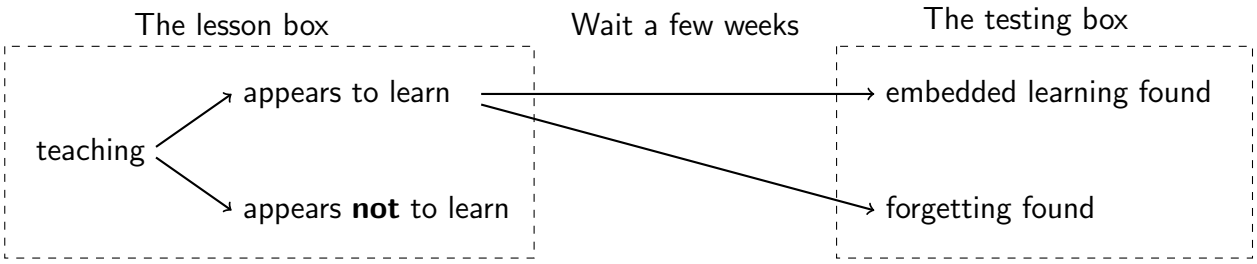
Description of timely practice

timely practice is a tool for teachers of low attaining maths learners. By which we mean learners who have or are expected to gain less than a grade 4 in GCSE maths. However we exclude learners who cannot read, write and add on 10 to a 2 digit number as the progression in topics to teach these learners is not yet complete.

The timely practice app creates personalised pdf assignments of mixed practice questions which schedule retrieval practice. The optimally scheduled practice embeds this learning over a number of weeks. timely practice's aim is that almost all teaching becomes embedded learning which is demonstrated by students consistently, independently and accurately answering questions on that learning.



timely practice makes assessment for learning, feedback, mastery learning and retrieval practice quick and easy for the teacher to integrate into their everyday planning, teaching and assessment.

Research that underpins the design of timely practice

timely practice helps teachers apply assessment for learning (Black and Wiliam 2001), feedback, mastery learning and retrieval practice (Hattie 2009) which have large learning gains.

In this section we will use chunk-based theory to explain how traditional maths teaching enables the majority of learners to learn; why a traditional each-topic-once-a-year scheme of learning doesn't work well for low attaining learners and the research timely practice hopes to use to overcome these problems.

We would summarise the pertinent research into 3 principles:

1. Teachers should "use assessment to influence learning and [ensure] that the teaching [is] contingent on what learners have learnt" (Wiliam 2009) and to hold back from teaching new learning until the pre requisites are mastered (Kulik et al 1990). **Teaching, more efficiently becomes learning, when we teach in the sweet zone between too easy and too hard.**

2. Chunks or mental schema are built more robustly when teachers teach using the "right grain size" for their learners (Sweller 1998). **Teaching, more efficiently becomes learning, when we teach in the sweet zone between too little and too much.**

3. Sufficient deliberate practice of similar but different problems may be seen as assisting in building the chunk (Gobet 2005) or repeated retrieval practice may be seen as embedding

learners' learning ever deeper over time (Bjork and Bjork 1992). Teachers can/should reduce overlearning, that is practice directly after teaching, because it adds little durability to learning (Krueger 1929, Rohrer and Taylor 2006). Instead retrieval practice, that is practice after the lesson, is more efficient at embedding more learning more durably/accessibly. (Kang 2016). Feedback should go hand in hand with retrieval practice when the learner is not successful (Pashler, et al 2007). **Teaching, more efficiently becomes learning, when we get the timing of practice and feedback right.**

When teachers combine principles 1 (not too easy, not too hard) and 2 (not too little, not too much) learners can begin to build chunks, or chunks of chunks or templates (Gobet 2005) or mental schema (Sweller 1998) in their long term memory. These will once built: effectively reduce the working memory load required to solve problems (Sweller 1998); provide triggers, called perceptual cues, so that the learner can quickly and easily decide what methods, skills or process(es) to use to solve a problem. (Gobet 2005)

When teachers apply principle 3 (well timed practice and feedback) then learners continue to build and refine their mental schema and these remain easily accessible for recall.

Rohrer and Taylor (2006) explain that their study is, as far as they know, the first published study on the effectiveness of overlearning versus spacing practice over time of maths - where the measurement of the learning is delayed. What they found is that once learners have "got it" if you wait to measure learning 4 weeks later, rather than measure learning 1 week later:

- there is little to no benefit in further practice questions i.e. overlearning,
- after 1 week most learners remembered, but after 4 weeks most learners forgot the new maths learning of the study,
- even limited spacing of questions - doing half the questions directly after teaching and half a week later is much more effective at embedding learning than doing all the practice questions directly after teaching.

We can think of practice questions as providing two different roles, depending on when they occur:

- to begin to learn (which previously may have been described as to learn) - a few but sufficient practice questions at very close intervals (in the order of minutes) within the lesson where teaching occurs;
- to embed that learning (which previously was rarely described). This is retrieval practice - once the learner has "got it" increase the wait between one practice and the next (in the order of days, weeks and months) after the lesson where teaching occurred.

Bjork (2012) explains that with retrieval practice, the teacher (or learner if the study is self directed) needs to find a balance between

- allowing too much forgetting to happen (since the learner would need feedback or re-teaching) and
- not allowing enough forgetting to happen, (since the testing effect would not extend the depth of the learning significantly and as a consequence many more practice questions than necessary would be done by the learner and assessed by the teacher). Pyc and Rawson (2009) call this the retrieval effort hypothesis.

What teacher's generally call retrieval practice - the focus being on the desirability of the learner retrieving from their long term memory in order to practice . . . the educational research community calls spaced repetition (Kang 2016), spaced practice (Rohrer 2009), distributed practice (Cepeda et al 2009) (Rohrer and Taylor 2006), distributed learning (Son and Simon 2012) - the focus being on the requirement to wait, space or distribute over time the practice questions. Roediger and Karpicke (2006) call it test-enhanced learning - referring to what psychologists call the testing effect.

