These 14 questions and answers are intended to lead the reader from dissatisfaction with what is currently happening to low attaining learners in maths:

> Despite good teaching and (too) many hours of teachers' time, learners with insecure learning foundations and large learning gaps, don't readily form firm foundations for future learning. Learners become progressively demotivated [1], teachers have insufficient time to give feedback and what's more it often isn't effective [2], learners make little year on year progress, and low attaining maths learners fall further and further behind their peers [3].

to a place of hope:

> timely practice helps maths teachers, help low attaining maths learners to make outstanding year-on-year progress. Within a year the (previously) lowest attaining learners begin to close the learning gap and often overtake their peers [4]. Firm learning foundations are found, and teaching and learning becomes easier. There is enough time for personalised feedback, when required. Soon, new learning becomes firm foundations for future learning and over time, learners become progressively more motivated.

The first 8 questions are intended to shine a light on why teaching isn't efficiently becoming embedded learning for low attaining learners at the moment.

The final 6 questions are about the changes that timely practice recommends and enables.

Q1: Which in your opinion is the greatest blocker to long lasting learning?

poor teaching and learning ☐ poor remembering ☐ other ☐ . . . . . .

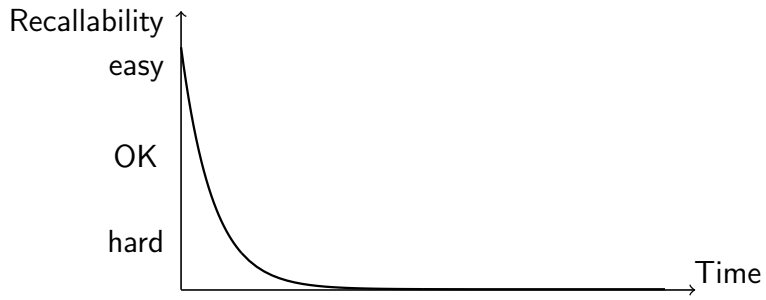
A1: In my opinion forgetting is the forgotten villain at the classroom door. Sometimes after what appears to be effective teaching and learning, forgetting happens after a while. When Ofsted was young, it was looking for sustained progress every lesson [5], but Ofsted didn't stop to think what might happen to that learning without proper nurture. Now Ofsted is growing up it is looking for retention of learning [6].

Q2: Does **when** we measure learning effect our assessment? e.g. typically, what proportion of maths "teaching" might we find "learned" if we assess:

at the end of the lesson . . . . . % a week . . . . . % or a month after the lesson . . . . . %

A2: The longer we leave assessment after teaching, the fewer learners can recall and use what was taught. We might find: end of the lesson: 100% [7]; a week after 70% [8]; a month after 30 % [8].

Q3: What do Ebbinghaus' forgetting curves tells us about learning and forgetting?



A3: When we learn something, over time we will forget it, unless we use it. That is recallability isn't durable without use. I use recallability rather than learning, as just because which we can't access a memory, doesn't mean that it isn't in long term memory e.g. I cant recall the German word for memory, but in a multiple choice I'd spot it and say "aha yes, that's it". However learning which is both recallable and usable is the gold standard of teaching and learning.

Q4: How long can we expect new learning, that isn't used, to last?

A4: The durability of recallability varies from learner to learner and from skill to skill. Our experience at timely practice is that many low attaining maths learners forget new learning within 3 days, but most maths learners remember new maths learning for somewhere between a week and a month [8].

Q5: Rate the utility of the following strategies to extend the durability of the recallability of learning. Use the key H: high utility, M: moderate utility L: low utility.

practice testing. . . self-explanation . . . overlearning$^{(a)}$ . . . retrieval practice$^{(b)}$ . . .

highlighting . . . interleaving . . .

(a) extra practice **within** the lesson, after sufficient practice, that the learner has "got it"

(b) extra practice **after** the lesson, after sufficient practice within the lesson so that the learner has "got it".

