EDUCATION & TRAINING FOUNDATION

CENTRES FOR EXCELLENCE IN MATHS

CHANGING THE EXPERIENCE OF FE MATHS

CFEM FINAL REPORT
SYNTHESIS OF ACTION RESEARCH REPORTS 2021/22

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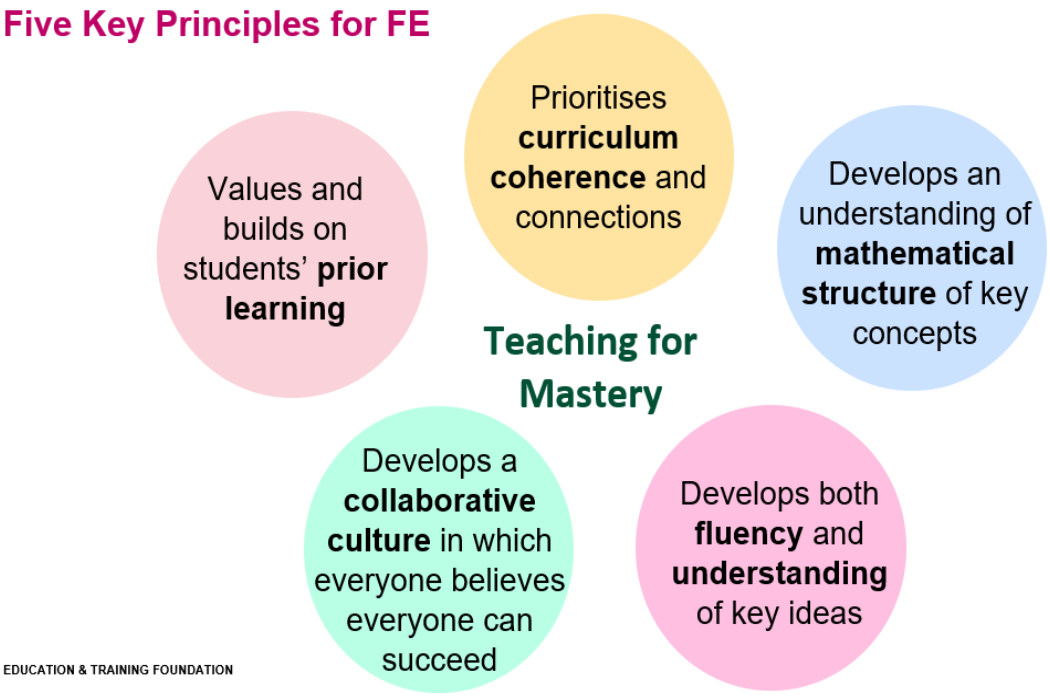
Centres for Excellence in Maths (CfEM) was a national improvement programme ending in 2023 aimed at delivering sustained improvements in maths outcomes for learners aged 16 to 19 up to Level 2, in general further education (FE) colleges and sixth form colleges in England. CfEM was funded by the Department for Education (DfE) and delivered by the Education and Training Foundation (ETF) and partners.

01 Introduction

The main aim of the Centres for Excellence in Mathematics (CfEM) programme was to find out 'what works' in FE maths and deliver sustained improvements in maths outcomes for 16-19-year-olds, up to level 2, in post-16 settings.

Since 2014, it has been a Condition of Funding by the government in England for 16 to 19 year olds to continue working towards a maths GCSE Grade 4 or equivalent until they achieve it. In practice, the overwhelming majority of those not achieving a GCSE grade 4 by the age of 16, and hence impacted by this policy, study in FE colleges. Since the introduction of revised GCSE subject content in 2017/18, the proportion of that cohorts achieving a grade 4 has remained stubbornly below 20%[1], and success rates have been similarly low in Functional Skills at level 2.

To address these issues, CfEM has focused on an adapted maths mastery approach suitable for post-16 learners, based on five key principles[2]:



02 Action research for professional development: a model for FE maths teachers

Central to the delivery of the CfEM programme was the work of 21 colleges who were designated as CfEM 'centres' and grant funded by DfE, and who recruited and collaborated with a local networks of other post-16 providers. A key part of these centres' activity was to undertake enquiries into their own practice to improve learning – i.e. action research.

