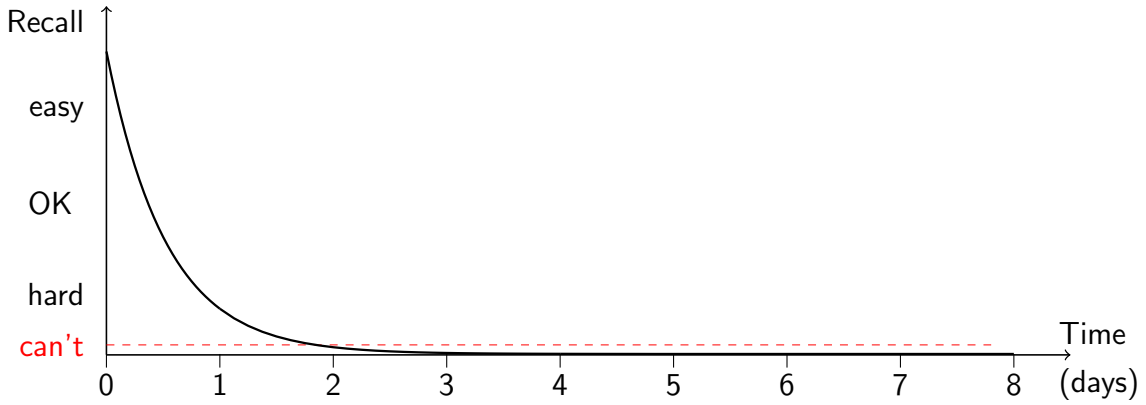
"Learning is the acquisition of knowledge and skills and their application at a later time and in a range of contexts" [1]

In this document I'll look at problems that low attaining learners have with respect to these three primary learning goals: acquire, recall and apply learning; and other problems they experience with our attempts to improve their learning.

(1) Retaining and recalling learning

Doug Rohrer and Kelli Taylor's research suggests that poor maths attainment is primarily because learners forget what they have learned.[2] My experience too,[3] tells me that learners ability to recall is far worse than their ability to acquire. Blake Richards and Paul Frankland[4] say that the primary goal of memory is "for intelligent decision-making in dynamic, noisy environments". They explain that, forgetting what we don't use is as important to us, in terms of decision making, as being able to recall what we need to use.

So let's look at what we know about retaining and recalling learning.[5] Retaining learning isn't enough, it's no good if we have filed away some learning, and then can't recall it when we need it. My experience is that almost all low attaining maths learners forget "new learning" within 3 days, unless they use it.



Ebbinghaus' forgetting curve can be summarised "if we learn something and don't use it, over time we will forget it". Using, i.e. applying, what we learn helps us recall it better, but if we can't recall learning then we won't be able to apply it. If we can't remember learning when we need to, and having our memory jogged is not effective, we will need to re-learn it. Although sometimes what we experience as that "I remember I've learned this before feeling" can make re-learning easier.

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[1] Matt Bromley
http://www.sec-ed.co.uk/best-practice/the-process-of-learning-and-the-implications-for-pedagogy-part-1/

[2] Reports which conclude e.g. "less than one third of U.S. students are rated as proficient in maths ... lead people to conclude that students are not learning, but it is possible that many mathematical concepts are learned but later forgotten." Rohrer, D. and Taylor, K. 2006 The effects of overlearning and distributed practice on the retention of mathematics knowledge. Applied Cognitive Psychology, 20, 1209 - 1224.

[3] 25 years working as a maths teacher, 5 years working on embedding maths learning

[4] The Persistence and Transience of Memory. Richards B.A., and Frankland P.W. Neuron. 2017 Jun 21;94(6):1071-1084.

[5] https://www.youtube.com/watch?v=1FQoGUCgb5w (the first 2 minutes)

If we want low attaining learners to be able to apply their learning and for the learning to become firm foundations for future learning we must dramatically increase that "up to 3 day" duration. With an annual scheme of learning, we need the duration of the "new learning" to be at least a year.

