education is better served by psychology and that neuroscience can add nothing new to what psychology already offers (Bowers, 2016). In response, those working across neuroscience and education point to how our understanding of the mind and brain are complementary to each other (Howard-Jones, Varma et al., 2016). Indeed, it is usually the collaboration of neuroscientists, psychologists and educators that characterises research involving neuroscience and education. Efforts to consider classroom practice in modern scientific terms have recently been referred to as the 'science of learning' (SoL). They do not promote a single model of classroom learning, but instead refer to a range of insights about learning that have been derived using the scientific method.

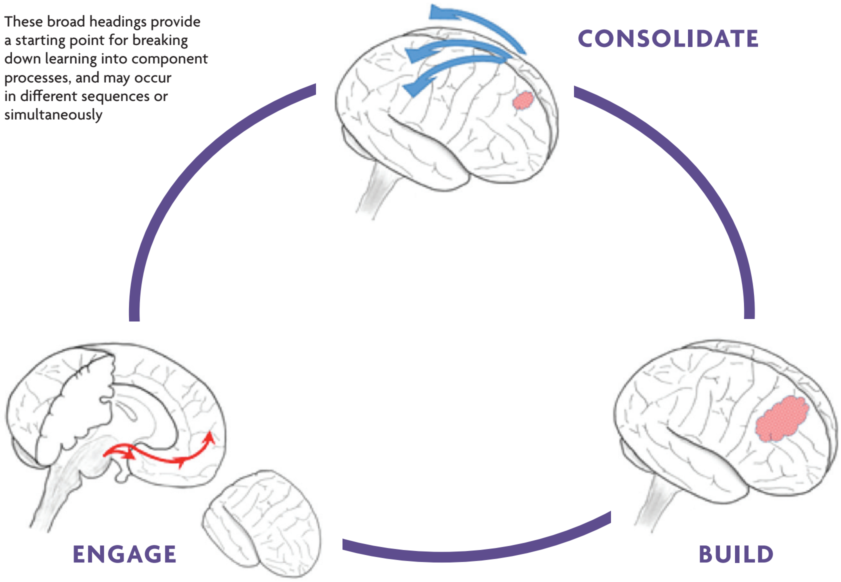
Categorising learning processes: Engagement, building and consolidation

One challenge with applying SoL insights to classroom learning is that they tend to arrive piecemeal from laboratory-based research studies. These findings usually focus on specific aspects of the underlying learning processes, rather than being directly aimed at improving education. We have lacked a SoL framework for analysing classroom practice that interrelates these scientific insights with the day-to-day decisions made by a teacher. However, thinking about some broad categories of learning processes can provide a convenient starting point for such analysis. Under three categories below, we have organised a selection of scientific studies that we consider relevant to 'everyday' classroom teaching and learning processes. We discuss insights into how a learner becomes *engaged* with a source of new knowledge prior to the *building* of new knowledge, and how this new knowledge later undergoes *consolidation*, causing it to become more permanent, accessible and useful. These three categories are broad headings that provide a starting point for breaking down learning into component processes. They are introduced in this order for the sake of convenience; in reality, they may be sequenced differently (**Figure 1**).

Engagement of the learner

The scientific study of engagement with educational contexts is in its infancy. However, scientific studies of 'approach motivation' may shed some light on some popular classroom strategies. These studies have revealed the role of subcortical structures deep below the cortex in the emotional states that encourage us to attend and learn. For example, praise is commonly used as an effective means to reinforce classroom behaviours conducive to learning (Dufrene et al., 2014; Sutherland et al., 2000). Praise is a social reward, and social reward appears to recruit similar subcortical regions of the brain's reward system as receiving money (Izuma et al., 2008) or anticipating food (Farooqi et al., 2007). A recent study has shown increases in reward system activity during the answering of educational questions in conditions that favoured engagement and educational learning (Howard-Jones, Jay et al., 2016). Other types of subcortical activity, including activations within the amygdala, are implicated in the development of maths anxiety and negative emotions towards learning (Young et al., 2012). It appears that both engagement and disengagement involve subcortical structures and

FIGURE 1:
BROAD CATEGORIES OF LEARNING PROCESSES



production of neuromodulators beneath the cortex that influence, in both positive and negative ways, the cortical processes required for learning (**Figure 2**).