Action research has been used across a wide range of educational, health and other sectors for decades as it has been shown to:

[1] Except for 2019/20 and 2020/21 when no summer examinations were held due to the impact of COVID lockdowns.
[2] For more details, see: https://www.et-foundation.co.uk/wp-content/uploads/2022/10/CfEM_Mastery_Handbook.pdf

- foster collaboration and sharing
- be highly contextualised and so relevant to very specialised sectors such as FE maths
- enable evidence-based practice
- generate findings that are directly applicable to the researchers' practice
- produce new knowledge for the wider sector
- be a model for genuinely continuous professional development.

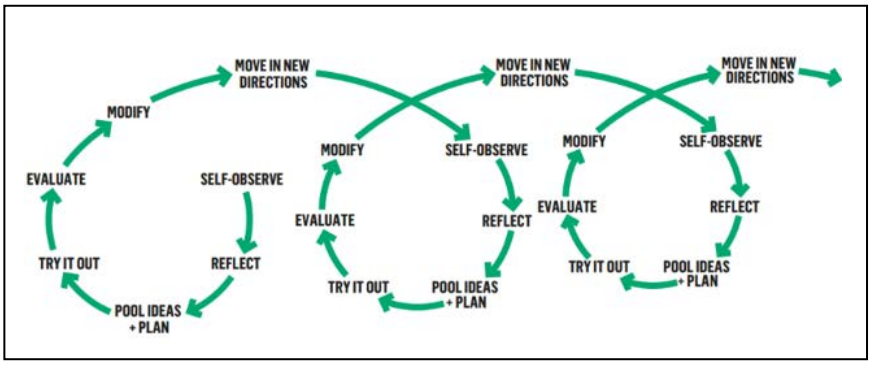
Action research, with its inherent flexibility and practitioner-led insights, offers unique value despite its modest sample sizes. While critics may question its rigour and generalisability, these studies provide a rich, context-specific understanding that may not be easily replicated. Therefore, the insights gained from these interventions, while treated with caution, offer useful contributions to understand ways to improve maths learning.

The definition of action research recommended to CfEM teachers was developed from McNiff and Whitehead (2007) who see action research as a collaborative, empowering and iterative model highly suitable for professional development, based on the **"power of sharing ideas to generate new ones".**

This means that teachers need to go into action research with, as Kemmis and McTaggart (1982) put it four decades ago:

> **"a desire [on the part of teachers] to learn about their own practice in its natural social context through collective self-reflective inquiry with a view to improving practice and as a means of obtaining new knowledge"**

The teacher-researchers were encouraged to use cycle model to give structure to their action research. Below is the version most CfEM teachers were using and found useful after three years of refinement and experience.



03 FE maths mastery research topics

In 2021/22, centres were asked to focus on three overarching (and overlapping) research topics – shown in the table below - which CfEM teachers had previously found particularly pertinent

Research topic selection was additionally guided by:

(a) findings from previous promising CfEM action research

(b) individual reflective practice, discussions between colleagues and initial reading

(c) consideration of wider contexts such as local communities, college priorities and national attainment data.

Summary of CfEM action research topics

Theme	Topics chosen for research
Teaching for understanding How can we develop learners' conceptual understanding and support their reasoning and problem solving skills?	• Using models and representations to reveal mathematical structure and support conceptual understanding (a) Visual models & representations (b) Use of manipulatives • Language issues in maths learning
Teaching responsively How can we deliver a maths curriculum that is responsive to the gaps in learners' skills and understanding?	• Diagnostic assessment approaches for identifying skills gaps • Teaching approaches for addressing misconceptions and filling skills gaps
Engagement and resilience How can we engage learners and overcome negative attitudes, anxiety and fixed mindsets?	• Strategies for addressing anxieties and negative mindsets • Coaching and mentoring approaches • Promoting engagement with mathematical problem solving and multi-mark exam questions • Creating positive learning environments

Issues, interventions and impacts of some of the 40 CfEM action research projects done in the academic year 2021/22 are now presented.