Repeated retrieval practice is best done with an increasing interval spaced repetition system (Kang 2016). When the learner can't remember, or makes an error it is strongly recommended that feedback is given. Pascler et al (2007) say "withholding corrective feedback after an error is always harmful, even if done only intermittently". Dunlosky et al (2013) say practice testing with feedback consistently outperforms practice testing alone. Balota et al (2007) say that after feedback, the interval should be reduced to the last successful interval. Finally, a small but pertinent detail for giving written feedback, Gnambs et al (2015) found "the color red impairs cognitive performance in achievement situations".

Gobet and Lane 2012, looking at feedback from a building and correcting chunks perspective says that "A possible avenue for future research is the design of computer tutors that use chunking principles for teaching various materials, optimizing instruction for the abilities and level of each student by providing personalized curricula, providing judicious feedback, and teaching strategies."

Task or process feedback (Hattie and Timperley 2007) given by the teacher can assist the learner with any of the following:

- replace scaffolding with transfer of responsibility (van de Pol 2010),
- build chunks in long term memory (Gobet 2005),
- choose the appropriate procedure (Rohrer 2009) and
- improve the learners' question reading or numeracy skills.

Feedback need not be given immediately. Pashler et al (2007), found feedback given after a day seemed to more effective than immediate feedback for embedding learning.

Finally, should feedback be given when the learners answers questions correctly?. Pashler et al (2007) found that it is not necessary to give feedback when the learner answers correctly. However Schiefele and Csikszentmihalyi (1995) emphasise the importance of positive emotional experiences to maintain (and I would add build) intrinsic motivation. Given how little teacher time is required to mark correct answers with ticks and equally how much quicker it is to return to learners all their answers (not just the ones that require feedback) it seems only sensible to do this.

Another important requirement to efficiently build mental schema is using a spiral curriculum (Gobet 2005).

Before I finish this section let me summarise what we know about working memory capacity.

- We know that people have 4 ± 1 slots in working memory (Cowan 2010).
- We know that the 10% of learners with a "poor working memory profile" make poor progress in reading and maths. That "those with poor [working memory] capacities will struggle to meet the heavy working memory demands of . . . the classroom". The mechanism seems to be that "their working memory becomes overloaded and the crucial information to guide the ongoing activity . . . is lost". (Gathercole 2008).
- We know that, above and beyond the natural variation of working memory capacity, learner's working memory capacity will be reduced by unpleasant emotional states (Figuera et al 2017), trauma (El-Hage et al 2006) and poverty (Farah et al 2006). We know that the longer the poverty lasts the greater the reduction in working memory both at school and into later life (Evans and Schamberg 2009).
- Finally we know that the "benefits of retrieval practice are greater for students with lower working memory capacity" (Argawal et al 2016)

When reading the research papers, especially on retrieval practice, one gets the feeling that researchers are getting ever more desperate for teachers to apply their findings. They speculate on how hard it is to engender change:

- structural issues with text books, exam timing,
- lack of role models of doing things differently and
- lack of time for training teachers, who would then need extra time to set up schemes of review of learning etc

We note two further issues which will reduce uptake:

- lack of imagination - politicians and teachers (by and large) are the successful product of an education system, we feel we deserve our success due to a combination of natural ability and our hard work - we think, what worked for me, will work for all;

- an assessment system of teachers which visits schools and expects to see and judge learning in the short term, and an assessment system of learners which judges learning in the medium to long term.

Finally suppose the learners who were most disabled by our current education system were the children of the most powerful in society: would we still be where we are today?

For us the motivation to create timely practice is 3 fold,

- "to do right by learners who are (in our opinion) largely failed by our education system",
- it is easiest to show progress with the learners who forget the most,
- if teachers/schools/Ofsted see the lowest attaining learners catching up and often overtaking their more highly attaining peers - this provides a stronger motivator for change across all ability ranges.

what timely practice thinks is happening with low attaining learners

Higher (and to some extent middle) attaining learners are assisted in building new mental schema by existing robust mental schema, the practice provided by homework, self or parent/carer directed revision, appropriately timed school tests and a curriculum which revisits and makes links between topics at suitable intervals.

However low attaining learners with traditional maths teaching have small learning gains and do not appear to be assisted much, if at all, by any of the above activities.

We concur with Rohrer and Taylor (2006) that it isn't poor teaching nor poor learning but poor remembering which is more likely to be the cause of low attainment for many learners.

what is happening in lessons

Teachers are good at giving scaffolding within the lesson, so it will often seem that all learners are learning what is taught. In fact teachers are so good at giving scaffolding, that they are often not aware of doing it, and so are not aware of the need to fade the scaffolding after the lesson.

Fading is a vital part of scaffolding (van de Pol et al 2010) and if done after the lesson, it will usually be retrieval practice. Teachers must either fade scaffolding within the lesson (which I believe is too soon) or teach lessons or parts of lessons where the purpose is fading scaffolding. The requirement by Ofsted (2013) that they should see "rapid and sustained progress" in every lesson discouraged teachers to fade scaffolding beyond the lesson. Ofsted's recent volte-face that "Progress, therefore, means knowing more (including knowing how to do more) and remembering more"(Ofsted 2019) should make it easier for teachers to justify time spent in fading scaffolding or doing retrieval practice.

When we measure learning at the end of the lesson, and see success; and next measure learning at perhaps an end of unit test and see failure, both the learners (and sometimes the teacher) can

come to believe that low attaining learners are not good at learning. Over the course of their schooling most low attaining learners become demotivated. (Nardi and Stewart 2003)

Our experience is that many low attaining learners forget, much, if not all of what was taught and seemed to be learned in a lesson, within 3 days of the lesson. Most teachers we have worked with are surprised by the speed of their learners' forgetting.

Returning to think about learners with smaller working memories. Gathercole (2008) suggests measures to reduce the working memory load demand of activities, so that children who regularly exhibit working memory memory failures, can access the same activities as their peers. However at many stages of schooling it is likely that learners with smaller working memories have built fewer and less sophisticated mental schema than their peers. Learners with smaller working memory can easily become trapped in a cycle of almost stagnant attainment because: mental schema which could have been used to overcome limitations in working memory capacity are less likely to be built by learners with smaller working memory capacities.