The relationship between engagement and learning is not a simple one. While engagement can lead to learning, learning can also lead to a more positive emotional response and further engagement with learning (Superkar et al., 2015).

Building of knowledge and understanding

Once a student is engaged with a source of new knowledge, such as an explanation provided by the teacher, a channel of communication opens that may enable new learning to occur, although much depends on the quality of this communication. Effective teachers (and the resources they use) communicate clearly and concisely, with efforts to minimise distraction. For new learning to be acquired in an educational and meaningful sense, it must also be connected to prior knowledge, and this requires two-way communication. To ensure students' readiness to learn new material, effective teachers encourage students to communicate their prior knowledge through a variety of means. They note their students' responses to questions in class and reflect on the questions their students ask, as well as on students' responses to classroom tests and homework, and use many other types of formative assessment.

A teacher's role here goes beyond just ensuring the student has the required prior knowledge before progressing to new learning content. In school children, the prefrontal regions required to make connections with prior knowledge are developing more slowly than other parts of the brain (Brod et al., 2013). This may disadvantage them in making use of prior knowledge, even when they possess it (Shing and Brod, 2016). It is, therefore, important that children are prompted to reactivate appropriate prior knowledge (e.g. revision question-and-answer) before new information is presented, and then encouraged to make connections between the new information and their existing knowledge. As well as learning new information, a student must also learn how to apply it. Applying new information requires using prior knowledge to transform, organise and elaborate the new input. This type of effortful processing also recruits circuitry in the prefrontal cortex (just behind the front of the brain), which, in turn, implements reflective processes that support performance in long-term and working memory tasks (Ranganath et al., 2003). Much educational learning, therefore, requires the type of effortful, conscious processing that activates the so-called 'working memory' network in the brain, as students attempt to control their attention and manipulate the information they are trying to hold in their conscious attention (Kane and Engle, 2002). For these reasons, the building of new knowledge is often accompanied by increased activation of the prefrontal regions of the brain (**Figure 3**).

Consolidation of learning

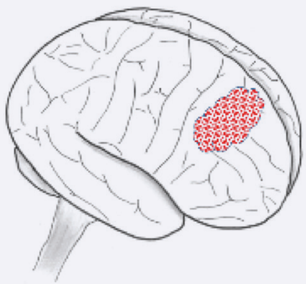
New learning is more vulnerable to loss, and the effortful processing required to recall and apply freshly learnt knowledge occupies the limited working memory capacity we have available. This is a capacity that needs freeing up if we are to learn more. Fortunately, when we consolidate our learning, it not only becomes more permanent, but accessing it also becomes easier and quicker, demanding less conscious effort (Tham et al., 2015). As illustrated schematically in Figure 4, practice tends to shift activity away from working memory regions to regions more involved with automatic unconscious processing (i.e. away from the front of the brain).

Reducing the burden of fresh learning ›

FIGURE 2:
ENGAGEMENT OF THE LEARNER

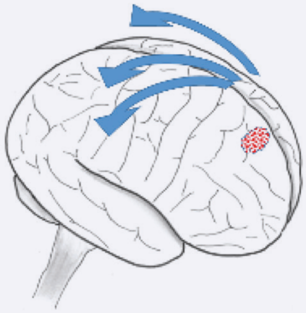
Engagement involves subcortical processes that influence cortical brain activity and our readiness to learn

FIGURE 3:
BUILDING OF KNOWLEDGE



Learning new knowledge activates the 'working memory' network

FIGURE 4:
CONSOLIDATION OF LEARNING



Consolidation shifts activity to regions more involved with automatic unconscious processing – freeing up our working memory network on working memory is important. Our limited working memory needs liberating before it can be occupied by new information, so enabling us to learn more. Consolidation can be helped by practising the recall and application of our new knowledge in different ways. This emphasises the need for engaging opportunities that challenge students to apply and test their knowledge in low-risk tasks that are free of anxiety (unlike exams or formal assessments).