It is also called distributed practice/learning, spaced practice/learning/repetition or test enhanced learning.

A5: High utility: retrieval practice, practice testing, [9]
Moderate utility: interleaving, self-explanation, [9]
Low utility: overlearning, [10, 11, 12] highlighting [9]

In terms of practice, "practice makes perfect" is an over simplification. Retrieval practice is efficient, interleaving less so and overlearning is not efficient. If we want to increase recallable learning we should choose testing or retrieval practice. When we think about it, they are the same thing: a practise-assessment-feedback triple, but they feel very different. Many maths teachers will tell you, it is often hard to get low attaining learners

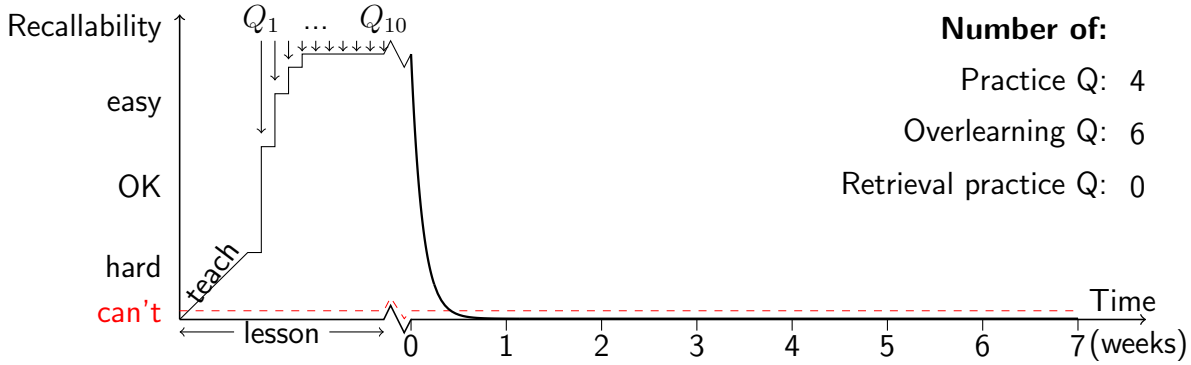
- to try to do tests,
- to engage in any feedback after tests and
- to continue to engage with further learning for a few days after tests.

I would suggest that retrieval practice is a much better answer for low attaining learners as its benefits are greater for learners with lower working memory capacity [13]. Increasing interval retrieval practice is the most efficient form of retrieval practice [14, 15], so that is what timely uses to make sure teaching becomes recallable learning as efficiently as possible.

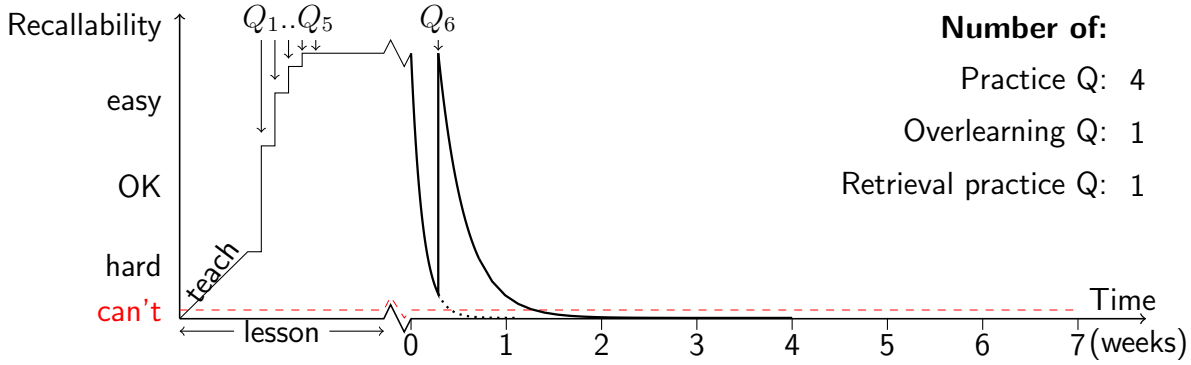
Q6: What are the difference between the practice strategies you mentioned?

