Institute for Effective Education
Empowering educators with evidence

Learning by Questions

Using low-stakes quizzing and interleaving to promote learning and retention of information in primary mathematics

Shireland Collegiate Academy

Introduction

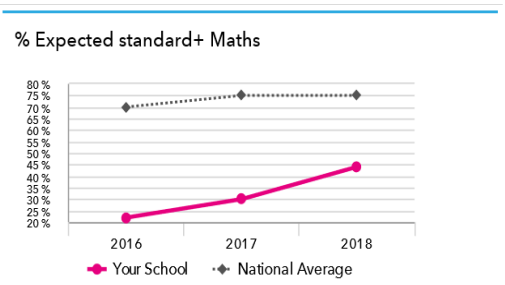
Problem: Describe the problem or issue your innovation addresses.

What challenge(s) do your school(s) have that need to be addressed?

Tameside Primary Academy has recently joined the Collegiate Academy Trust.

Both 2017 Key Stage 2 SATS data for all maths indicators and in-house CEM standardised assessment data for the current Year 5 cohort indicates that mathematics attainment data is very low.

Maths						
% Expected standard+	22%	30%	44%	-38%	-37%	-22%
% Higher standard	2%	0%	9%	-8%	-14%	-4%
Scaled Score	95	96	99	-6.9	-6.3	-2.8
Level 4+	-	-	-	-	-	-
Level 4B+	-	-	-	-	-	-
Level 5+	-	-	-	-	-	-
Average Point Score	-	-	-	-	-	-



Tameside CEM data summary Oct 18

Year	Reading Start of Year	Reading End of Year	Gen Maths Start of Year	Gen Maths End of Year	Mental Arith Start of Year	Mental Arith End of Year	Dev Ability Start of Year	Dev Ability End of Year
Year 1								
ARE +	79%		92%		49%		36%	
GDS	1%		13%		5%		0%	
Year 2								
ARE +	75%		84%		68%		63%	
GDS	14%		9%		5%		6%	
Year 3								
ARE +	81%		84%		76%		66%	
GDS	18%		9%		10%		7%	
Year 4								
ARE +	91%		85%		73%		75%	
GDS	20%		14%		14%		20%	
Year 5								
ARE +	87%		57%		66%		70%	
GDS	9%		8%		8%		16%	
Year 6								
ARE +	65%		41%		46%		66%	
GDS	2%		7%		5%		9%	

We would like to investigate whether using quizzes and spaced practice can promote learning and retention of information in primary mathematics resulting in improved performance on CEM standardised tests.

Existing evidence: What existing research evidence exists?

What does the existing research evidence say about this problem and how it could be addressed?

The advantages provided to memory by the distribution of multiple practice or study opportunities are among the most powerful effects in memory research (Benjamin, A. S., & Tullis, J. (2010).

Teachers aim to ensure that information is learned and understood during a lesson, unfortunately a lot of the material may be forgotten over subsequent weeks. This is reflected in the performance of our Year 5 pupils who are struggling to retain mathematical information over the longer term.

While some forgetting may be inevitable, as a process it is well understood by memory researchers, and steps can be taken to reduce it. One simple option is to manipulate the timing of study activities, and in particular to increase the gaps of time between initial learning and consolidation work. The ‘spacing effect’ is a phenomenon first observed during the early days of Psychology in the 1880s; spacing out learning over time (sometimes called 'distributed practice') has the potential to double retention over timescales relevant to school or college courses (Mozer et al., 2009).

Evidence from a number of studies revealed that retrieval practice in authentic classroom settings improves long-term learning (Agarwal et al., 2012). Studies have also revealed that using retrieval practice resulted in increased retention, particularly when retrieval was equally spaced and the initial test was delayed. (Karpicke, J. D., & Roediger, H. L., 2007.) Over longer timescales, repetition may serve to remind learners of their earlier learning experiences, thereby activating relevant episodic memories and making them easier to access in future (Benjamin & Tullis, 2010).

Moreover, several recent studies have shown that testing itself not only enhances learning—it also reduces the rate at which information is forgotten. (Roediger and Karpicke, 2006b)

Innovation: Describe the innovation you will evaluate.

Give a brief description of the innovation. What existing research suggests the innovation will help improve the problem you have identified and benefit teachers and learners?

We would like to review the way that teachers assess learning after a topic has been taught.