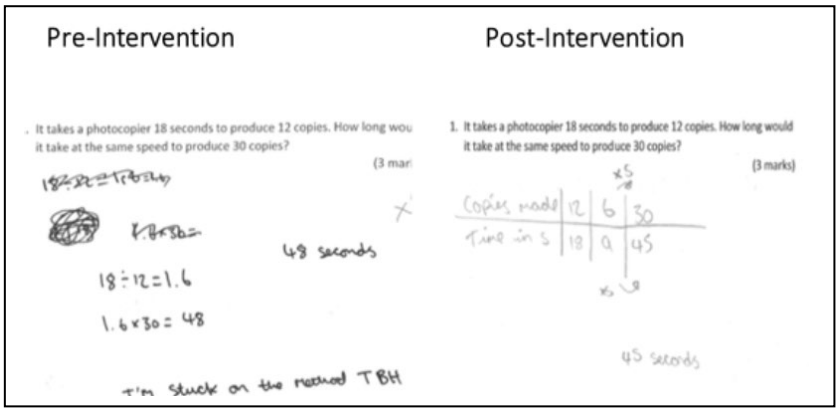
04 Teaching for Understanding

4.1 Using models and representations to reveal mathematical structure and support conceptual understanding

One of the five 'big ideas' of mastery is the use of models and visual representations to reveal mathematical structure, show links between maths concepts, and make mathematical concepts more accessible. Particularly popular with CfEM centres were bar models, ratio tables and double-number lines. Some centres went further to test the use of manipulatives within a wider Concrete-Pictorial-Abstract (CPA) model, while others incorporated carefully chosen contexts to reval mathematical structure, borrowing from the ideas of Realistic Mathematics Education (RME).

Teachers needed plenty of CPD and planning time before introducing models and representations to learners, and learners needed plenty of practice applying their learning to maths problems, but it was well worth it. Teachers and learners also found it valuable to use the same representations across several different topics.

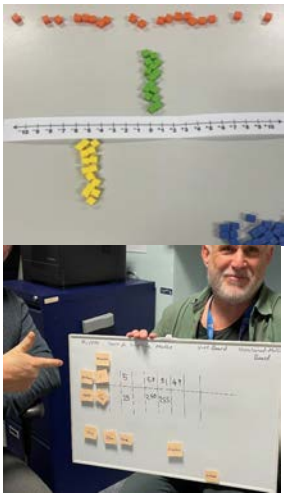
Visual Representations

Proportional reasoning through ratio tables	Evidence base
Issue Prior to attending the college, learners had mainly been exposed transmission approaches. Literature suggested that ratio tables could be a good alternative solving method for learners without a secure algorithm – particularly in relation to proportional reasoning. **Intervention** Ratio tables were introduced and modelled by teachers over several weeks. Each time they were used, real contexts were used so that learners could relate to the maths. Learners were encouraged to practice completing or drawing ratio tables based on abstract and worded maths problems requiring proportional reasoning. The technique needed repeatedly revisiting and learners reminding that they could apply ratio tables to exam-type questions, if they thought they would be useful. **Impact** In general, through use of ratio tables to represent real-life problems, teachers saw an improvement in learners' ability to make connections between maths concepts and real life. By the end of the research period, some learners were successfully solving a range of mathematical problems using ratio tables ere they did not previously have a successful strategy. Classroom inquiry concluded that more than one strategy is a vital part of using this approach when teaching  	Evidence base 4 teachers from 2 colleges Test-teach-test Harlow College CfEM

Models and representations in small group workshops	Evidence base
Issue Learners who attained GCSE maths grade 2 and below at school were arriving in the college with issues stemming from a negative history of maths, engrained self-doubt and questions about the relevance of maths which were difficult to unpick. **Intervention** Four small group workshops on different maths topics were designed and delivered each week for five terms to supplement the traditional resit offer. Learners had free choice but were encouraged to attend the topic they found most tricky. All focused on contextualising maths in ways that learners could relate to. **Impact** Learner confidence in maths improved, and this was attributed to the relatability of workshop content. Models and representations were found by teachers to be ideal in facilitating relatability as they support memory and further application, and use of physical manipulatives kept learners engaged. Attendance improved over time, with	4 staff and 88 learners from 2 campuses Focus groups, observations, attendance data, snapshot surveys Nelson and Colne College Group CfEM

teachers learning to set the expectation of workshops being integral not additional to the learning journey.	