Can we extend the duration of "new learning" through teaching? We know a number of ways to improve, at the point of teaching, how much learners can learn and retain of what we teach:

- provide an environment that learners feel safe in
- gain learners attention
- stimulate the senses . . . onto that which we wish to teach
- increase learners' motivation to learn
  - motivation is an outcome not a cause of achievement
  - motivation is a medium-long term goal of the teacher
- make learners think
  - ask learners to guess before we teach
  - find the sweet spot between too easy and too hard
- encouraging learners to make links with existing knowledge
  - have students practise pre-requisite skills before adding new
  - contextualise
  - use metaphor
- make thinking easier for students (not harder)
  - hearing words and seeing pictures makes thinking easier but hearing words and seeing the same words makes thinking harder
  - interleaving examples and practice makes thinking easier but blocking examples and practice makes thinking harder (i.e. all the examples 1st, all the practice 2nd)
  - scaffold and then gradually remove the scaffolding

These, can move a student from one forgetting curve to one which lasts a little longer, we may perhaps increase the "long lasting-ness" of the learning by a small proportion we cannot expect to increase it many-fold. Even the very best teacher can't, at the point of teaching, enable even the most diligent low attaining learner to retain "new learning" for long enough to become firm learning foundations for next years teaching and learning.

(2) Applying learning

Low attaining learners are worse at "transferring their skills" than their peers. This means even once "new learning" is firmly embedded, we need to spend more lesson time to teach low attaining learners to apply their skills in different situations.

(3) Acquiring learning

All learners are limited by how much "new learning" they can acquire at one time - this is constrained by two factors

- what the learner "already securely knows" and
- working memory capacity.

What the learner "already securely knows", that is, the existing learning accessible in long term memory, can be used to "hang new learning on". If we try to teach several cumulative skills from a topic at one time, the first skill can be built on the firmest learning foundations, the next on more insecure foundations and so forth. The more we try to teach at one time, the less "firm" or the more "unstable" the learning foundations are.

Nelson Cowan[6] tells us that we have 4 $\pm$1 slots in working memory. A learner who only has 3 slots[7], can't learn a process with as many stages as a learner with 4 slots. Working memory capacity limits how many cumulative skills we can teach at a time. But working memory capacity also limits how many similar but different skills we can teach, since some of the working memory capacity needs to be used to differentiate between those skills.

We, too often, see working memory overload symptoms: missing steps, muddling methods and "giving up" from low attaining learners in maths. We know if we teach "too much" at one time, we won't be successful - the new learning won't be built on "firm enough" learning foundations and working memory will become overloaded. At best, some of the "too much" won't be learned and at worst all of the "too much" becomes muddled and none is learned.

If, to overcome this the problem of teaching "too much", we teach "less on a topic at one time", then if topics are taught only once a year - as they are in most secondary schools - the gap between low attaining learners and their peers will continue to increase.

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[6] Cowan N. The magical number 4 in short-term memory: a reconsideration of mental storage capacity. Behav Brain Sci. 2001;24:87 - 114. [PubMed] [Google Scholar]

[7] Psychologists estimate that 10% of learners have, what they class as, "poor working memory" Gathercole, 2008 Working memory in the classroom, Presidents' Award Lecture at the Annual Conference of The British Psychological Society
https://thepsychologist.bps.org.uk/volume-21/edition-5/working-memory-classroom

(4) Giving feedback

We know that feedback is effective in raising attainment[8], especially for low attaining learners. In order to be effective, the feedback needs to be remembered until it can be applied. With annual schemes of learning, neither the "feedback", nor the "new learning" are likely to be remembered until the topic is next tested or taught.

(5) Scaffolding

Scaffolding is a valuable teaching tool that is used more with low attaining learners than their peers. Scaffolding needs to be "faded" if we wish learners to be able to independently apply their learning without scaffolding.[9] However if we fade the scaffolding too fast - and I would say during a lesson is too fast - we increase the working memory load and the learner will struggle. If we fade the scaffolding more slowly, the learner may have forgotten both the new learning and how to use the scaffolding before we manage to fade it.