A6: The three graphs are intended to represent the same low attaining learner who needs to follow up the teaching of the lesson by doing 4 practice questions in order to "get it". In this imaginary scenario, the learner will forget the learning of the lesson within 3 days, unless they "use it".

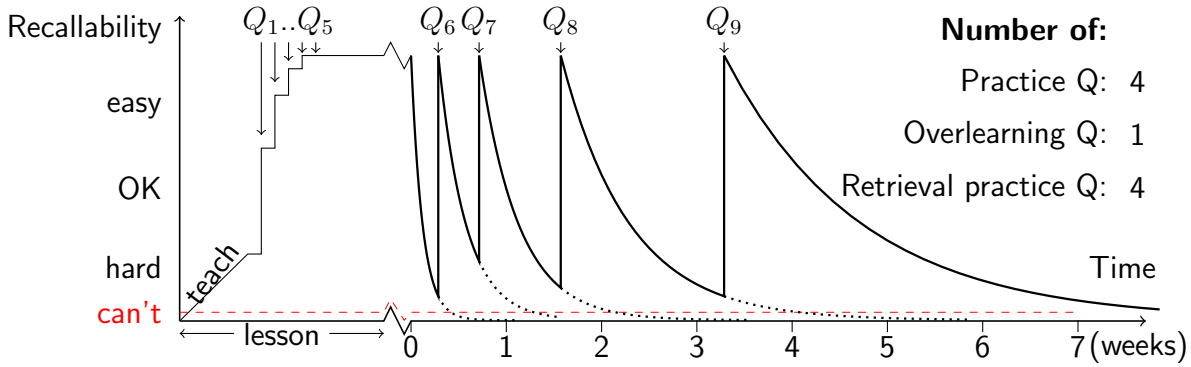
- Overlearning is extra practice after the learner has "got it" - within the same lesson as the teaching. Overlearning barely (if at all) increases recallability.



- Retrieval practice is at least one extra practice at least one day after the teaching lesson. This one retrieval practice question increases recallability from 3 days to a week.



- With increasing interval retrieval practice extra practice is done on more than one occasion and on each occasion, the wait time (interval) between one practice and the next is increased. The 4 retrieval practice questions increase recallability from 3 days to a month. That is, our low attaining learner is now remembering the learning of the lesson for as long as their more highly attaining peers.



The next two questions look at the interrelationship between teaching, learning, working memory and long term memory.

Q7: What are chunks and how do they help learners retain learning?

A7: Chunks, are groups of well developed links in long term memory. They take time and require similar but different practice to build [15, 16] We generally have very well developed chunks for interpreting what we see and hear, we tend to develop chunks for speaking and listening naturally but we need schooling to develop chunks for reading, writing and mathematics.

Retrieval practice works by the brain saying "ooh, that was hard to remember, but useful", this triggers links to be formed or strengthened that is chunks to be built or refined. The more we know, the more likely it is we already have, a suitable chunk on which to build another chunk or make the chunk bigger or better [16].

With low attaining leaners we are trying to solve a "grow more chunks" problem. However let's look at why low attaining learners might have grown less chunks than their peers, to date. If we don't create the circumstances where chunks are more easily grown and avoid the circumstances where chunks are hard/impossible for the learner to grow, then teachers and learners will have to work harder and we still may not be successful.

Q8 (a) Why do some learners build fewer chunks?

(b) Why by age 16, is the spread of attainment in maths so wide?

(c) Why are learners living with poverty and trauma less likely to be successful in school?