Bar models and manipulatives to bridge from Functional Skills to GCSE	**Evidence base**
Issue Teachers urgently needed to find ways to support those learners who would in previous years have done the more applied Functional Skills Level 2 curriculum but are now put on the relatively abstract GCSE course. **Intervention** They worked together to map the differences between skills required by Functional Skills and GCSE. They co-designed and tried out visual representations, variation theory and other FE maths mastery techniques, aiming to develop mathematical understanding to bridge the gaps. **Impact** In line with existing research, the use of models and representations helped learners relate to the maths and was motivating and engaging. Bar modelling, variation and collaborative activities were found to support the mapping of skills learned from Functional Skills Level 1 to GCSE grade 3 skills. Concrete manipulatives needed to be purchased or produced and time for teachers to build up their own experience before introducing models and representations routinely into lessons.	Two groups of teachers from 5 large colleges Pre- and post-assessment data learner feedback and teacher reflections. Newham College CfEM

Visual management boards in vocational areas	**Evidence base**
 **Issue** Few maths learners related to the maths in the GCSE curriculum. This project connected vocational and maths tutors in order to connect learners' own real experiences to the maths. **Intervention** **Visual Management (V-M) Boards** were co-produced to represent various maths topics in pictorial form. The Boards were then introduced to learners with time given for practice and application to exam questions. **Impact** V-M Boards had an 'incredible impact' on the teachers, improving their understanding of underlying structures of maths and supporting their use of concrete manipulatives in conjunction with ratio tables. It took time for teachers to learn mastery approaches but collaborative working relationships are now set up for the future.	1 maths teacher from each of 5 colleges and tutors from 4 vocational areas Examples of learners' work, interviews with teachers and learners Weston College CfEM

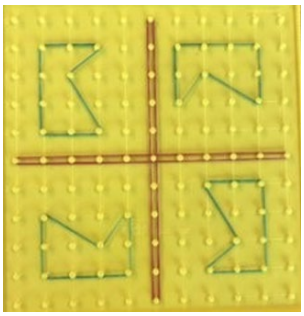
Use of manipulatives

Counter to some expectations, in general, **concrete manipulatives**, if introduced appropriately, were well-received by learners and not dismissed as being too young for 16 to 19 year olds. They provided a fresh new way for teachers and learners to approach maths topics and their use brought deeper understandings of maths concepts to both learners and teachers.
After two or three cycles of action research, success was widespread but particularly effective with learners:

- working in small groups,

- with prior GCSE attainment below grade 3
- without existing methods and/or struggling to progress in specific maths topics.

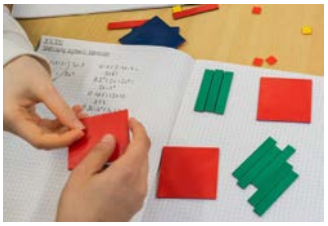
It was important for teachers to have extended periods of time observing and using manipulatives first-hand prior to their introduction into classrooms.



Issue
Concrete manipulatives are the 'C' of CPA but would post-16 learners engage with them and could they deepen understandings?

Impact
Some learners with existing methods were reluctant but, for most, the physical and tactile experience of **Geoboards** were enjoyed and learners reported feeling better able to concentrate. Open ended tasks were shown to support learner engagement and understanding, as were bridging activities and low-threshold starter activities.

Evidence base
3 action research cycles by 4 teachers working with 10 classes
Reflective logs, surveys and interviews
Christ the King Sixth Forms CfEM



Intervention
These teachers decided to investigate using **algebra tiles** as a way to deepen understanding of linear equations and develop problem-solving skills. A 'shared pedagogy' approach was used. Each session, a teacher sat with small group of learners, solving problems with them, demonstrating, questioning, encouraging dialogue and reinforcing key concepts.

Impact
Learners improved on their baseline tests by 84%, on average. Teachers found them useful for scaffolding learning. Most students were observed successfully transitioning efficiently from the concrete (algebra tiles) through pictorial to abstract working. Spending time securing understandings of zero pairs and directed numbers saved time later.