Further it seems likely that at every stage of their schooling this attainment gap or deficit of mental schema, relative to that of their peers increases. Lower attaining learners (almost by definition) have fewer mental schema on which to hang new learning. Increasing the quantity, strength and accessibility to mental schema in the learner's long term memory can perhaps be seen as a key part of education. However, if we try to "fix long term memory" without due consideration to the role of working memory in building the mental schema we may (I would go as far to say are likely) to set up lower attaining learners for more failure.

The question to consider is, if we want lower attaining learners to catch up with their peers should we try to help them catch up,

- by teaching them as before, following a curriculum which we know is successful at teaching their peers who rarely exhibit working memory overload symptoms?
- or teach them in a way which is more likely to help them build those necessary yet missing mental schema?

I am not suggesting that all lower attaining learners have smaller working memories than their peers,

- however my experience is that many lower attaining learners frequently exhibit working memory overload symptoms,
- that if we can see a mechanism whereby learners with smaller working memories are falling behind their peers, and we want to help low attaining learners catch up with their peers (and there is at least some overlap between low attaining and smaller working memory) should we not try to teach in a more "smaller working memory friendly way"?

what is happening due to the scheme of learning

The avowed intention of the changes to the national curriculum (first examined in 2017) was to raise attainment. What can most generously be described as a philosophy that teaching more, harder and more quickly will result in increased attainment for all learners.

This does not bode well for low attaining learners who already struggle to learn alongside their peers because they were often already taught too hard and too much.

Primary teachers are given flexibility to teach maths as they feel fit within the school year. However once learners have not retained/learned in a school year, what the curriculum expects that they should have, now have a considerably reduced chance to catch up this missing learning in subsequent years.

Secondary maths teachers are not caught in such a tight strait jacket, but most UK secondary schools use a scheme of learning for teaching maths which requires teachers to teach each-topic-once-a-year. I'd like to address the problems that this creates for low attaining learners.

Assuming a best case scenario where assessment for learning is used and the teacher begins teaching the topic by re-teaching the forgotten pre-requisites for the topic; this often takes a small proportion of the teaching time allocated for the topic (perhaps 15 minutes out of 120 minutes). Any more teaching on the topic, beyond this re-teaching, will often prove (a few days after the lesson) to be both too hard and too much for the low attaining learner.

Our experience is that, the more that is taught from a topic at one time, when low attaining learners attempt practice questions after the lesson, the more likely we are to see working memory overload symptoms - missing steps, muddling methods, and giving up. Sometimes the too hard and/or too much is muddled with the recently revised and all learning is lost or sometimes a small amount of what was taught is retained.

Even if low attaining learners can retain some of what was taught on a topic, they are destined to fall further and further behind their peers, who can easily retain much more of what was taught from each topic in the each-topic-once-a-year scheme of learning.

Worse, because schemes of learning are not created with a follow up review or retrieval practice programme, teachers miss the opportunity to catch new learning before it is forgotten.

Retrieval practice is obviously easier to achieve

- if learners can, (as we think middle and higher attaining learners can), retain new learning for a longer period of time,
- if most learners in the class, are learning the same new learning (as often happens with middle attaining learners in schools which set for maths - nearly all UK schools) since a test that "fits all" is easier to manage within the classroom.

We are not alone in thinking that the curriculum could be improved for low attaining learners.

The report Mathematics: Made to Measure (Ofsted 2012) requested schools review "for learners who struggle to learn" how topics "were taught in the first place and how that teaching and/or the curriculum might be improved so that pupils in the future do not struggle with them", rather than schools putting their effort into remedial action long after teaching has taken place.

The Warnock report (Warnock 1978) looked at what the teaching of the "up to one in five of learners" who have difficulty learning should be like. It led to an acceptance that teachers and schools should teach within a lesson to better suit all learners (using assessment for learning, differentiation and scaffolding).

A grade 4 can be seen as the minimum grade to succeed in our society. Currently at least 40% of learners do not achieve a grade 4 or above in their GCSE maths exam (TES 2019). That 40% is not evenly distributed throughout society however. The Guardian (2019) reporting on 2018 data said "The Education Policy Institute think tank found the attainment gap between disadvantaged pupils and their wealthier classmates is widening. The most persistently disadvantaged pupils are almost two years (22.6 months) behind their peers by the time they finish their GCSEs"

There are government agencies, charities and quangos looking in to how we can reduce the likelihood that poverty will become educational disadvantage. Some focus on changing parenting, some try and replace what poor parents can't afford - private tutoring. In the long term the research on poverty and trauma leading to smaller working memory (and other cognitive impairments) leading to lower attainment might encourage the politics of poverty and trauma reduction. In the meantime what can schools and teachers do to address these outcomes?

We at timely practice believe, there are many who could achieve more if we taught **over an academic year** in a way to better suit these learners. That is we add retrieval practice, timely feedback and a more tightly spiralled scheme of learning to the more commonly accepted **within lesson** practices of assessment for learning, differentiation and scaffolding.

Our conclusion is that we need to make 3 changes simultaneously

- principle 1: teach in the sweet zone between too easy and too hard,
- principle 2: teach in the sweet zone between too little and too much,
- principle 3: get the timing of practice and feedback right.

Principle 1 is commonly acknowledged in schools as the right thing to do. However low attaining learners have unpredictable learning gaps. Gathering data and being able to see and thus use data on which learners have mastered and which have learning gaps is very time consuming for the teacher. Worse, such data can't be passed on from one teaching of the topic to the next as

- learners forget both existing and new learning,

- it is hard to quantify the simplicity or complexity of questions - as the disbandment of levels within the national curriculum attests e.g. subtracting fractions 5/6 - 1/6 versus 5/6 - 2/5 versus 5/6 - 2/9 within a word problem.