Rather than the standard practice of issuing blocked homework on the same day / week that a topic has been taught, this would be replaced by a process of delaying each such task by two weeks, at no extra time cost to the teacher. The latter possibility is supported by the finding that maths homework which is both spaced and intermixed – newer tasks mixed together with revision of earlier lessons - leads to higher attainment (Rohrer et al, 2014)

Research with practical implications for the classroom:

- Practice is essential to learning new facts, but not all practice is equivalent (Ericsson, Krampe, & Tesch-Römer,1993)
- Teachers can space practice over time, with content being reviewed across weeks or months, to help students remember that content over the longer term. (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006)
- Teachers can explain to students that trying to remember something makes memory more long-lasting than other forms of studying. Teachers can use low- or no-stakes quizzes in class to do this, and students can use self-tests. (Agarwal, Bain, & Chamberlain, 2012; Pashler, Bain, Bottge, Graesser, Koedinger, & McDaniel, 2007)
- Teachers can interleave (ie., alternate) practice of different types of content. For example, if students are learning four mathematical operations, it's more effective to interleave practice of different problem types, rather than practice just one type of problem, then another type of problem, and so on. (Pashler, Bain, Bottge, Graesser, Koedinger, & McDaniel, 2007; Rohrer, Dedrick, & Stershic, 2015)

We would like to design a study programme that incorporates spaced practice and interleaving in order to improve learning in mathematics. We intend to use low stakes quizzing using the 'Learning by Questions' platform to allow regular opportunities for material to be revisited. Correct-answer feedback will be provided. We already use the White Rose maths hubs long term planning so the assessment materials available are closely aligned to our taught curriculum.

1. All pupils (control and intervention classes) will complete a pre-test assessment. This will be a CEM incas standardised test in mathematics.

2. Pupils in the intervention class will undertake a series of low stake quizzes throughout the intervention period. The quizzes which children are set will be carefully selected so that:

a. There is a delay of two weeks between classroom learning and testing

b. Teachers interleave practice of different types of mathematical content so that newer tasks are mixed together with revision of earlier lessons / maths topics.

c. Key topics are presented multiple times to pupils before the final test.

Pupils in the control will continue with business as usual which involves a topic being taught in class and a blocked quiz / assessment on that topic immediately afterwards.

3. All pupils will take a post -test which again will take the form of a CEM Incas standardised test in mathematics.

We have a three form entry school so there is the potential to use a three-armed design with a control group (no online quizzes) and two different intervention groups (online quizzing with spaced practice and online quizzing with spaced practice **and** interleaving of topics).

Research question(s) or hypothesis

What effect will the intervention, implemented for how long, with which pupils, have on which outcomes?

What impact does using low stakes quizzing, and in particular interleaving, have on Year 5 pupils' mathematics attainment over a period of three months?

Method: Describe exactly how the evaluation will be conducted

Sample

Who will participate in your evaluation? What consent will be gathered for them to participate? Briefly describe the key characteristics of the setting and participants.

The evaluation will take place in Year 5 at Tameside Primary Academy, which has recently joined the Collegiate Academy Trust. The school is three-form entry with a pupil premium percentage of 39%. Technology for learning is currently not used widely within the school.

As the intervention involves a change to classroom practice might ordinarily implement and is not very obtrusive, opt out consent will be obtained from parents for their child's data to be included as part of the evaluation.

Assignment to condition

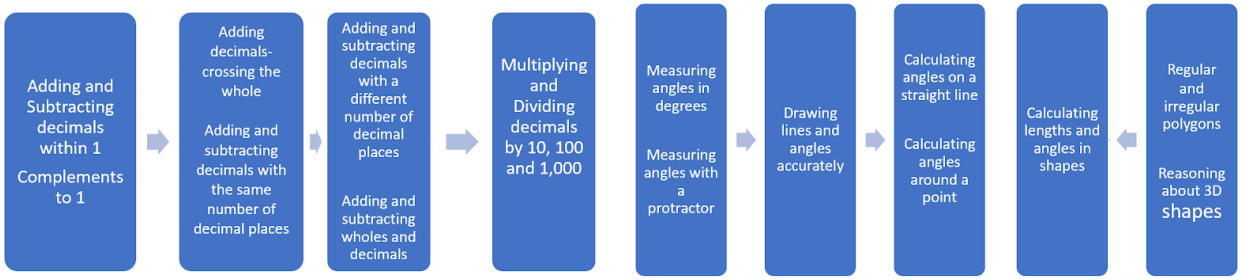
How will you allocate participants to the intervention and control groups?

The three classes will be randomised with a coin toss (or similar) to each of the conditions described in the next section below.

Innovation

Describe your innovation in detail.

All three Year 5 classes currently follow the White Rose maths suggested long term plan for mathematics. Over the Summer term they will be teaching the following mathematics topics:



All teachers in Year 5 will continue to teach in this order. At a class level, pupils will be assigned to the following conditions:

1. **Control class** – business-as-usual. Teacher-led activities with paper-and-pencil worksheets, quizzes and similar. Post topic quizzes are presented in a blocked fashion corresponding to the topic which has just been taught in class.
2. **Intervention class 1** – LbQ with spaced practice. Post topic quizzes will be presented with a delay of 2 weeks between classroom teaching and quizzing.
3. **Intervention class 2** – LbQ with spaced practice and interleaving. As for Intervention 1, but in addition maths topics will be tested an interleaved fashion in addition to spaced practice rather than in a blocked fashion (ie, when practising, questions about different

topics will be mixed together, eg, for subjects a, b and c, questions will be asked a1, b1, c1, a2, b2, c2, etc rather than a1, a2, …b1, b2, ….c1, c2.

