If you are short on time you could read the précis.

Follows is a précis of a literature review published in 2014 covering over 30 years of Cognitive science studies as well as other recent publications from the last decade.

The conclusions are counter intuitive (as science discoveries typically are) and have implications for lesson design and assessment.

They are the main reason I have moved to embedding direct instruction into flipped lessons – my own attempt at squaring the circle, details of how to follow by tomorrow.

I will send separately some test data of the effect of using these implications on my classes with that email.

Contents

[A] Précis of the claims.

1. ***Memorisation leads to understanding***, ***not understanding leads to memorisation (remembering) or that the two are needed in balance***.

Understanding is not a separate parallel mental process but one that is intimately entwined with memory, which takes precedence.

I cannot find a single science paper that provides evidence for rote learning, that it even exists or is a negative, it appears to be an arbitrary ad hoc classification based on the misunderstanding of the necessity for repetition to build memory.

2. ***Thinking skills cannot be taught***, they are species specific (other species do not possess the same range or depth as ours) and they are species limited, they are not infinite.

3. **There is no evidence for "Higher Order Thinking skills" instead they occur in parallel and are modular.**

    a. *Quote* "**Biologically primary knowledge** is **modular** (e.g. the modularity of number sense has been demonstrated by Mandelbaum, 2013), **with different skills likely to have been acquired at different evolutionary epochs**. For example, we are likely to have **evolved** the **ability** to **learn** to **recognise faces independently** of **learning** to **listen** and **speak**."

(Tricot,A; Sweller,J. (June 2014)see top of page 5.

    b. See numbers and [6] and [9] here http://sciencesite.16mb.com/page14.html

I will review the evidence for these conclusions both empirical and evolutionary via hyperlinked citations in brackets.

Science researchers are typically understated in their claims however such is the depth of evidence in relation to claims [1] and [2] above that John Sweller commented on critical and creative thinking and problem solving skills in his submission to the Australian Curriculum Review that;

Quote ***"There is little more useless than attempting to teach generic thinking skills and expecting students to be better thinkers or problem solvers as a result.***

Despite decades of work, there is no body of evidence supporting the teaching of thinking or other generic skills… It is a waste of students' time placing these skills in a curriculum because we have evolved to acquire them without tuition.

While they are too important for us not to have evolved to acquire them, insufficient domain-specific knowledge will prevent us from using them.

We cannot plan a solution to a mathematics problem if we are unfamiliar with the relevant mathematics.

Once we know enough mathematics, then we can plan problem solutions.

Attempting to teach us how to plan or how to solve generic problems will not teach us mathematics. It will waste our time."

(Sweller,J. (January, 2014). Submission to the Austrailian National Curriculum Review)

He goes on to state that (reformatting and emphasis is mine);

Quote "Indeed, many randomised, controlled trials that now have been run indicate that ***too many recommended instructional procedures are useless***.

The data is overwhelming that:

1. ***We should be teaching domain-specific knowledge, not generic skills***.
2. ***Initial instruction*** when dealing with ***new information should be explicit and direct***.
    a. ***Students only should be asked to explore an area after they have acquired a knowledge base sufficiently large to ensure that they are unlikely to waste their time following dead-ends and irrelevancies.***
3. Assuming instruction will be directed to the acquisition of domain-specific knowledge and will be explicit, it needs to be organised in a fashion that ***takes into account some critical aspects of human cognition***.
    a. Instruction should consider;
        i. the well-known ***capacity and duration limits of working memory [also known as short term memory]*** when dealing **with novel information**
        ii. and the ***relations between working memory [also known as short term memory] and long-term memory***.

b. We should remember that ***if nothing has changed in long-term memory then nothing has been learned***. There are many instructional procedures based on our knowledge of human cognition that have been shown by randomised, controlled trials to facilitate learning compared to current procedures.

(Sweller,J. (January, 2014). Submission to the Austrailian National Curriculum Review)

This submission was based on this research and literature review.

(Tricot,A; Sweller,J. (June 2014). Domain-Specific Knowledge and Why Teaching Generic Skills Does not Work. *Educational Psychology Review*. Vol. 26 (Issue 2), p265.)