Principle 2 is for low attaining learners, in direct opposition to the teach-each-topic-once-a-year schemes of learning used in almost all schools and which work for most middle and higher attaining learners. A teach-each-topic-once-a-year scheme of learning doesn't work for low attaining learners, but neither does a more tightly spiralled scheme of learning if forgetting is allowed to happen.

In fact a more tightly spiralled scheme of learning shows up forgetting more. If each term, the teacher (and the learners) find out what can be recalled on a topic before teaching more on the topic, that is principle 1 is applied, it would be much more apparent that little learning has survived. Teachers and learners would feel that they had made no progress learning the topic, and worse that they could make little to no progress in the future. This also happens when retrieval practice happens too late (i.e.s.)

Principle 3 only works if principle 1 and 2 are in place. For principle 3 to work, that is for low attaining learners to try to recall what they have learned from previous lessons, we need the following:

A when learners are doing their retrieval practice questions they can (nearly always) remember what they have learned,

- so that learners will try to work independently,
- so that the teacher has time to give personalised help and feedback to the learners when they need it;

B copying not to happen, so that assessment is not compromised, so that future practice can be well timed, so that (see A)

Before explaining how timely practice was designed with the remit that a higher proportion of teaching could/should/would become embedded learning I'll explain

5 definitions needed to understand timely practice

layer

timely practice has divided traditional maths topics into smaller than traditional bites of learning which we call layers. Layers vary in the amount of time they take to learn, but generally layers take about 5 minutes to teach, up to 15 minutes to practise within a lesson and at least 5 further retrieval practice questions to master. Each layer consists of a description and up to 30 similar but different practice questions. This learning resources link found by choosing the "Resources" button at www.timelypractice.com shows for each layer within each topic: sample questions, teach-learn and practise-learn resources.

depth of learning

For each learner, for each layer that they are learning, the timely practice app calculates the depth of learning: the minimum number of days which the timely practice app thinks should elapse between one practice question on a layer and the next practice question on the same layer. It is a measure of how many days the app is confident the learner will be able to recall and use the learning for.

progress on topic

There is a progress on topic page for each topic. Using the depth of learning information, the app allows the teacher to see for any topic for each learner which layers are mastered and which are not. The teacher sees an array of colour coded lozenges: the learner names are the column headings and the layer number and description are the row headings. The colour of each lozenge indicates the degree of mastery. We define mastered as a depth of learning of at least 3 weeks.

timely practice assignment

When the teacher requests for example a 10 question timely practice assignment, the timely practice app creates for each learner a personalised assignment containing a question from each of the 10 layers the app thinks each learner should most urgently do retrieval practice on.

best learned later

This assessment option is used when the teacher realises that they have already/will continue to need to spend too much time on feedback on a layer. Deciding that a layer is best learned later also makes non threatening feedback for the teacher on the efficacy of their teaching. Without the best learned later option, the learner might soon end up with an assignment containing only practice questions for which they need help or feedback.

How timely practice enables and recommends teachers to teach

the scheme of learning

Almost all UK schemes of learning require maths teachers to teach "a large chunk" from a few topics within the few weeks allocated to a unit. We could call this a depth first scheme of learning, or an each-topic-once annual scheme of learning. In timely practice vocabulary we could say a handful of layers from a few topics.

timely practice recommends that teachers teach "a small bite" from many topics within the time frame of a unit. We could call this a breadth first scheme of learning or a more tightly spiralled scheme of learning. In timely practice vocabulary we say the teacher should teach a single layer from many topics. If 3 to 5 layers are taught within a week and the learner is learning new layers from 40 to 60 topics, then the teacher can return to teach more from each topic in 8 to 20 weeks. This is clearly significantly more tightly spiralled than an annual scheme of learning where the teacher will return to teach more on the topic after a mean of 38 school weeks.

The main advantages of a using a more tightly spiralled scheme of learning is that the teacher can easily apply principle 2: teach in the sweet zone between too little and too much, by teaching only one layer from a topic within one spiral of the scheme of learning.

Other advantages of a more tightly spiralled scheme of learning are that

- when learners are absent they miss less learning from any one topic, so that they are less likely to have unexpected pre-requisite skills missing which prevent the teacher applying principle 1 when teaching other topics,
- if the teacher teaches too hard or too much, neither the teacher nor their learners will have wasted too much lesson time,
- the scheme of learning can be more easily adapted to the requirements of the class e.g. if the class is particularly weak at place value, the teacher can teach place value 4 times per year and some other topics only once or twice per year.

the lesson

In a "traditional teaching approach" a learning episode on a topic might take 1 to 2 hours, and learners will generally be taught between 2 and 4 timely practice layers on the same topic.

In a timely practice one hour maths lesson, we encourage the teacher to regularly plan lessons made up of shorter learning episodes: the timely practice assignment and teaching from one or two topics.

The availability of the data within the progress on topic makes it easier for teachers to apply principle 1: teach in the sweet zone between too easy and too hard.

During 10 to 25 minutes of most maths lessons, the learners do their new personalised timely practice assignment and review the assessment of their previous timely practice assignment. Most learners, most of the time, can independently and accurately answer the questions in their assignment, since these provide carefully timed retrieval practice. Since the learners, in the main, work independently the teacher has time to give personalised feedback on the questions from the previous lesson's assignment that the learners need feedback on.

Through learners regularly doing their timely practice assignments and getting feedback when they need it - the teacher should be able to apply principle 3 - get the timing of the practice and feedback right.

timely practice assignments are constructed so that there is little chance of learners being able to copy their peers. So timely practice assignments have all the benefits of tests (can't copy, must recall, must match question with process) but without the disadvantages (can't get help when needed, can't use the time after finishing the test early for something more useful, can't think for fear of the shame that assessment might/will bring).

With traditional teaching, the teacher may start by teaching in the sweet spot between too easy and too hard, but because the teacher is teaching too much the learners will soon be attempting to learn too hard. Worse because learners will usually be learning just one topic over a few days, they will more easily (I would say too easily) be able to recall the skills in this time. The teacher, learners and any observers of the lesson will be easily seduced into seeing "rapid and sustained progress". Only later during testing or retrieval practice will we know how much learning has become embedded and remains readily accessible within long term memory and how much has been forgotten.