A8 (a): To begin let's look at the effect of having just 3 slots in working memory, when one's peers have 4 or 5 [18]. Symptoms of working memory overload are muddling methods, missing steps and giving up. Any one of these can mean that sometimes a learner with a smaller working memory can't follow the intention of the the lesson activities [19]. The learner then doesn't build a chunk in long term memory, when their peers do. Over the course of schooling - fewer chunks - fewer hooks for new learning - a recipe for increasing the attainment gap . . . but this is not the worst of it.

Chunks, once built, are used to reduce the number of working memory slots required to solve problems [16, 17]. The learner with a smaller working memory has a double whammy: they are more reliant on chunks in long term memory to boost working memory capacity, yet they are less likely to build the necessary chunks.

(b) Maths learning is particularly hierarchical, so having missing chunks can preclude/make so much harder learning new skills, this is why assessment for learning, when done effectively, is so efficient at raising attainment [20]. When teachers use scaffolding within the lesson, the intention is to enable all learners to access the lesson. Teachers are generally excellent at scaffolding within the lesson, often not even aware that the are providing scaffolding. However for that learning to be retained we must fade the scaffolding, [21] and I would contend that the time frame required for fading scaffolding, for low attaining learners, is longer than a lesson or two.

(c) We know that poverty [22], trauma [23] and even uncomfortable feelings [24] reduce working memory capacity. Of course not all learners with a smaller working memory go on to become low attaining maths learners, but 80% do [25]. When looking at attainment in maths, low attaining learners are six times as likely to have a smaller working memory than their peers who are not classified as low attaining [26].

Q9: What can teachers do to help embed learning more efficiently in low attaining learners?

A9: Teaching in a "smaller working memory friendly way" is an excellent place to start to help learners build more, bigger and better chunks. There are four essential requirements, to help the low attaining learner build, improve and find chunks in long term memory.

(A) use assessment for learning, [20]

(B) teach smaller bites of learning more frequently, [16, 27, 28]

(C) schedule increasing interval retrieval practice, [27]

and (D) when errors are made give feedback soon. [29]

(A), (C) and (D) are widely proven to increase the attainment of all learners. Only (B) is specific to learners with smaller working memories.

The first part of (B) "teach smaller bites of learning" is a clarification on Sweller's recommendation to use the "correct grain size" [28]. What appears to be the correct grain size, if we measure learning at the end of the lesson, is often too large to allow low attaining maths learners to embed the learning of the lesson into long term memory.

The second part of (B) "more frequently", means more than once a year. If we stick with a teach-topic-once-a-year scheme of learning we are left with two poor choices:

- If we teach the same amount from each topic at one time, retrieval practice won't work efficiently (or often not at all) because we are overloading low attainers working memories, so that when they fall asleep at night, rather than building accurate chunks in long term memory, they will build inaccurate chunks or incomplete chunks or no chunks.

- If we teach less from each topic at one time, so that retrieval practice can work efficiently, when learners fall asleep at night they will build/begin to build/improve a chunk on what they learned; but it will add only a little more learning, crucially less learning than their peers.

In either case low attaining learners will continue to fall further and further behind their peers.

However if we teach small grains of learning more frequently, i.e. have a scheme of learning to work with smaller working memories, low attaining learners have a chance to catch up with their peers. Gobet [16] calls this scheme of learning "an 'improving spiral', where you come back to the same concepts and ideas and add increasingly more complex new information". Kang [26] calls it a 'spiral' curriculum. If he was addressing a UK audience, he might describe it as a revisiting topics several times a year.

In order to apply these requirements together and maintain the teachers' work-life balance some help is required - that's what timely practice was designed for. timely practice can be considered as the maths teacher's "admin assistant" which

- schedules the retrieval practice, so that learners:
  - increase the duration of recallability, because the interval between practices is long enough,
  - can still remember the skill, because the interval between practices is not too long,
  - can't copy from each other and each time they practice a skill, they get a different question,
  - can remember feedback until they next practice another similar question,
- automatically updates the assessment for learning data for each grain for each learner.