Questioning is often used to assess what learning has been achieved, but it is also an effective means to ensure that this deeper processing occurs, and to accelerate the rate at which learning becomes consolidated. Questioning can take the form of simple retrieval practice, but even this can enhance learning through the unconscious act of reconstructing knowledge (Karpicke, 2011). This is in line with recent neuroimaging research that suggests that repeatedly retrieving information causes it to become represented in the brain in different ways, essentially connecting it with different meanings and making it easier to retrieve in the future (Wirebring et al., 2015).

No prescriptions

It is important to be clear that there is no three-stage model of pedagogy being suggested here, and the categories 'engage', 'build' and 'consolidate' should not be used to conveniently partition a lesson. Such partitioning would over-simplify many learning experiences that are encountered in a real classroom. In everyday teaching and learning, all three types of process might occur simultaneously, or at least in such quick succession that allocating one type of process to any single stage in a classroom activity is unhelpful. For example, consider the situation in which a teacher uses a quiz activity to introduce a new topic and link it to yesterday's learning. In this example, all three types of processes would be involved, if the

When we consolidate our learning, it not only becomes more permanent, but accessing it also becomes easier

teacher successfully engages the children with building new knowledge while also consolidating their old.

Although the science provides principles and a scientifically determined understanding of how learning works, based on concrete measurement of behaviour and brain function, it does not provide a list of 'top tips' or practices that are guaranteed to work with any class or individual in any context. In the absence of a one-size-fits-all prescription for effective teaching, teachers must constantly make decisions based on their own ideas of how learning proceeds and what they observe occurring in their classrooms. It makes sense that this critical theorisation, and the decisions that arise from it, can benefit from an up-to-date and scientific understanding of learning from the sciences of the mind and brain. We are very much at the beginning of being able to apply such understanding in the classroom. There are significant theoretical and cultural gaps that exist between the disciplines of education and the sciences of mind and brain that will require investment, collaborative research and time to fill. However, if learning and the fostering of learning are key concerns of education, there may never be a better time to begin considering classroom practice in scientific terms.

REFERENCES

Bowers J (2016) The Practical and Principled Problems with Educational Neuroscience. *Psychological Review* 123(5): 600-612.

Brod G, Werkle-Bergner M and Shing YL (2013) The influence of prior knowledge on memory: A developmental cognitive neuroscience perspective. *Frontiers in Behavioral Neuroscience* 7: 13.

Dufrene BA, Lestremau L and Zoder-Martell K (2014) Direct behavioral consultation: Effects on teachers' praise and student disruptive behavior. *Psychology in the Schools* 51(6): 567–580.

Farooqi IS, Bullmore E, Keogh J et al. (2007) Leptin regulates striatal regions and human eating behavior. *Science*, 317(5843): 1355–1355. DOI: 10.1126/science.1144599.

Howard-Jones PA (2014) Neuroscience and education: Myths and messages. *Nature Reviews Neuroscience* 15(12): 817–824.

Howard-Jones PA, Jay T, Mason A et al. (2016) Gamification of learning deactivates the default mode network. *Frontiers in Psychology* 6: 16.

Howard-Jones PA, Varma S, Ansari D et al. (2016) The principles and practices of educational neuroscience: Comment on Bowers (2016) *Psychological Review* 123(5): 620–627.

Izuma K, Saito DN and Sadato N (2008) Processing of social and monetary rewards in the human striatum. *Neuron* 58(2): 284–294.

Kane MJ and Engle RW (2002) The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective. *Psychonomic Bulletin & Review* 9(4): 637–671.

Karpicke JD and Blunt JR (2011) Retrieval practice produces more learning than elaborative studying with concept mapping. *Science* 331(6018): 772–775.

Ranganath C, Johnson MK and D'Esposito M (2003) Prefrontal activity associated with working memory and episodic long-term memory. *Neuropsychologia* 41(3): 378–389.

Shing YL and Brod G (2016) Effects of prior knowledge on memory: Implications for education. *Mind, Brain, and Education* 10(3): 153–161.

Supekar K, Iuculano T, Chen et al. (2015) Remediation of childhood math anxiety and associated neural circuits through cognitive tutoring. *Journal of Neuroscience*, 35(36): 12574–12583.