In a timely practice lesson, the teacher should spend less time teaching a topic (because one layer is only a small bite of learning) before the learners move on to practising the new learning. The learners should spend less time practising their new learning (because overlearning isn't a good use of time, and because they will soon meet it in retrieval practice provided by their timely practice assignment) we encourage this by providing short practise-learn worksheets for each layer, for the teacher to use.

There will usually be sufficient time in a lesson for the learners to complete their timely practice and learn a layer from one new topic. The teacher can often/sometimes teach another layer from a different topic to at least some learners within a lesson. Sometimes the teacher can set a very short timely practice assignment (or none) and this allows the teacher to plan group, extended or consolidating task(s) within the lesson.

After the lesson, the teacher tells the app which layers have been taught (and appear to have been learned) by which learners. These layers receive the highest priority to go into the next timely practice assignment.

After the lesson, the teacher assesses each question within the app, using the answers provided by the app. If the teacher decides that the learner has independently and accurately answered the question on the layer, the app increases the depth of learning. Whereas an answer which the teacher assess as needing feedback, or for which the learner has already had help, the app decreases the depth of learning. The teacher should only assess not mark (i.e. choose one of the 4 assessment options within the app and not correct work or write hints on the assignment). The teacher should clearly indicate on the assignment whether the learners answer is correct (tick) or needs feedback (star) or is best learned later (see the 5 timely practice definitions above). The teacher should encourage the learners to look through the assessment on their previous assignment every lesson.

The teacher will then plan the next lesson - the teaching of the next topic(s), any whole class or group feedback they wish to give and the teacher will create a new timely practice assignment with the number of questions which they think the learner will be able to finish within the next lesson.

How can we find evidence about the efficacy of timely practice?

Within timely practice

Evidence within timely practice that the teacher is applying principles 1 and 2 is found within the progress on topic. After the pre assess phase, each topic should have at most one layer that is not mastered. For topics where the difficulty of the layers is clearly indicated by the layer number there should be few gaps between layers.

Evidence within timely practice that the teacher is applying principle 3 is found by looking at the number of fragile layers. Fragile layers are layers which the app thinks are within 5 days of being forgotten, so the number of fragile layers should be low, certainly below 20 layers.

Beyond timely practice

Evidence beyond timely practice that timely practice enables learners to learn better, through the application of principles 1, 2 and 3 with timely practice, is that low attaining learners begin to close the learning gap with their higher attaining peers. We seek to show this through school set tests.

Ethical considerations

The teachers and the maths department decided to trial timely practice in order to see if it could help with two identified but unfulfilled needs of their low attaining learners

- retaining learning
- more effective feedback

Trialling timely practice was also seen as part of the school's commitment to raising attainment through the continuing professional development of teachers.

We have used school summary data to keep personal information confidential.

Research question

What is the effect on the attainment of (currently) low attaining maths learners, when teachers and learners regularly use timely practice in their lessons for at least one academic year, compared to a traditional teaching approach without using timely practice?

Research Method

The "timely practice almost every lesson" efficacy trial was carried out in one school with one class for 2 academic years (this class have taken their GCSE exam in June 2019) and one class for 4 terms to date (who will take their GCSE exam in June 2020).

The school was chosen because they agreed to do the trial.

timely practice gave training and offered advice on

- how to pre assess learners in advance of teaching,
- creating a suitable scheme of learning,
- what teaching a timely practice lesson should look and feel like.

The school had free use of the timely practice app and support upon request.

Technical support was around missing or wrong answers, assignments not created or that couldn't be assessed etc.

Educational support included

- creating extra layers for some topics in response to teacher requests,
- reviewing the learners progress via the Progress on Topic pages in the app, at approximately termly intervals. This was followed up with advice on topics and layers to teach soon and on layers which might be "best learned later" for some learners.
- visiting the 2017-19 class twice and the 2018-20 class once (to date). The main purpose of these visits was to see how well the assessment-feedback cycle was working.

How we decided which classes would use timely practice

The school splits the cohort of each year into two roughly equal halves for timetabling purposes. Each half of the cohort was split into 5 maths sets for the 2017-19 classes and into 4 sets for the 2018-20 classes.

For both cohorts one of the two lowest attaining classes used timely practice for almost every lesson of their 2 year GCSE course.

- One class of 8 learners used timely practice for the academic years 2017-18 and 2018-19. The teacher volunteered her class to be part of the trial because she thought timely practice would raise the learners attainment and as a continuing professional development project.
- One class of 12 learners used timely practice for the academic years 2018-19 and continues to use it for this current academic year 2019-20. This teacher was directed to use timely practice.

All the more highly attaining classes used the schools existing scheme of learning and review/testing schedule. The other lowest attaining class in each cohort used timely practice for some time (see unwanted complexity 2 for more information on this).

How we measured learning gain

We used the schools marks for GCSE practice tests. The tests were either a full set of GCSE Foundation exam papers (3 x 80 minutes) or "cut down" versions of past exam papers (exams

with some of the harder questions removed). The closer the learners got to the final exam, the more complete the test papers were. For the 2017-19 class the final GCSE exam percentages are included.

We compared the test results of the class using timely practice (TP) with their peers in the corresponding set in the other half of the year - the control class (CC). Where there are common tests we also compared the TP and CC classes' progress with their peers in the more tightly attaining classes: the class above TP is called AT (above timely practice) and the class above CC is called AC (above control).