Evidence base
Two cycle of action research over 5 months by teachers from 3 colleges.
Baseline assessment, observations, reflective logs,
Warwickshire College Group CfEM

(a) Visual representations

Visual representations of abstract maths concepts had a positive impact on student confidence and achievement. Ratio tables, double number lines and bar models enabled learners to relate to and visualize, and therefore access, attempt and solve, questions on ratio, proportion, fractions and percentages.

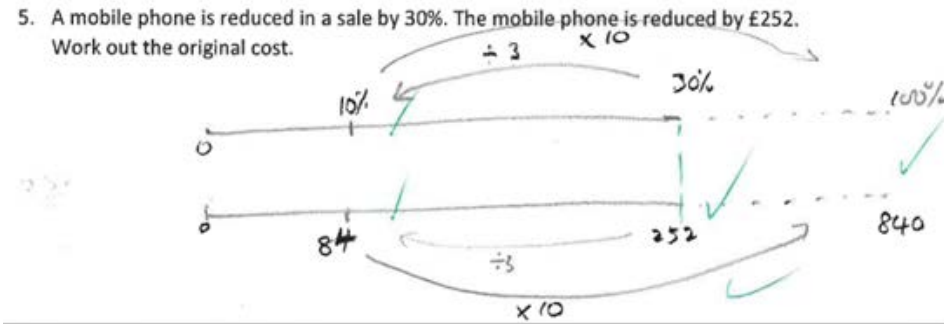
Before introducing to learners, maths teachers needed time and support to develop their mathematical pedagogies, including understanding of CPA, threshold concepts and strategic decision-making about how to teach when learners are 'stuck' with maths problems.

Many teachers investigating representations recommended introducing them early in the academic year with familiar topics, repeatedly demonstrating their use throughout the year for, and allowing time for practice on more complex problems.

Double-number lines

Issue
Many learners had previously attained grade 3 at GCSE but had become disengaged with a range of maths topics that they found difficult but would need to be able to answer in their resit to get the desired grade 4.

Intervention
The action research group collaboratively designed and taught lessons using different representations and manipulatives, as part of a wider CPA approach, to support understanding within solving equations, compound measures and percentages.



Example of a double number line

Impact
All representations were found to be useful for developing understanding but **double number lines** were reported to be particularly successful because they also gave a structure for learners to solve problems, were flexible across a range of maths topics and supported progression through to more difficult questions. Allowing students to use their own methods alongside, but demonstrating how they work with trickier questions, helped get learners engaged.

Evidence base

5 teachers working in 4 colleges

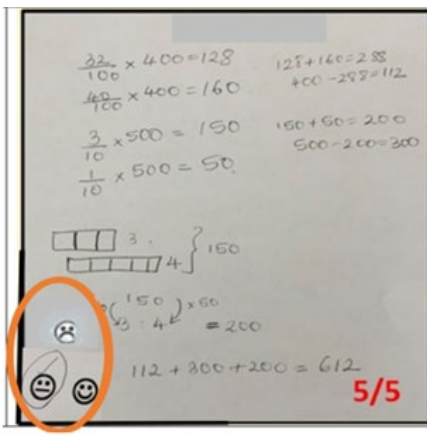
Learner quizzes before and after intervention lessons, teacher reflections, learner feedback.

Leyton Sixth Form College CfEM

Ratio tables & bar models for AO3 questions

Issue
Previous experience and analysis of initial assessments indicated that many learners skip worded problem-solving (AO3) exam questions thereby missing out on crucial potential marks.

Intervention
Teachers introduced first **ratio tables** for proportional reasoning then **bar models** for ratio, fraction and percentage topics.



Example of ratio table

Impact
70% of learners improved their score in the post-intervention assessment. They reported that representations helped them both deepen their understanding of the maths and gave them a way to attempt more questions. Teachers reported improved engagement and resilience of learners and their own enjoyment at using representatives to teach. Using open-ended questions, such as 'If we know …., then what else do we know?" were reported to be critical for developing learners' thinking and efficacy.

Evidence base

4 teachers working across FE Colleges on 3 cycles of action research

Pre- and post-intervention assessments, learner and teacher feedback.