5. Regarding Claim [2] on the myth of rote learning

Quote **:**

"Question: So often, **even if I inventively present new material or emphasize applying the new knowledge in various situations, what I get back from my student seems "rote."** Why is this? What can I do about it?

Answer: Cognitive science has shown us that **when new material is first learned, the mind is biased to remember things in concrete forms that are difficult to apply to new situations.**
This **bias** seems best **overcome by the accumulation of a greater store of related knowledge, facts, and examples**.

To understand this bias, we need to first **distinguish between what I would call genuinely "rote" knowledge and the much more common "inflexible" knowledge.**
Second, we'll look at a number of experiments that strongly suggest the mind tends to remember new concepts in terms that are concrete and superficial, not abstract or deep.
Third, we'll review experiments designed to illuminate the nature of expertise, which can be thought of as consisting of "flexible" knowledge.
Fourth, we'll consider what this means for teaching.

What is Rote Knowledge?

Much of what is commonly taken to be rote knowledge is in fact *not* rote knowledge.
Rather, **what we often think of as rote is, instead, *inflexible* knowledge, which is a normal product of learning and a common part of the journey toward expertise**."

http://www.aft.org/periodical/american-educator/winter-2002/ask-cognitive-scientist

[B] SUMMARY OF COGNITIVE SCIENCE MODEL see TLA from last year.

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1. This model states that a human being will only construct an understanding to the extent that they;

1. pay **attention**,
2. **encode** the **knowledge** of the topic by and **memorising** the;
    a. **concepts**,
    b. **facts**,
    c. **relationships** (between concepts, between facts and between concepts and facts, normally expressed as an If...Then statement)
    d. and **sequences** *(also known as '**procedural knowledge'**, **'cognitive routines'** or **'skills'**)* (This was the area my TLA looked at last year – **encoding**)
    e. this **memorisation** ***then leads*** to ***understanding*** **not the other way around.**
3. and **avoid overloading** their **short term (working) memories** which only lasts for a couple of minutes, **hence the need to reduce pace and variety as these introduce new instructions and processing**.

(Eggen, 2010: Azevedo & Cromley, 2004).

4. **Store** the newly acquired knowledge in **long term memory** by **deliberate independent practice** (rather than independent / discovery learning).
5. **Retrieve from long term memory after a period of deliberate forgetting the knowledge** (includes **skills** / **sequences**) that then need to be practiced to **automaticity prior to testing**.

[C] Implications

Quote **regarding claim [2]**

"After more than 20 years of lamentation, exhortation, and little improvement, maybe it's time to ask a fundamental question: ***Can critical thinking actually be taught?***

Decades of cognitive research point to a disappointing answer: not really.

People who have sought to teach critical thinking have ***assumed that it is a skill, like riding a bicycle, and that, like other skills, once you learn it, you can apply it in any situation.***

Research from cognitive science shows that thinking is not that sort of skill.

The processes of thinking are intertwined with the content of thought (that is, domain knowledge).

Thus, if you remind a student to ***"look at an issue from multiple perspectives"*** *often enough, he will learn that he ought to do so,* ***but if he doesn't know much about an issue, he can't think about it from multiple perspectives.***

You can teach students maxims about how they ought to think, but without background knowledge and practice, they probably will not be able to implement the advice they memorize.

…. Along the way, we'll see that ***critical thinking is not a set of skills that can be deployed at any time, in any context.***

It is a type of thought that even 3-year-olds can engage in—and even trained scientists can fail in. And it is very much dependent on domain knowledge and practice."

Willingham,D. (SUMMER 2007). Critical Thinking Why Is It So Hard to Teach?. *AMERICAN EDUCATOR*. . p8-18, **SEE Pages 8 to 9**

Quote **re claim [2] & METACOGNITION**

"Cognitive scientists refer to these maxims as metacognitive strategies. They are little chunks of knowledge—like "look for a problem's deep structure" or "consider both sides of an issue"—that students can learn and then use to steer their thoughts in more productive directions… Unfortunately, metacognitive strategies can only take you so far. Although they suggest what you ought to do, they don't provide the knowledge necessary to implement the strategy… Likewise, you may know that you ought not accept the first reasonable-sounding solution to a problem, but that doesn't mean you know how to come up with alterative solutions or weigh how reasonable each one is. That requires domain knowledge and practice in putting that knowledge to work

[D] Evidence

Types of Knowledge taken from (Sweller,J. (January, 2014). Submission to the Austrailian National Curriculum Review)

This submission was based on this research and literature review.