Scheme of learning differences

Non-timely-practice classes: The scheme of learning was different for each set but what they had in common was teaching groups of similar topics within units. The units took 2 to 4 weeks to teach. Topics were taught once or twice during the 2 year course.

timely-practice classes: The teachers created their own scheme of learning as the two year course progressed. The 2017-19 teacher started following the schools scheme of learning, but since she was teaching less from each topic, the year 10 scheme of learning was finished approximately half way through year 10. From then on the teacher selected from the year 11 scheme of learning, suggestions from us at timely practice, by using data from the Progress on Topic, requests from learners and as a response to misconceptions noticed when assessing timely practice assignments and marking GCSE practice tests. The 2017-19 teacher created the scheme of learning in a similar way. This time with a little more advice from us on time to wait between one teaching on a topic and the next and stronger encouragement to add only one taught layer at a time. (The 2018-20 learners were significantly more lower attaining than the learners in the 2017-19 class, so repurposing their scheme of learning was not considered appropriate.)

Differences at a lesson level

Non-timely-practice classes: The majority of lesson time was spent teaching and practising new learning. Teachers spent at least part of one lesson per week doing what the school called "nothing new, just review" - that is retrieval practice questions. The retrieval practice questions were chosen by the teacher.

timely practice classes: About one third of the lesson was spent on completing timely practice assignments and getting feedback. About two thirds of the lesson was spent on teaching and practising new learning. On some occasions two topics were taught per lesson, but this was rare.

Assessment differences

Non-timely-practice classes: The assessment included the following in class assessment of the "nothing new, just review" quizzes - these were done at least weekly, and for some classes almost every lesson, end of unit tests, where the learners were tested on the topics taught within the unit, marking and assessment of the learner's books - usually after the teaching of each unit.

timely-practice classes: The assessment was almost entirely through assessing timely practice assignments after every lesson. The learners did no end of unit tests and the teacher did not formally assess the learner's books.

Both classes (the timely practice and the non timely practice): did formal exam conditions tests at least twice a year.

Feedback and what happens as a consequence

Non-timely-practice classes:

- Feedback from the "nothing new, just review" quizzes was given in the same lesson. Sometimes the feedback would be giving the answers, sometimes modelling answers. Some teachers would choose the questions in future quizzes in response to learners' answers to previous quizzes.
- Feedback from the end of unit tests and learners' books was normally within a week after the end of the unit. Some feedback was written, some was oral to the whole class and occasionally the teacher did extra teaching in response.

timely-practice classes: the teacher would give feedback on the last lesson's assignment whilst the learners completed the current lesson's assignment. Feedback was usually one to one but occasionally to a group or the whole class.

Both classes (the timely practice and the non timely practice): The feedback on formal tests was similar for all classes and consisted of encouraging learners to look through marked exam papers and trying some questions again, giving advice, modelling worked answers and to some extent adding in extra teaching as a response to badly answered questions.

Real life data is not clear cut: unwanted complexity 1

Comparing the progress of TP and CC with the maths sets above them for the 2018-2020 cohort was made more difficult because the two maths sets above TP and the two maths sets above CC were created "equal". Let me explain what that means.

A common way to allocate learners to maths classes is to divide the cohort into a number of sets. Normally a group of the lowest attaining learners (by whatever measure) are put in one set, a group of slightly higher attaining learners are put in the next set and so on.

In both cohorts the setting was done towards the end of year 9

In 2017-19 the 5 sets were created in the way described above:

- $a1 < a2 < a3 < a4 < a5$ they are called TP, AT, 2AT, 3AT and 4AT
- $b1 < b2 < b3 < b4 < b5$ they are called CC, AC, 2AC, 3AC and 4AC

For key see overleaf

However in 2018-20 the sets were created:

- $a1 < a2 \approx a3 < a4$ a1 is called TP and a4 is called 3AT
- $b1 < b2 \approx b3 < b4$ b1 is called CC and b4 is called 3AC

Where $<$ means "contains lower attaining learners than"
$\approx$ means "contains similarly attaining learners to"
AT means the set above TP
2AT means two sets above TP etc
CC means the control class, the same set as TP but in the other half the cohort
AC means the set above CC
2AC means two sets above CC etc

In order to compare TP (timely practice) and CC (control class) with AT (the set above timely practice) and AC (the set above the control class) the learners in a2 and a3 were notionally combined and then split into a slightly lower attaining class called AT and a slightly higher attaining class called 2AT (2 sets above time practice). Similarly b2 and b3 (in the control half of the cohort) formed AC and 2AC. The splitting has been done based on the test results at the end of year 9, just as the 2017-2019 learners were split. The exam result data has been processed as if the standard setting had happened.

Real life data is not clear cut: unwanted complexity 2

Both the 2017-19:CC and 2018-20:CC were not true controls as each time in the second year of the two year trial the CC class used timely practice. The reasons for both classes using timely practice in the second year of the two year course were different but this was unfortunate for two reasons:

- the control class is not a true control, so the results of the trial are less clear,
- we don't recommend starting to use timely practice in the final year of the GCSE course.

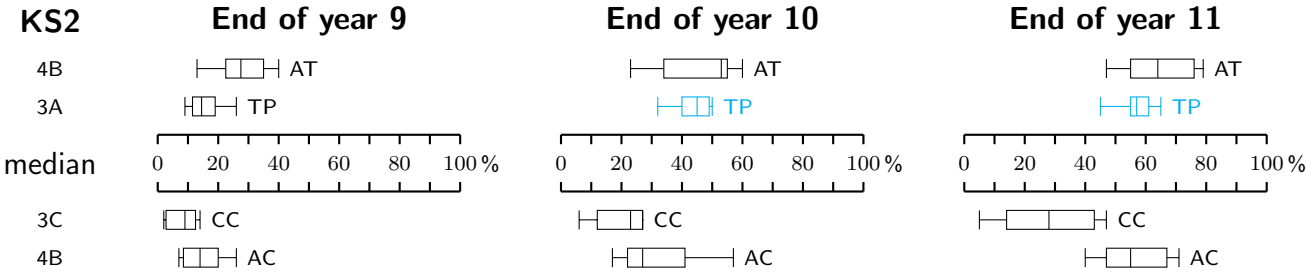
Fortunately for us, this didn't seriously impact on our ability to show progress with timely practice as, we were able to compare TP with AT and AC. Since TP and CC were in both cohorts quite different in their attainment, it is likely that TP's progress relative to AT and AC would have been more meaningful even if CC had remained "untainted" by timely practice.