The teacher is freed up from admin to concentrate on the more interesting business of teaching, using the granula assessment for learning data available, and for any feedback required. The learners can concentrate on their learning without fear of feeling a failure or a fool.

Q10: Won't the outside of lesson assessment and the inside of lesson feedback required for timely practice be too time consuming for teachers?

A10: In our experience to date, no, not if teachers respect the four essential requirements:

(A) build and use the assessment for learning data,

(B) teach smaller bites of learning more frequently,

(C) schedule p.d.f. timely practice assignments most maths lessons,

and (D) when errors are made give feedback soon or decide the bite is best learned later.

For classes made up entirely of the low attaining learners i.e. those below the lower quartile, the maximum class size for a teacher with/without a consistent learning support assistant is 26/16 learners. With timely practice the teacher, supported by the app, does the assessment of the p.d.f assignments and gives any necessary feedback the next lesson.

timely practice makes sure the learning of the lesson isn't forgotten by the learner, because the practice questions are timely. Sometimes the practice reveals accuracy errors or already seems too late. Feedback will be helping the learner improve accuracy or is needed because the learner hasn't **yet** replaced the scaffolding in the lesson, with a chunk in long term memory. Once built, the

chunk will become the learner's "internal scaffolding". The learner can be said to have mastered the skill, that is the skill will have become a firm foundation for future learning.

In order for the teacher to have the time and headspace to give high quality feedback when the learners require it, we need most of the learners, most of the time to be able to independently and accurately apply their learning to most of their timely practice questions. The timely practice questions which the learners are doing independently and accurately are not "make work", they are stretching the duration that the learner can recall their learning for.

Q11: How will teachers have enough lesson time to do timely practice?

A11: The teacher will have more time in the lesson for the learners to do their retrieval practice, their timely practice assignments by reducing overlearning. The learner will do less practice questions on the teaching of the lesson and so have time to do practice questions on prior learning, their timely practice. The teacher will find teaching easier and the learner will find learning easier, because they are only teaching/learning a small bite, and so teaching and learning will be quicker.

The teacher will have more time in future lessons to teach harder skills, because with timely practice, skills very rarely need to be taught more than once.

Q12: Why should teachers and schools change how they teach low attaining learners? Schools already provide differentiation, scaffolding, smaller pupil to teacher ratios and often learning support assistants for low attaining learners. Why don't low attaining learners buck up their ideas, work hard in every lesson, do their homework and revise for tests as their peers do?

A12: If schools are equally happy with the progress of their high and low attaining learner, then of course they shouldn't change. However let me turn this question around. Why wouldn't teachers/schools want to ensure that the increased gain in learning **within** the lesson, from the measures you list, is retained **after** the lesson. That is learners can independently recall and accurately apply the learning of the lesson, for weeks, months and years after the lesson?

It is likely that low attaining learners will always need more time to learn than their more highly attaining peers, but if we can make more efficient use of lesson time, then we can begin to close the attainment gap.

Q13: How can timely practice help schools "catch up" after school closure?

A13: timely practice was designed to

- find and firm up existing learning foundations,
- ensure teaching is on the learning foundations that learners do have, not those they should have,
- ensure that teaching becomes firm foundations for future learning within half a term.

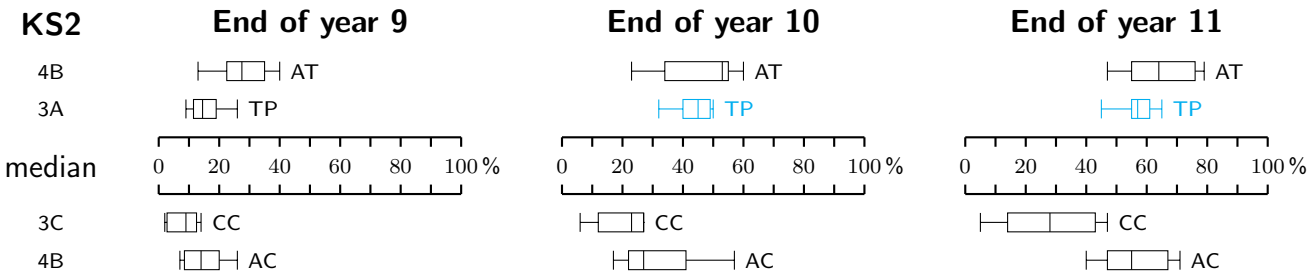
What could address "catching up" better?
Best of all timely practice is free in return for comparative data, by signing up for our one or two term trial. The trial is intended to answer the question:

"Does teaching with timely practice embed significantly more learning than teaching following our current scheme of learning and program of study?"

Q14: What evidence do you have that timely practice can help teachers and learners improve the attainment of low attaining maths learners?

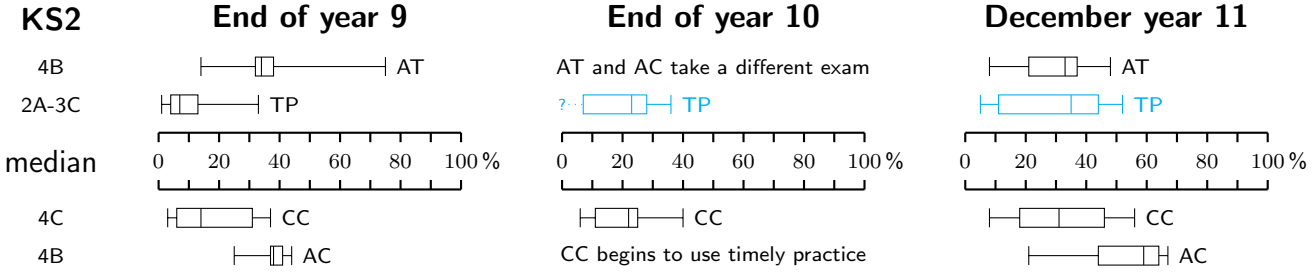
A14: In one school, for two consecutive years, one of the two lowest attaining maths sets in each cohort was chosen to be the timely practice class. Here are the exam results of the four lowest attaining sets during KS4.

2017 to 2019 cohort: 5 figure summary data for end of year and final **GCSE** exams.



Key	the timely practice half of the year	the control half of the year
Lowest attaining set	TP (timely practice)	CC (control class)
The set above	AT (above timely practice)	AC (above control)

2018 to 2020 cohort: 5 figure summary data for end of year and mock **GCSE** exams.



The big picture

2017 to 2019 cohort

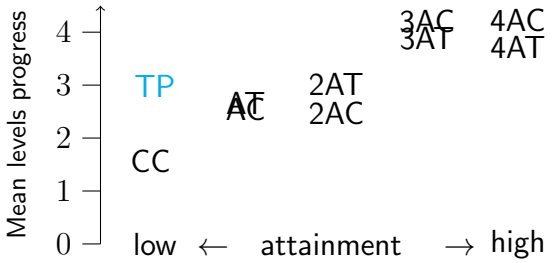
- TP closes the learning gap with AT
- TP progress on parr with 2 sets above →

2018 to 2020 cohort

- TP closes the learning gap with AT

2017-19: school summary data

"Number of levels" progress since KS2.



Learner numbers in the lowest attaining sets were low timely practice classes were low, 8 learners in 2017-19 and 12 learners in 2018-20. Clearly further testing is required for more robust evidence. Our other shorter term comparative studies are due to give results in September 2020, or have been compromised by school closure, but initial anecdotal evidence is extremely promising.

If teaching was efficiently becoming learning, as it does for higher attaining maths learners, then timely practice would be a sledge hammer to crack a nut. If, for low attaining learners, teaching is often not becoming long term learning, then timely practice is a nut cracker to crack a nut.

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