(Tricot,A; Sweller,J. (June 2014). Domain-Specific Knowledge and Why Teaching Generic Skills Does not Work. *Educational Psychology Review*. Vol. 26 (Issue 2), p265.)

*D.1 [**MEMORISATION**] **Domain-Specific Knowledge (reformatting and emphasis is mine);***

Quote

"***Generic skills** are far more basic and **far more important than domain-specific knowledge**, **but they do not need to be taught because we have evolved over countless generations to acquire them effortlessly and unconsciously simply by membership of a society**.*

***Generic skills are a component** of what has been labelled **biologically primary knowledge** (Geary, 2012).*

*Examples are learning to use general problem solving skills such as **relating a current problem to a previous problem with known solutions, or engaging in planning**.*

It is a waste of students' time placing these skills in a curriculum because we have evolved to acquire such skills easily, automatically, unconsciously and without tuition.

Because of their importance, we have evolved to acquire generic skills and so do not need to have them placed in a curriculum.

Attempting to teach students how to plan or how to solve generic problems will waste their time.

***Biologically secondary knowledge** is knowledge we have **not specifically evolved to acquire** but that we **need** for **cultural** reasons.*

*We will not acquire such knowledge automatically and indeed, **we invented schools and other educational institutions precisely in order to teach biologically secondary knowledge** because otherwise it tends not to be learned.*

*Until the advent of universal education, **while everyone knew how to listen and speak because those skills are biologically primary**, **very few people knew how to read and write because reading and writing are biologically secondary and need to be explicitly taught**. Other examples of biologically secondary knowledge can be found in virtually every topic taught in schools.*

Biologically secondary knowledge is domain-specific [it is not transferable between domains/subjects]**. We learn that when faced with a problem of the form, a/b = c, solve for a, we should multiply both sides by the denominator b. **This knowledge is invaluable when solving similar problems but useless for other purposes.

It is domain-specific (Tricot & Sweller, in press)."

D.2 Explicit Instruction

*Quote “We obtain **domain-specific knowledge from other people by imitating what they do, listening to what they say or reading what they write. We do not need to be taught to obtain information from others because we are one of the few species to have evolved to do so.***

It is a biologically primary skill that is missing in most species of animals.

***Given our natural skills in obtaining information from others, it is bizarre that many educators recommend that learners do not need to be explicitly taught. Rather, according to this view, the role of teachers should be to facilitate the acquisition of knowledge by learners rather than to provide it**.*

On this view, explicit guidance should be rarely provided. Curiously, this view can be easily tested.

Provide one group of randomly chosen learners with minimal guidance and another group with explicit instruction.

The result will be exactly as one might expect. Minimal guidance results in minimal learning.

Of course, in one of many cases of ideology trumping data, those advocating the use of minimal guidance never bothered collecting the data because they were certain minimal guidance was good for learners and so did not feel they needed supporting data. How did this ludicrous view gain currency, indeed dominance, among educators?

*The argument was easy and plausible at the time. **We were told to look at how readily children learned to walk, talk etc. without explicit instruction. The reason they found it so hard to learn in school, it was suggested, was because we insisted on teaching them rather than leaving them to discover things for themselves**. The previous section on biologically primary and secondary knowledge should have put paid to that argument but only if one knows the distinction between these two forms of knowledge. Based on the distinction, the domain-specific information relevant to all areas of education should be provided explicitly to students (Kirschner, Sweller, & Clark, 2006).”*

Quote D.2 **“Instructional Design**

We know enough about those aspects of human cognition associated with biologically secondary knowledge to design effective instruction.

