A review of research conducted by Leyton Sixth Form College CFEM network 2019 - 2022

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As participants in the National Centres for Excellence in Mathematics (CFEM) programme, Leyton Sixth Form College (LSC) and our network partners conducted a series of action research projects focused on improving the teaching of GCSE re-sit mathematics.. We developed practice in the classroom using key aspects of teaching Mathematics for engagement and mastery including dialogic learning, representations, blended learning and responsive teaching. We found that students were more able to engage with and articulate mathematical ideas when discussion was scaffolded using conversation structures, talking points, and representations. This led to improvements in their willingness to attempt problem-solving assessment questions. Doing the research supported teachers to experiment with and refine new practice over a full academic year. The result has been improved confidence using the new techniques and longer term changes of practice. In this report I outline 5 projects and give details of how to access the full version.

Keywords: mastery; bar models; double number lines; dialogic; blended; responsive; GCSE resit

Key aspects of Mastery Learning in mathematics

Mastery Learning can be achieved in a number of different ways but in our research we focused on bar models, double number line diagrams and dialogic learning supported by regular checks and formative assessment. We have now integrated these into our scheme of work and shared lesson plans for GCSE resit Mathematics at Leyton Sixth Form College.

Common methodology

All of these projects have a common methodology inspired by Lesson Study.

In our projects a small group of experienced GCSE mathematics re-sit teachers commit to meeting regularly to investigate and try out a new approach. After doing some reading and sharing what they have learned, they collaboratively plan an activity to use in the lesson. Every teacher then tries the activity with their group of learners as part of their regular classroom teaching. They then meet to reflect on the results and how to refine the approach for the next activity.

Because the research is being done with the same groups of learners, the new activity is usually on a different mathematical topic but uses the same improving pedagogical approach. Most of the projects had 3 or 4 cycles of testing, reflection and improvement over the course of one academic year.

The data collection and analysis were primarily qualitative and comes from student surveys, collection of students' work, teacher reflections, teacher observations

of students' behaviour and some peer observation. There is also some quantitative analysis of students' work from assessment but it's important to note these are usually from samples of less than 100 students.

The research projects

Dialogic learning for GCSE resit students: How does the use of problem-solving activities engage students with mathematical tasks? (2019 – 2020)

From September, three teachers at NewVIC, our CFEM network partner met on a weekly basis to put together sets of three lessons for a range of topics containing activities to gauge prior knowledge and misconceptions (using open tasks where students have to make decisions), elicit students' thinking (regular feedback between students, in groups, as a whole class) and help students rebuild their own knowledge (using tasks with inbuilt checks such as matching activities) then develop their ability to apply this (topic test questions).

Table 1: comparison of lessons observed early in the use of the approach and then further into the project. Each time, one set of students was observed attempting a group task and the activity that each student was engaged in was recorded every two minutes. The results are shown as percentages.

Activity	NV Ob 1	NV Ob 2	NV Ob 3
Off task	14	6	5
Talking	23	35	36
Listening	32	35	33
Writing / using calculator	41	24	17

The consistently high amount of time spent talking and listening that these tasks encourage, seems significant. It is also notable that the number of students who were off task has dropped immediately and remains low even after potential novelty would have worn off.

		Talking about Maths problems helps		
		Yes	Neutral	No
I like maths	Yes	8	2	0
	Neutral	23	19	5
	No	20	14	8

Table 2: the response to a student survey which was part of the project. I have highlighted the fact that the majority of students who identified as not particularly liking mathematics still thought that talking about mathematics problems was helpful to them. This may be connected to the reduced time spent off task in lessons.

How can blended learning be used to engage students in the learning experience? (2020 - 2021)

This project was inspired by a need to develop a more effective and engaging pedagogy for remote learning.

In Cycle 1 several platforms were trialled, including Jamboard, Dr Frost Maths whiteboards, whiteboard.fi, OneNote class notebooks, Zoom whiteboard/ annotation & chat, Desmos, MyMaths and MS Teams. Of these Desmos was chosen for further investigation because it is designed with maths pedagogy in mind and stimulates mathematical discussion and quality student feedback.