Sutherland KS, Wehby JH and Copeland SR (2000) Effect of varying rates of behavior-specific praise on the on-task behavior of students with EBD. *Journal of Emotional and Behavioral Disorders* 8(1): 2–8.

Tham EKH, Lindsay S and Gaskell MG (2015) Markers of automaticity in sleep-associated consolidation of novel words. *Neuropsychologia* 71: 146–157.

Wirebring LK, Wiklund-Hornqvist C, Eriksson J et al. (2015) Lesser neural pattern similarity across repeated tests is associated with better long-term memory retention. *Journal of Neuroscience* 35(26): 9595–9602.

Young CB, Wu SS and Menon V (2012) The neurodevelopmental basis of math anxiety. *Psychological Science* 23(5): 492–501.

Taking curriculum seriously

CHRISTINE COUNSELL
DIRECTOR OF EDUCATION,
THE INSPIRATION TRUST, UK

Curriculum is all about power. Decisions about what knowledge to teach are an exercise of power and therefore a weighty ethical responsibility. What we choose to teach confers or denies power. To say that pupils should learn 'the best that has been thought and said' is never adequate. Start the conversation, and questions abound: 'Whose knowledge?'; 'Who decides on "best"?'.

Such questions reflect concern about whether schooling reproduces inequalities or interrupts them. Such questions matter. But reducing knowledge to voice will not get us far either. The contentious questions – Which works of literature? Which historical stories? Which art? – cannot be resolved by some optimal blend of diversity, some nirvana of neutrality, as though distribution across the sources of knowledge or types of knower will settle things. No matter how redemptive of former injustice, no holy grail of content selection will be reached.

Nor does adding in preparation for the 21st century help. How can we decide what is relevant to the ever-shifting 'now'? Worse, relevance quickly merges ›

ISTOCK

with *perceptions* of relevance and, before we know it, content is chosen for being engaging or deemed 'relevant' by the pupil. Then we have completely lost our moorings. At that point, we lose touch with the duty of including the next generation in a shared language of abstract concepts, in common tools for precise thought, in the possibility of objective knowledge underlying them and in the possibility of citizens appraising it. These things serve the rationalised sensibility on which participation in a democratic society depends.

Appeal to knowledge *and* skills is no corrective either. These terms invoke such diverse assumptions that discussions end up at cross purposes. And to suggest that knowledge is less important than skills is to ignore the way in which our knowledge changes us, including our curiosity and capacity for new knowledge.

As educators, we need something more coherent concerning the character of knowledge – its structure, its origin, its status as a set of truth claims (such as their revisability) and the relationship of teachers and pupils to that knowledge. How, how far and when can teachers or pupils participate in challenging or reaching those truth claims? In which subjects and under what circumstances must they just accept them (for now) as givens?

How can a senior school leader tackle these questions? School leaders need practical solutions; few have time to swallow philosophical tomes. Yet to shy away from big ideas is always a false saving. And intellectual resources exist that are rigorous, accessible and useful. First, we have longstanding traditions of practice and debate within subject communities concerning ways of teaching the structure, status and origin of knowledge. Second, a relatively recent research programme arising from the sociology of knowledge advances the idea of 'powerful knowledge'. In this article, I will reflect briefly on just one theme emerging from the first, which is further illuminated by the second, namely the curricular distinction between substantive and disciplinary knowledge.

Substantive and disciplinary knowledge

Substantive knowledge is the content that teachers teach as established fact – whether common convention, concept or warranted account of reality. You might want pupils to know of crotchets, percentages, the Treaty of Waitangi, Debussy or prokaryotic cells. In calling this 'substantive', we are treating the material presented as givens.

Disciplinary knowledge, by contrast, is a curricular term for what pupils learn about how that knowledge was established, its degree of certainty and how it continues to be revised by scholars, artists or professional practice. It is that part of the subject where pupils understand each discipline as a tradition of enquiry with its own distinctive pursuit of truth. For each subject is just that: a product and an account of an ongoing truth quest, whether through empirical testing in science, argumentation in philosophy/history, logic in mathematics or beauty in the arts. It describes that part of the curriculum where pupils learn about the conditions under which valid claims can be made, and associated conventions such as what constitutes evidence or argument in that subject.