Summary of problems

The depressing picture is that low attaining learners aren't embedding much learning and can't learn much from a topic at one time. Teachers need to spend more lesson time, than with other learners, teaching low attaining learners to apply skills they have learned. An "each topic once per year" scheme of learning means we are forced to teach less new learning to low attaining learners than their peers, and scaffolding and feedback are not as effective as they could be.

The solution: part 1

We can extend the duration that "new learning" can be recalled for by using retrieval practice.[10] Both feedback and scaffolding can be applied more effectively with retrieval practice. For maximum embedded learning with a minimum number of practices:

- the learner should recall and apply the learning, i.e. practise it, just before they would otherwise forget it;
- and the practices should be spaced over increasing intervals of time.

So should we use retrieval practice? As with everything we should consider the costs as well as the benefits. The main cost is that teachers need to think outside the "lesson box". It will take a few months for low attaining learners to improve "new learning" to "firm foundations for future learning". We can no longer think that what we "taught last lesson" has been learned. Perhaps we

[8] Kluger, A. N., and DeNisi, A. (1996). The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. Psychological Bulletin, 119(2), 254?284.

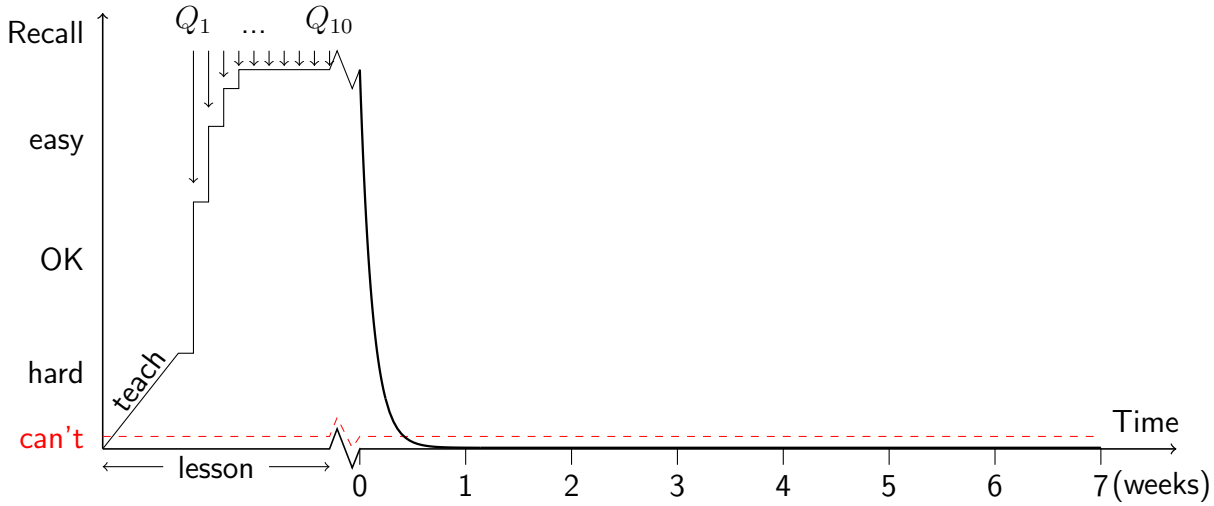
[9] van de Pol, J., Volman, M. & Beishuizen, J. Educ Psychol Rev (2010) Scaffolding in Teacher?Student Interaction: A Decade of Research 22: 271.

[10] retrieval practice is now catching on with teachers. In academic research retrieval practice has been called distributed practice and spaced learning. It uses what is called either the spacing effect or the testing effect.