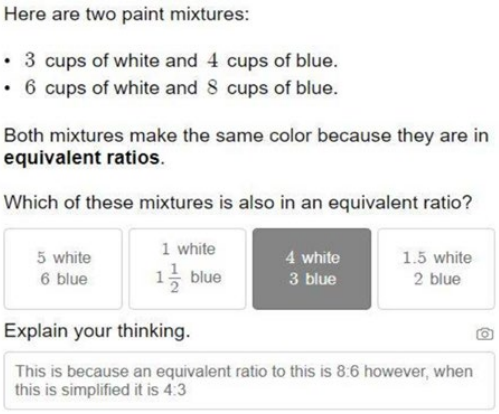


Figure 1: Extract from an activity "Paint" authored by the Desmos creators designed to explore and test ideas about equivalent ratios. You can also see a response from a student. During the lesson the teacher can see the students' responses to each question on a dashboard. Students can also see the responses of 3 others once they have submitted their own. Students can be anonymized by the teacher to allow for the sharing of ideas without embarrassment.

For cycle 2 teachers experimented using a task written and tested by the Desmos team to build their confidence using the features of the platform to intervene individually or to pause and gather the students for discussion. "Instant formative feedback from this task meant students were more resilient, having multiple attempts until the correct answer was found." In Cycle 3: Proportion - Standards Unit (adapted by the AR team), having built some confidence, the teachers experimented with adapting a resource designed & tested for discussion in person to the Desmos platform. It was not a seamless transition. "Trying a range of proportion questions, spotting and commenting on mistakes, showing working on the DNL and inventing their own puzzles was too much for one session both in terms of time and ability to focus." In Cycle 4 teachers had developed their pedagogy for remote learning using Desmos to the point where they felt ready to try a new activity by a colleague. They discovered that in designing the activity thought should be given to building up to the main points much more slowly than you might in class because it is much harder to notice whether students have the necessary underlying skills to access them.

Students' responses to Q: Did you enjoy the Desmos activities?

> "They are good as they have diagrams and describe it more for you. I enjoy them as you can understand more"
>
> "They are useful and usually a bit of fun. They have different stuff in it, like robots"

Using double number lines and bar modelling to teach the GCSE maths curriculum based on the Mastery approach (2020 - 2021)

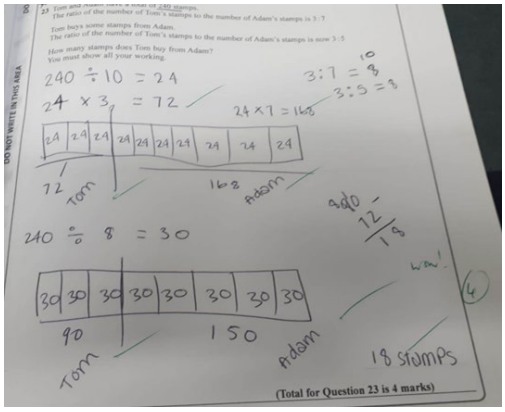
This project involved 4 teachers and 7 classes totalling 125 students. All the teachers were based at LSC which enabled both formal and informal shared reflection on the collaboratively planned lessons and improvements were made during each cycle.

In Cycle 1 teachers experimented with teaching ratio using the bar model based on existing resources designed for KS3. Students then went on to try a variety of exam questions. They were much more able to solve the problems with the scaffolding of a pre-drawn bar model but mostly not able to draw their own.

In Cycle 2 we taught proportion using double number lines. As this was a new diagram, we again based our lesson on existing resources, this time from the University of Nottingham. Students were able to use double number lines that had been set up for them to solve problems in their own ways and were able to identify incorrect diagrams in a later quiz but found it much harder to set up their own well enough to be of any use.

Having built some confidence using double number lines in Cycle 3 we experimented with using them to teach speed based on the idea that speed is distance travelled in 1 hour. The double number lines did give students this more concrete concept of speed and linked into the formulas they had learned. Even with fixed quantities (distance & time) on the lines, students struggled to construct the double number lines for themselves.

After early testing of the collaboratively planned materials on equations in cycle 4 we introduced a starter activity using bar models to solve 1 step missing number arithmetic problems. This made a considerable difference to the students' ability to access the rest of the lesson. We insisted that students draw their own models and did some checking of their models using mini whiteboards before letting them practice with a set of GCSE exam questions.