In those subjects where content choices are potentially infinite and selections must be made, it is through due attention to the disciplinary dimension that pupils know that *what I teach is not all that there is*. In those subjects where truth is sought through argumentation, pupils learn that even the selection and juxtaposition of two facts in a narrative amount to an interpretation, and that interpretation can be conducted responsibly or irresponsibly, but never definitively. A successful history, geography, RE or literature curriculum, in which the disciplinary was visible, will leave pupils absolutely clear that *even the curriculum itself*, as they received it, was one such selection, and must not be confused with the whole domain.

This substantive–disciplinary distinction works to differing extents and in very different ways across subjects. The disciplinary dimension is barely relevant, for example, in school-level modern languages. Moreover, *how* it gains expression in a school curriculum varies widely. In history, pupils encounter historical scholarship in order to learn how historians participate in a social process of claim and counter-claim. But they can't read scholarship without being drawn into the argument themselves. The date of the Treaty of Versailles is a given. Many events before and after the Treaty of Versailles are givens. But attributions of cause, consequence or significance to the Treaty of Versailles are *not* givens. The humblest of Year 7 history essays is elementary training in argumentation and produces legitimately different conclusions. Moreover, teacher-led, subject-specific research traditions have explored multiple ways of doing

To suggest that knowledge is less important than skills is to ignore the way in which our knowledge changes us, including our curiosity and capacity for new knowledge

SHUTTERSTOCK

this well by blending secure substantive with rich disciplinary knowledge so as to refine pupils' appreciation and practice of historical argument (e.g. Foster, 2013).

Is it the same in science? Not quite. The substantive and disciplinary distinction definitely holds. Pupils study scientific methods, understand degrees of certainty, conduct investigations. But in terms of pupils' relationship to those processes and conclusions, there are differences. At school level, conclusions are not normally 'up for grabs' by pupils in quite the way they are in philosophy, literature or history, where argumentation itself is the method. In other words, each school subject stands in a slightly different temporal relationship to its real-world cognate of scholarly and professional knowledge production.

Therefore, when schools talk about pupils 'being' artists, historians or scientists, they are rarely talking about the same thing across subjects. In some subjects, we see frequent knowledge production processes (composing and creating; arguing and judging). In others, even those full of practising and doing within subject skills, the balance tilts towards knowledge reproduction, with less open-ended interpretation (a reason to avoid conflating 'disciplinary' with 'skills'). This doesn't mean that disciplinary knowledge is less important where less is 'up for grabs'. It may just mean that pupils (for now) are learning more about how *others* have established truth claims. Even for a textbook or teacher to state, '*Scholars are unsure* whether trade in seventh-century Arabia…' is to show disciplinary attentiveness by modelling responsible claims.

All this matters in whole-school leadership. 'Substantive' and 'disciplinary' are illuminating categories not only for understanding curriculum but also for grasping the implications of curriculum for teaching and assessment. Regarding teaching, they help senior leaders to interpret teaching activities in the light of an object. Before one can apply research into the efficacy of (say) pair/group discussion, one needs to establish *what* is being taught. Failure to do this has caused untold problems. A world of difference exists between a paired discussion designed to practise a facet of open argument derived from a particular discipline and a paired discussion designed for learning substantive content. In one, the dialogue teaches a disciplinary process; in the other, the rationale is constructivist pedagogy. They cannot be appraised in the same way. Regarding assessment, an understanding of substantive and disciplinary would have seen senior leaders questioning the use of level descriptions for formative assessment years earlier than actually happened. Each subject has its own pattern and interplay between learning substantive content and engaging with its origins or processes. The practice of treating *progress* as mini-versions of level descriptions and GCSE mark schemes has dangerously distorted subject structures and journeys.

The expression 'knowledge-rich' curriculum is normally associated only with substantive knowledge. This is understandable given that we're emerging from an era in which mastering content was sidelined, even demonised, and given the attention now paid to research on the relationship between academic content knowledge and reading, on the vocabulary gap between advantaged and disadvantaged and on the role of knowledge in making subsequent learning possible (Willingham, 2017). But we cannot neglect the disciplinary dimension. This is achievable even in the primary phase. Our Year 4 pupils' questions show that they are fascinated by Mendeleev's cleverness in making the periodic table open and revisable, by van Leeuwenhoek's worries about the Royal Society taking his microscope seriously, by the questions that geographers ask about borders and boundaries.