Knowledge held in long-term memory transforms what we can do and transforms who we are. Immense amounts of domain-specific knowledge can be stored in long-term memory and that is the foundation of expertise (De Groot, 1965; Ericsson & Charness, 1994).

It takes a long time and lots of practice. In the early stages of learning, we are dealing with a limited capacity, limited duration working memory that must process all new, domain-specific information before it can be stored in long-term memory.

We need to design instruction to reduce working memory [short term memory] load and transfer information to long-term memory. [Hence the need to reduce variety and pace]

We now have many techniques for doing so (Sweller, 2012; Sweller, Ayres, & Kalyuga, 2011).

Once knowledge has been stored in long-term memory, we are transformed. The limitations of working memory disappear and we can do things that we otherwise could not dream of doing. *Acquiring new, domain-specific skills, both cultural and practical, provides a major purpose of education. Those skills come from knowledge held in long-term memory.*

People who can think, have not been taught to think because thinking is a biologically primary skill. Rather than having been taught to think, people who can thing have acquired immense amounts of knowledge that allows them to think about things that are useful to us. *Without the requisite knowledge, nobody can think in a useful manner.* ***There is little more useless than attempting to teach generic thinking skills and expecting students to be better thinkers or problem solvers as a result. Despite decades of work, there is no body of evidence supporting the teaching of thinking or any other generic skills.***

We now know much more than we did about the ;

1. ***nature of the knowledge that students need to acquire,***
2. ***about our cognitive architecture that allows us to assimilate that knowledge,***
3. ***and about the instructional procedures that will facilitate knowledge acquisition.***

Educators also require knowledge of these structures and functions. At present, too few do. The result can be recommendations that are random in their effectiveness."

[D.3] 3 examples from real life, chess players, memory savants, Physics students **that show that memory leads to understanding.**

[1] Chess players

Quote **"These results altered our view of human problem solving and, indeed, of human cognition.**

[CHESS] Masters were superior to lower-ranked players not because they had acquired complex, sophisticated general problem solving strategies, nor general memory capacity, but rather, because they had acquired an enormous domain-specific knowledge base consisting of tens of thousands of problem configurations along with the best move for each configuration (Simon & Gilmartin, 1973).

No evidence, either before or after De Groot's work **has revealed differential, general problem solving strategies, or indeed, any learned, domain-general knowledge [transferable skills], that can be used to distinguish chess masters from lower ranked players.**

The only difference between [chess] players that we have is in terms of domain-specific knowledge held in long-term memory.

Furthermore, no other difference is required to fully explain chess problem solving skill".

(Tricot,A; Sweller,J. (June 2014)see page 18.

[2] Memory savants

Quote "Contrary to popular opinion, studies indicated that the **techniques used by exceptional performers to memorise lists of random digits or random letters are readily learnable**.

People who perform at a high level in memory tests are simply experts in memory test tasks because they have domain-specific knowledge concerning these tasks.

Investigation of the strategies used indicated that they were *domain-specific* rather than [*domain*]-general [thinking skills / abilities and so transferable] (Ericsson & Charness, 1994).

Learning to remember long strings of digits does not transfer to learning to remember long strings of letters [hence thinking skills are not transferrable]"

(Tricot,A; Sweller,J. (June 2014)see page 20.

Physics Students

Quote *"She presented novices and experts with a task in which they were presented with a variety of physics problems that they **had to sort into categories**.*

The experts were advanced PhD students in physics, and the novices were physics undergraduates.

*The results showed that **experts sorted the problems based on structural cues relevant to Domain-Specific Knowledge** problem solution **while novices used superficial, physical cues.***

*For example, **novices might group problems together because they included an inclined plane** while **experts were more likely to group problems together because, for example, they all relied on conservation of energy for their solution.** "*

The basic expert-novice result, that experts' knowledge is represented at a "deep" level (however one characterizes "deep"), while novices' knowledge is represented at a more concrete level, has been replicated in many domains, ranging from knowledge possessed by scientists to taxi drivers" (Chi, 1993, p. 12)."

(Tricot,A; Sweller,J. (June 2014)see page 22-23.