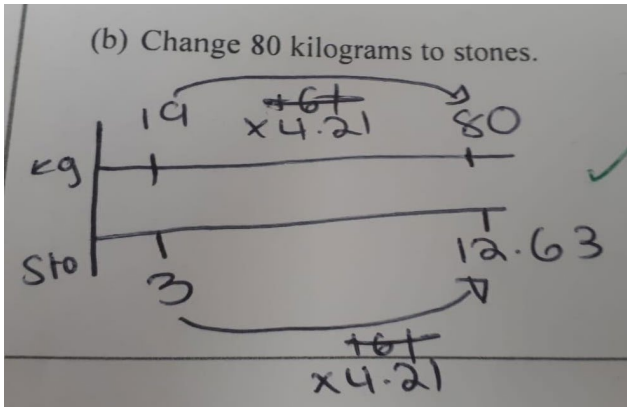


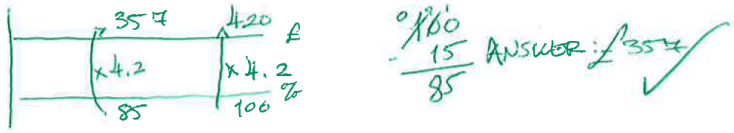
Figure 2: Examples of students' work in later mocks. Students who used the diagrams in the mocks tended to be more successful.

Representations for mixed ability GCSE re-sit classes (2021 - 2022)

Following the success of the representations project at LSC more work was done on the use of representations with our network partners. This project involved 5 Staff from 4 FE colleges teaching a total of 150 students. Most of the colleges group the students by vocational course not by prior GCSE Maths grade and this leads to a wide range of mathematical ability within the classroom. A pre and post-test was carried outdone to measure improvements and changes in problem solving approach.

Figure 3 shows an example of a student's work on solving 2 percentage problems in the post test. The first is a percentage decrease and the second is a reverse percentage. These would often be taught as separate topics and students struggle to identify the type of problem so as to select the correct strategy, but you can see that this student has been able to use the double number line to support their reasoning in both starting from a similar setup.

3. The normal price of a cooker is £420. In a sale, the price is reduced by 15%. What is the sale price?



4. A washing machine has been reduced in a sale by 20%. The sale price is £512. Work out the original cost.

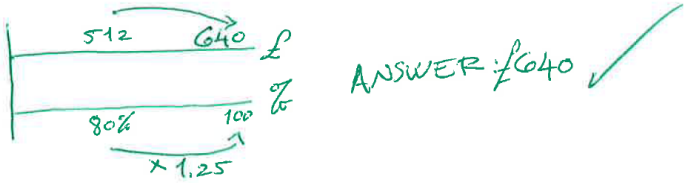


Figure 3: Student's work on solving 2 percentage problems in the post test.

Responsive teaching: responding to persistent misconceptions (2021 - 2022)

This project involved 6 teachers and 5 classes totalling around 100 students, all based at LSC. We have recently introduced low stakes end of unit checks and we wanted to investigate ways of responding to the misconceptions that persist after teaching without introducing long delays or unsustainable workload. Influenced by the work of William & Leahy (as described by Jones, 2021) we experimented with 3 different ways to activate students as resources for each other.

First, we sat the students in mixed groups. We returned their tests and asked them to identify who had got the question right and make them explain. We observed that students were paying close attention to the explanations offered but we were not satisfied with how transferable those explanations would be. Students were unwilling to discuss their misconceptions.

Second, to encourage better explanations while also directly addressing the common misconceptions that persisted after teaching, we prepared some anonymous work (one right and one wrong response for each focus question) and some guidelines on good feedback. Students were much more comfortable to discuss misconceptions and the quality of feedback improved after review and praise of the better explanations. After the discussion when students were given their own work they recognised that they had the same misconception and were likely to make corrections.

Third, we prepared anonymous wrong work only and again asked students to give feedback using the same guidelines. After the discussion students made notes of the best feedback and then went on to challenging connected work, usually an exam question on the same topic but with an additional element. We noticed excellent levels of completion and achievement on the more challenging work once the underlying misconception had been addressed.

Details of the full reports of the projects I have outlined here, in the same order

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