Powerful knowledge

The categories 'substantive' and 'disciplinary' are merely one cross-section of useful curriculum analysis but they are foundational. Their significance is further illuminated by a body of research within the sociology of knowledge that tackles education's knowledge question within a progressive agenda for social justice (Rata, 2016; Young, 2008). Associated with the concept of 'powerful knowledge', these theorists challenge the view that academic knowledge necessarily perpetuates disadvantage by remaining the preserve of the powerful forces that created it. Drawing on Durkheim, they argue that knowledge developed by academics in intellectual communities becomes independent of those socio-historical origins through its abstract and generalising tendencies. Because this specialised knowledge is not acquired or produced informally in everyday experience, entitlement to it through curriculum is vital (Young and Muller, 2016).

Not only does this knowledge offer the language of abstract concepts, but these precise concepts also become tools with which to imagine change. They enable humans to theorise possibility and think the un-thought (Wheelahan, 2010). To achieve this, a curriculum must enact processes of 'epistemic ascent' (Winch, 2013), by which concepts already understood by students are brought into new relations of abstraction and generality, giving the student yet more power to challenge, rethink and create. McPhail (2014) illustrates this with music. He explains how without epistemic understanding, pupils are restricted to subjective experience of music. Discussing the complex relationships between music's subjective and objective dimensions, McPhail shows how teachers can integrate students' ownership of music's affective power with access to knowledge fundamental to the conversations of the discipline.

Powerful knowledge theorists emphasise that specialised knowledge is emergent, provisional and revisable through continuing social processes such as scholarly research and critique

While collaborating in building a trust-wide, knowledge-rich curriculum, we have found it useful to reflect on this body of work, not only regarding the power inherent in the abstractions of substantive knowledge, but also regarding each subject's disciplinary dimension. Powerful knowledge theorists emphasise that specialised knowledge is emergent, provisional and revisable through continuing social processes such as scholarly research and critique. For pupils to learn how knowledge is formed and changed distinguishes a knowledge-rich curriculum grounded in 'powerful knowledge' from one merely ossifying a canon. In a stark prediction of three futures, Young and Muller (2016) contrast a Future 1 in which knowledge is fixed and tied to the social context that produced it, and a Future 3 whose radical potential harnesses the fertile, generative qualities of knowledge to give all citizens access to intellectual tools for rational change.

This article scratches the surface of debates that school and system leaders cannot ignore. Given its implications for democracy, curriculum is a serious business. We must engage with its provenance and properties.

REFERENCES

Foster R (2013) The more things change, the more they stay the same: Developing students' thinking about historical change and continuity. *Teaching History* 151: 8–17.

McPhail G (2014) Pathways to powerful knowledge: A case for music. In: Barratt B and Rata E (eds) *Knowledge and the Future of Curriculum: International Studies in Social Realism.* Houndmills: Palgrave Macmillan, pp. 123–135.

Rata E (2016) A pedagogy of conceptual progression and the case for academic knowledge. *British Educational Research Journal* 42(1): 168–184.

Wheelahan L (2010) *Why Knowledge Matters in the Curriculum.* Abingdon: Routledge.

Willingham D (2017) *The Reading Mind.* San Francisco: Jossey Bass.

Winch C (2013) Curriculum design and epistemic ascent. *Journal of Philosophy of Education* 47(1): 128–146.

Young M (2008) *Bringing Knowledge Back In: From Social Constructivism to Social Realism.* London: Routledge.

Young M and Muller J (2016) *Curriculum and the Specialisation of Knowledge.* London: Routledge.

YOUR professional body

RAISING the status of teaching

CELEBRATING
your commitment to the profession and for making a difference

SUPPORTING
you to deliver excellent teaching and constantly develop through research and insight

CONNECTING
you with other teachers to share practice and shape your profession

JOIN THE CHARTERED COLLEGE OF TEACHING