Weston College CfEM

4.2 Language issues in maths learning

Teaching the definitions of mathematical terms commonly used in exam questions and giving learners opportunities to apply this learning was found to strengthen mathematical understanding for many and enable some to attempt what used to be inaccessible questions. This reinforces findings from previous action research at different colleges done on the same topic.

Command words	**Evidence base**
Issue Reflecting on recent classroom experiences, teachers agreed that learners often struggle to comprehend key terms commonly found in worded maths problems. **Intervention** Building on action research by another CfEM the previous year, teachers taught mathematical definitions of a manageable number (10) of 'command words' published by examination boards. Then, activities were provided for learners to practise applying new knowledge of mathematical language. **Impact** Repeated exposure to the 10 command words shown here and their definitions over 3 months improved recall in resit learners, so these teachers recommend incorporating them throughout the year. Describe Estimate Expand Factorise Product Rearrange Sensible Significant Simplify Translate Teaching the words discretely was found too repetitive to teachers switched to embedding in other activities. Being able to successful apply their knowledge of command words to exam-type questions bolstered mathematical understanding for many and unlocked previously inaccessible questions for some.	65 learners selected from 10 classes with 5 teachers from across 2 colleges. Learner and teacher interviews and teachers' reflective logs Leeds City College CfEM

05 Responsive Teaching

Responsive teaching is about identifying what learners know and don't know, what they have understood and where they are struggling – and responding to this through both careful planning and minute-by-minute reactions in the classroom.

Approaches developed by FE maths teachers included the use of in-class diagnostic questions and ways of highlighting and addressing common misconceptions.

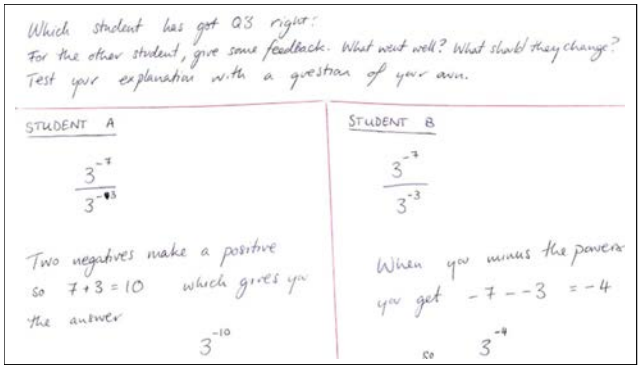
Identifying and addressing misconceptions through learners giving feedback

Issue
Checking skills are secure before moving on is a key principle of maths mastery, so these FE teachers set out to develop an efficient and effective process for them to identify and address skills gaps and misconceptions that would work for GCSE resit learners in FE.

Intervention
Over three cycles of action research, teachers trialled different ways of analysing learners' work and managing the feedback process, to see what was effective for teaching, practicable for teachers and that learners were willing to engage with. After several adaptations, 30 minute discussion-based reviews were found to work very well.
In the first of a pair of lessons, learners were taught how to give constructive feedback on common misconceptions identified from end-of-unit assessments. In the second lesson, learners were put into pairs comprising one learner whose knowledge is more secure than the other and asked to discuss and write down feedback on two anonymised answers to the same maths problem.

Impact
Students engaged well with this process of reviewing tests and saw the value in addressing a persistent misconception, though anonymity was essential for learners' willingness to discuss the work.. They subsequently recognised the misconception in their own work when it was returned to them.

The workload for teachers in marking these assessments and preparing anonymous work for students was manageable - in total around 30 minutes per unit per class. Teachers' wider reflections included that building metacognitive skills like learning from your mistakes is important for long term success and need extended periods of time to develop.



Evidence base

9 teachers and 33 learners

End-of-unit assessments, teacher and learner questionnaires, peer observations

Leyton Sixth Form College CfEM

Sharing maths assessments to identify learner focus

Issue
Reflecting together on their practice, teachers agreed that they too often teach Functional Skills learners already know.

Intervention
They collaboratively developed a responsive teaching system based around sharing maths assessment feedback reports for learners to see what maths areas to improve and no set scheme of work.