Results, analysis and interpretation

Results and analysis of the 2017-2019 classes

The box and whisker graphs show the percentages the learners attained in their end of year tests

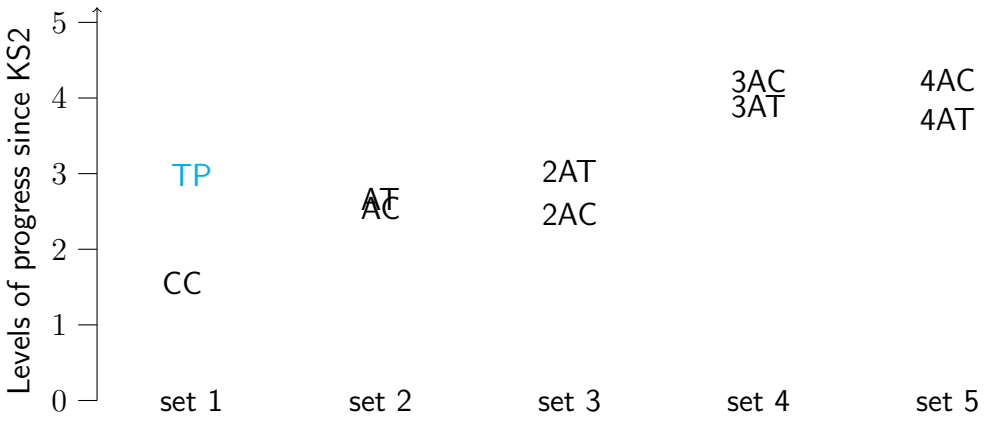
- at the end of year 9 (prior to use of timely practice)
- at the end of year 10 (mid way through TP's use of timely practice)
- at the end of year 11 (the final exam)



Over the two year GCSE course:-

- TP closes the gap with the set above, AT — Before the intervention, over three quarters of the TP class are below the lower quartile of the AT class. After 2 years, both TP and AT have similar lower quartiles.
- TP extends the gap with the control class, CC — Before the intervention three quarters of the control class are below TP's median. After 2 years all of CC are below TP's lower quartile.
- TP makes similar progress to AC — The upper and lower quartiles of TP lie between the upper and lower quartiles of AC at the beginning and end of the 2 year intervention.

The school measures the mean "levels increase since KS2" to compare each class' progress. These are shown for set 1 (TP and CC) to set 5 (4 sets above) in the diagram below.



The progress measure indicates the progress over the five years of secondary schooling.

- TP's progress is on parr with the maths classes 2 sets above them (2AT and 2AC).

The national trend is that lower attaining learners fall further and further behind their peers during their schooling. (Ofsted 2012)

- In the box and whisker graphs of the results of end of year tests, we expect to see the learners in higher attaining sets make more progress than the learners in lower attaining sets.
- In the scatter graph of the average levels of progress since KS2, we expect to see the higher attaining sets make the most progress and the lower attaining sets make the least progress.

The evidence of TP's attainment rising faster than expected is:-

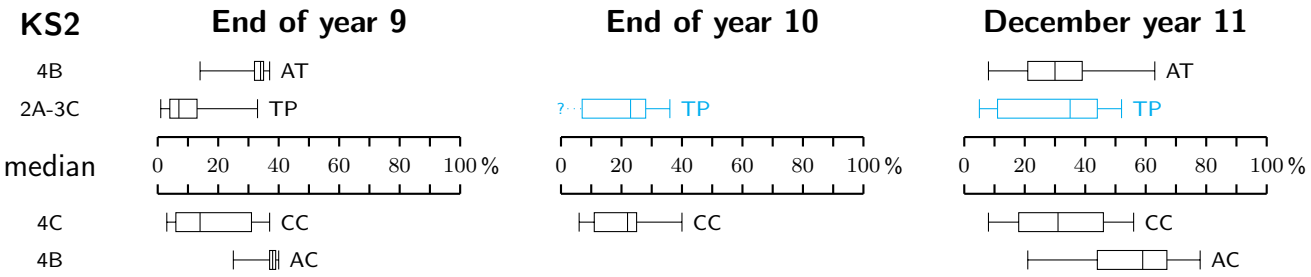
- TP closes the gap with the set above, AT
- TP makes similar progress to the set above the control class, AC.
- TP's mean "levels increase since KS2" is on parr with the maths sets 2 above them, 2AT and 2AC

Without intervention - we would expect TP to extend the learning gap with the lower attaining control class, CC - as indeed they did.

Results and analysis of the 2018-2020 classes

The box and whisker graphs show the percentages the learners attained in their end of year tests

- at the end of year 9 (prior to use of timely practice)
- at the end of year 10 (mid way through TP's use of timely practice)
- after 1 term of year 11 (the mock GCSE exam)



Over the four terms of the GCSE course:-

- TP closes the gap with the set above, AT — before the intervention, over three quarters of the TP class are below the lower quartile of the AT class. After 4 terms the median of TP is above the median of AT
- TP closes the gap with the control class, CC — before the intervention, over three quarters of the TP class are below the median of CC, the control class. After 4 terms the median of TP is above the median of CC

Notes

- In year 10 the AT and AC classes took a hybrid Foundation-Higher GCSE paper and the TP and CC classes took a cut down Foundation GCSE paper (so TP and CC's results cannot be compared with AT and AC's results).
- The three least able learners were dis-applied from the year 10 tests i.e. not asked to take the tests - hence the length of the tail (to the minimum score) is not known.
- In the year 11 mocks the AT and AC classes took a Higher GCSE paper and the TP and CC classes took a Foundation GCSE paper (but since we have "cut-off" marks for grades, 3, 4 and 5 we were able to scale the Higher marks to Foundation marks).

Conclusions

The low attaining maths learners in the 2017-19 and 2018-20 classes, seem to have closed the attainment gap with the classes one set above them. This is evidence of timely practice raising attainment by more than would be expected had they been taught using traditional maths teaching.