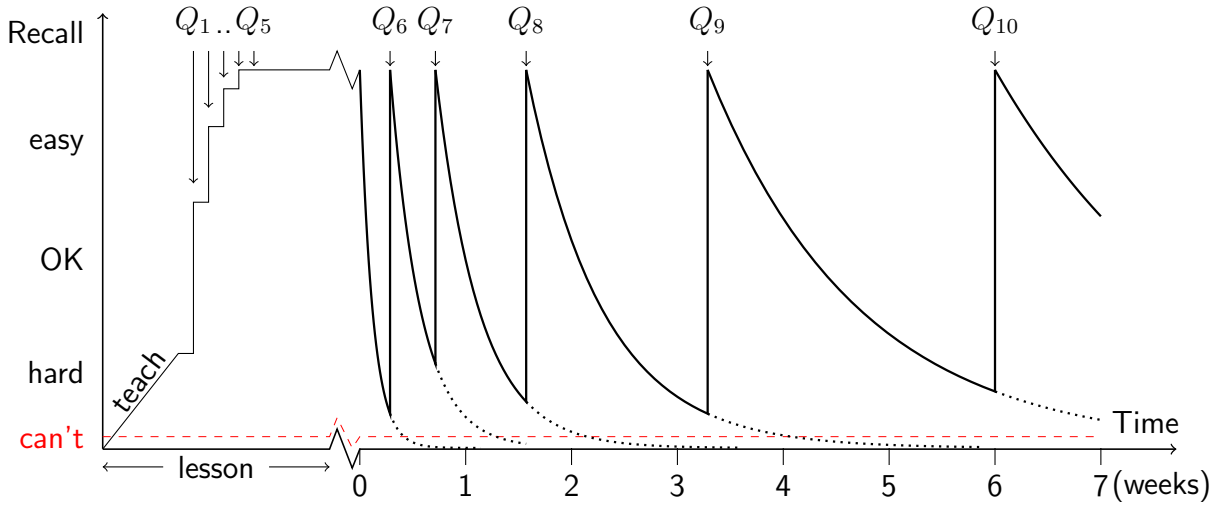
will need to think of having a scheme of retrieval practice to sit alongside or within our scheme of learning.

Rohrer and Taylor state that "the most popular practice schedules are designed to minimize long-term retention."[11] Here are two graphs showing a low attaining learner's ability to recall the learning from a lesson to illustrate their point:

- The first - a lesson where the learner did 10 practice questions in class.



- The second - a lesson where the learner did 5 practice questions - and then 5 further retrieval practice questions spread out over the following few weeks.



In "the solution: part 1 - retrieval practice" I explain how we can stop wasting the time of low attaining learners and their teachers: instead of allowing most learning to become forgetting, we can ensure that the vast majority of teaching becomes deeply embedded learning.

[11] in a summary document of The effects of overlearning and distributed practice on the retention of mathematics knowledge. Rohrer, D., & Taylor, K. (2006). Applied Cognitive Psychology, 20, 1209-1224.

The solution: part 2

We will do our low attaining learners a great disservice if we miss out the second part of the solution - a more tightly spiralled scheme of learning.

Retrieval practice doesn't help us to teach more from a topic at one time. In fact, knowing that it will "take a few months for low attaining learners to improve new learning to firm foundations for future learning", tells us that we shouldn't. If we are prepared to teach many topics more than once a year, to teach outside our current "scheme of learning box", then low attaining learners will be able to learn more in an academic year than they do currently.

In the "the solution: part 2 - a more tightly spiralled curriculum" I explain how we can teach more within the same lesson footprint by teaching "smaller bites" more frequently.

The depressing summary

Low attaining learners are disadvantaged by their memory, and they are further disadvantaged because we teach them in a way which works for most learners, but which makes low attaining learners' problems, if anything worse.

The ray of hope

The two part solution:

- use retrieval practice - to extend long term memory and
- use a more tightly spiralled curriculum - to increase the amount of retained learning,

can be hard to apply with classes rather than tutoring individuals.

timely practice was designed to apply the two part solution, to embed maximum learning in low attaining learners. It works well for classes of up to 16 with one teacher, or up to 26 with one teacher and a support teacher.

In a time where we have, nationally, a higher proportion of learners who are eligible for pupil premium[12] and disadvantaged pupil are twice as likely to fail their GCSE maths as their wealthier classmates,[13] is it not time to look into a solution such as timely practice?

[12] increase from 1 in 4 to 1 in 3 in one year - Matt Bromley Pupil Premium Conference 2019

[13] https://www.theguardian.com/education/2019/aug/21/poorer-pupils-twice-as-likely-to-fail-key-gcses