Impact
Teachers reported stopping teaching what learners don't need to be taught again. Tracking of assessment data showed some good improvements in scores. The wider aim became to help learners mentally re-organised their maths knowledge and skills under concepts that they can readily retrieve. It was concluded that this responsive approach can be very successful and it had a positive effect on Functional Skills outcomes when implemented robustly.
There were wider benefits to doing this action research:

- Increased teacher collaboration and improved communication across the Group.
- Standardisation of high quality teaching resources and increased sharing of good practice, with peer observation becoming the norm.
- Supporting teachers to develop their FE maths mastery practices.

Maths Assessment Feedback

Paper	ACP 3 - FS Level 2 (Past paper 2)
Name	Anon.
Teacher	Anon.

Question	Maths topic	Score	Practice activity
1a	Find the median	2/2	ME 14.08
2	Formula	3/3	MF 49.01
3	Fraction of an amount	4/4	ME 9.08
1	Unit converstion	3/3	ME 3.07
3	Find the mean or median	2/4	ME 13.04
4a	Percentage	0/2	MF 11.13
4b	Reverse calculation	0/1	in class
5a	Completing 2-way tables	3/3	ME 14.06
5b	2-way tables: probability	1/2	ME 15.03
6	Mean from g'ped freq. table	2/2	ME 14.11
8a	3-part ratios	1/3	MF 15.05
8b	Money problem	2/3	MF 16.04
10	Speed, distance, time	0/3	in class
12	Estimation/ % increase	2/6	MD 6.06
	Your score	25/42	

Based on my results from this assessment I will focus on the following three topics:

Evidence base

10 teachers working with 11 cohorts across 8 college sites

Surveys, diagnostic assessment reports, exit tickets and learning walks.

EKC Group CfEM

Flipped learning to allow time for higher- level thinking and problem solving

Issue
As there are not enough weeks in the FE maths year to fill all of learners' gaps in knowledge *and* enable them to practise higher level thinking and problem-solving skills, could flipped learning be a solution?

Intervention
Over two action research cycles totalling 13 weeks, teachers agreed to try shifting introductory teaching out of the classroom to free up time for a more responsive pedagogy in classrooms that is suited to higher level thinking and problem-solving. It was a big step for all teachers to abandon introductory teaching in the classroom.

Impact
Targeted CPD and adapting from video and quiz-based to more 'structured thinking questions' helped to build teacher confidence in persevering with flipped learning. Learner completion and engagement was mixed and required self-study habits, which would be a sensible complementary activity to introduce alongside flipped learning.

Evidence base

11 teachers delivering to all their GCSE classes

Teacher and learner surveys, online maths data tracker, teacher interviews.

GBMET CfEM,

Using technology inside and outside the classroom	Evidence base
Issue Learners were notably less engaged in maths after Covid pandemic lockdowns, too self-concious to speak up in front of peers in class and enjoyed using computers in their home lives. **Intervention** Online platforms could be engaging for many young learners and enable them to actively participate simultaneously. Therefore, Nearpod and then Doctor Frost maths-specialist software was introduced for all learners to use in lessons and receive feedback privately. Teachers could then address common skills gaps with the groups.  **Impact** Nearpod enabled the teacher to see on their computer what every learner was doing in real time and send private comments. A thread of conversation was established between tutor and learner, helping develop teacher-learner rapport and openness to more detailed feedback and insights. More learners completed work within the sessions because they could all answer at once and provide answers privately to the tutor, which was safe for them. However, Nearpod was little used outside of classrooms and poor WiFi sometimes limited its use within college. So, Dr Frost software was then introduced, this time specifically as a tool for revision. By the end of a year of action research cycles, overall engagement with the technology was good. Those learners who used it for revision showed more progress in mock assessments and the summative exam than they they would have done otherwise.	2 teachers at 1 GFE college Learner surveys, observation, data reports Nelson and Colne College Group CfEM