A valid criticism of this research is that each trial is of a small number of learners. Further trials would be needed to verify the validity of the findings to the population of low attaining maths learners.

Each of the changes that timely practice recommends and facilitates are supported by well respected research:

- use assessment for learning to plan teaching (Black and Wiliam 2001) and ensure all the pre requisites are mastered before teaching new learning (Kulik et al 1990). Throughout this report I've called this principle 1: teach in the sweet zone between too easy and too hard. Teachers generally say "teach on firm learning foundations".
- teach using "an improving spiral", i.e. teach smaller "bites" more frequently. Throughout this report I've called this principle 2: teach in the sweet zone between too little and too much. Teachers generally say "teach little and often".

Finally what I've called principle 3: get the timing of practice and feedback right

- use spaced repetition practice to ensure learning can be recalled for longer (Kang 2016). When deliberate practice is varied, this helps learners build chunks or mental schema. Once built, the chunks reduce the working memory load required to solve problems (Gobet 2005, Sweller 1998). Teachers might say "increasing interval retrieval practice creates firm foundations for future learning".
- use assessment for learning to decide whether teaching has become learning, (Black and Wiliam 2001) and if not, give effective feedback. Feedback needs to be applied, shortly after it is given. (Hattie and Timperley 2007). Teachers generally say "give effective feedback in a timely manner".

What timely practice does is to make it much easier for maths teachers to apply all these principles together without excessive work load.

We believe we have demonstrated that it is **possible** to significantly increase the quantity of learning that low attaining learners retain from their maths lessons by making changes to when during the school year practice questions and teaching new learning is done.

If it is possible to significantly increase the quantity of learning low attaining learners retain from their maths lessons, by making changes to the spacing over time of teaching, practise and feedback then we believe that social justice says that we **should** make these changes.

. . . but who should take responsibility for the retrieval practice and feedback:

- the learner, their family and possibly a tutor?
- the learner, the teacher and the school?

Many learners, with encouragement from school and family support, revise and practise what they have learned in their maths lesson at home. This is the status quo - yet it isn't working for many low attaining learners.

If schools take on the responsibility for retrieval practice and any necessary feedback in cases where progress is currently poor there is, we believe, a huge potential to improve the attainment of (currently) low attaining maths learners and of course school exam results.

Logic Model

Resources or inputs	Assumptions
• maths topics split into layers (small bites of learning) - layers provide a staircase to progress through a topic • teach-learn resources on each layer for the teacher to use to teach new learning • practise-learn resources for learners to practise new learning directly after teaching • sufficient retrieval practice questions on each layer, so that copying is unlikely and for the app to use to schedule retrieval practice • a method of tracking depth of learning for every learner on every layer within every topic • "learned?" assignments provide pre assess with fast track option • timely practice PDF assignments provide an increasing interval retrieval practice system which is adaptive for each learner to the independence and accuracy of learners' answers and the depth of learning of each layer	• teachers interact with the app • learners interact with the PDF assignments created by teachers using the app • timely practice assignments to be done for 5 to 25 minutes of maths lessons, at least 3 times per week • the lowest attaining learners will generally use for several years • learners merely with large learning gaps will use for up to a year • classes of mixed ability learners with special needs may use for the long term (e.g. alternative provision)
Activities	**Assumptions**
• teacher creates a personalised assignment for each learner • learners attempt all the questions in their new assignment, getting help if they need it • learners review their previous lesson's assignment and get feedback from the teacher when necessary • teacher teaches less on a topic at any one time than is normal • learners practice fewer practice questions on new learning than is normal, the questions are more similar than is normal • teacher tells the app which learners learned which layers in the lesson • teacher assesses learners' answers to each question in the assignment using the app supplied answers and one of the 4 assessment codes • teacher plans teaching for the next lesson, using the progress on topic data for 1 or 2 topics • teacher may use teach-learn and practise-learn resources • this cycle is repeated most maths lessons • teacher returns to teaches more from most topics several times a year	• most learners can independently and accurately answer most questions - most low attaining learners find this very motivating • therefore there is time for the teacher to give help/feedback to the learner when required • the teacher can see detailed depth of learning data on pre requisite skills so most new teaching is easy to teach and easy to learn

Outputs	Assumptions
• learners answer many more questions than is normal • learners are more motivated than is normal • learners generally know which maths skills to use (very quickly) and become better at novel problem solving (more slowly) • teacher can see and print out both progress on topic (depth of learning for each learner on each layer within the topic) and learner progress data (depth of learning for one learner for all layers within all topics) • the app records (internally) more data to facilitate efficient retrieval practice	• depth of learning is not measurable per se - by measuring we extend retention • our aim is that learners can recall and use all learning (past and recent) so the teacher never needs to remind nor re-teach • we rely on edge conditions to recalibrate depth of learning e.g. after longer holidays
Outcomes	**Assumptions**
• learner immediate: retain more learning per lesson • learner medium-term: more engaged in learning, more resilient • learner long-term: find new learning easier, attainment raised • teacher short-term: accurately targeted teaching • teacher medium-term: know and "tutor" learners better • teacher long-term: can predict and avoid learners stumbling blocks • teacher long-term: have a 'feel" for retrieval practice and chunk-based theory • teacher and schools long-term: teachers are trusted to create class specific schemes of learning	• learners enjoy mastering learning when they are taught with gently rising aspirations • low attaining learners like familiarity • teachers notice that learners are easier to teach • teachers and learners notice better exam results
Impacts	**Assumptions**
• schools and inspectors aware that without appropriate spacing of teaching (more tightly spiralled curriculum) and learning (retrieval practice with feedback) low attaining learners are more disadvantaged than their peers • schools change schemes of learning to include how and when retrieval practice will happen • the attainment gap between low attaining learners and their peers closes • schools measure working memory capacity for all learners and provide appropriate teaching and schemes of learning	• low attaining learners (begin to) catch up with their peers • when teacher to learner ratios are lower they are more effectively used • much more learning is retained year on year • fine grained transition data sharing is possible e.g. year 6 to year 7

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