Outcome measures

What outcome measures will you use? When and how will they be administered and scored?

1. All pupils (control and intervention classes) will complete a pre-test assessment at the start of the summer term. This will be a CEM Incas standardised test in mathematics.
2. All pupils will take a post -test after nine weeks at the end of the summer term, which again will take the form of a CEM Incas standardised test in mathematics.

The CEM Incas assessments will provide us with both standardised age scores and age-equivalent scores for general mathematics.

All classes will cover the same material, and though the final post-test is a general maths test (ie, not specifically on the topics covered during the term), no group should be disadvantaged.

Learning by Questions will be used to provide the quizzes to pupils, whilst the CEM Incas standardised test will be used to measure performance pre and post intervention.

Process analysis

What data will you gather for the process analysis?

We intend to carry out a process evaluation alongside the impact evaluation of mathematics attainment to help us understand if the innovation was delivered as intended, to gather teacher and pupil views of the innovation, and also to gather teacher and pupil perceptions of things that went well or could be improved.

To achieve this, there will be a number of aspects to the process evaluation:

1. To encourage implementation validity, we will not go into detail about the theory of spaced practice and interleaving with class teachers during training in order to avoid overstating which group we expect to see the most success in. The training session will focus on the use of the LBQ system and may include some information about the more general testing effect on memory. The schedules for testing in each group will be provided to teachers.
2. Over the course of the nine week evaluation, Jen Devaney will conduct two classroom observations of the innovation being implemented and the control and will also carry out

regular online audits of LBQ to check that the intervention is being delivered as intended and that the control class is not receiving spaced or interleaved practice.

3. With the support of the IEE we will develop both a pupil interview and teacher questionnaire to gather teacher and pupil perceptions of the innovation which will take place towards the end of the summer term.

Analyses

How will you analyse your outcome and process data?

The CEM Incas test provides us with a standard age score. We will calculate the mean pre-test, post-test and progress scores for each group and then calculate effect sizes to compare the progress of the three groups (Intervention class 2 vs Intervention class 1, Intervention class 1 vs control and Intervention class 2 vs control).

Conclusion

Potential limitations

What are the potential limitations of your design?

The main limitation for this study is that each group will be taught by a different teacher and so the quality of teaching may not be controlled for. It would be interesting to compare two classes who were taught by the same teacher using either business as usual or spacing and / or interleaving to compare the impact but logistics do not allow this in the current study.

In addition to this, the school has joined the Collegiate Academy Trust during the academic year and so there may be other changes to teaching practice which are unaccounted for. However, since all three classes were from within the same school and year group we believe these differences will be the same across all three conditions.

The small sample size and the fact the evaluation is carried out in one school limits the generalisability of the findings. We would also like to try the approach with a larger number of pupils and analyse the performance of different groups such as pupil premium pupils or prior attainment.

The mean control group pre-test score was much lower than those of Intervention groups 1 and

2. This suggests that the groups may not have been equivalent before the intervention. Among other things, this may have influenced the teaching and support pupils in the control group received outside the intervention.

References

Agarwal P K, Bain P M & Chamberlain R W (2012). The value of applied research: Retrieval practice improves classroom learning and recommendations from a teacher, a principal, and a scientist. Educational Psychology Review, 24(3), 437–448.

Benjamin A S & Tullis J (2010). What makes distributed practice effective? Cognitive Psychology, 61(3), 228–247.

Cepeda N J, Pashler H, Vul E, Wixted J T & Rohrer D (2006). Distributed practice in verbal recall tasks: A review and qualitative synthesis. Psychological Bulletin, 132(3), 354–380.

Ericsson K A, Krampe R T & TeschRömer C (1993). The role of deliberate practice in the acquisition of expert performance. Psychological Review, 100(3), 363–406.

Karpicke J D & Roediger H L (2007). Repeated retrieval during learning is the key to long-term retention. Repeated retrieval during learning is the key to long-term retention. Journal of Memory and Language, 57, 151–162

Lindsey R, Mozer M C, Cepeda N J & Pashler H (2009). Optimizing memory retention with cognitive models. In A Howes, D Peebles & R Cooper (Eds.), Proceedings of the Ninth International Conference on Cognitive Modeling (ICCM). Manchester, UK.

Pashler H, Bain P M, Bottge B A, Graesser A, Koedinger K, McDaniel M and Metcalfe J (2007). Organizing instruction and study to improve student learning. US Department of Education. Washington DC: National Center for Education Research, Institute of Education Sciences.

Roediger H L and Karpicke J D (2006). Test-enhanced learning: Taking memory tests improves long-term retention. Psychological Science, 17, 249–255.

Rohrer D, Dedrick R F & Stershic S (2015). Interleaved practice improves mathematics learning. Journal of Educational Psychology, 107(3), 900–908.