Addressing post-COVID skills gaps	Evidence base
Issue Learners were arriving in FE colleges having had a wider variety of experiences of GCSE maths at school than usual due to COVID lockdowns. Teachers aimed to investigate how best to support learners and how to identify and address their diverse skills gaps in order to support attainment. **Intervention** In the first action research cycle, each teacher tried a different way of identifying skills gaps: coaching, initial assessment tool, manipulatives and an app. The 'most promising' was the app so this was tried by all four teachers in cycle 2. **Impact** The teachers were surprised to find the lasting impact of COVID on learners was that learners seemed need much more personal interaction, preferring a teacher-led and instructional approach to more innovative technology-based methods trialled during this research.	4 teachers from 4 FE colleges Teacher discussions, scoring and analyses of tests Fareham College CfEM

06 Engagement and resilience

6.1 Strategies to address anxiety and negative mindsets

A very widespread and profound issue facing FE maths teachers is the feeling of failure experienced by many re-sit learners, resulting in a 'I can't do maths' attitude. Such fixed mindsets, lack of self-belief and are very common, and many learners suffer from anxiety from being required to study maths again. Teachers report these self-perceptions and attitudes being even more prevalent following the pandemic. In their action research, teachers quantified learner attitudes to maths and designed and trialed various ways of addressing self-belief, mindset and maths anxiety. The concept of growth mindset, developed by Carol Dweck and others, was found particularly useful in the FE maths resit context. Indeed, throughout numerous action research projects over the past three years, teachers have consistently concluded that FE learners should be taught how the brain works and the implications for maths learning at the

beginning of the year and then have this repeatedly reinforced throughout their maths learning programme.

Growth mindset activities and learning goals

Issue
Maths is a subject that almost all resit learners find challenging and so they tend to give up easily when facing tricky questions.

Intervention
Literature on the theories of effort beliefs and growth mindset suggest that if learners believe the brain and intelligence to be malleable it could help them feel that they can learn maths and be willing to attempt more questions.
Discrete activities explaining growth mindset to learners led on to setting active learning goals that were connected to coping strategies.

> "A learner who believes their ability to be malleable is more likely to show a greater level of resilience when faced with setbacks and a greater level of motivation to correct and improve learning."
> (After De Castella and Byrne, 2015)

Impact
The teachers observed more sustained motivation and higher achievement than before the intervention. However, it was embedding growth mindset interventions into teaching activities that the teachers concluded would be most effective in helping learners to become more resilient and increase motivation. The impact of including growth mindset activities in lessons depends on how it is delivered by individual teachers.

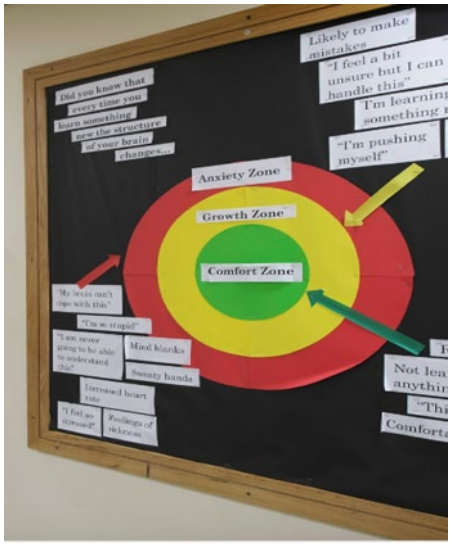
Evidence base
3 teachers and 8 cohorts of learners
Observations, professional discussions, reflective logs, learners' work
Lakes College CfEM

Mindset language and getting 'unstuck'

Issue
Learners needed practical strategies to change fixed mindsets, especially when they got 'stuck' because they were overwhelmed by multi-mark questions and so tended to skip them.

Intervention
Two teachers examined ways learners could become 'unstuck' while the other two teachers explored how positive mindset language could be bedded into schemes of work and the effect this could have.

Impact
Teachers found 'notable' changes in learners' mindset and attributed this to their interventions.



More learners attempted more multi-mark questions at the end of the intervention than they did before it started. Learners reported feeling more confident and less afraid of giving practice exam questions a go. They were familiar with and could often successfully apply strategies to move between zones on the Growth Zone model.

Teachers saw frequent shifts from fixed to positive mindset, for example, after receiving perceived low mock exam scores or getting questions wrong when they believed they had done every step correctly. Overall, the teachers concluded that mindset work is worthwhile, requires time and a highly individualised approach.

Evidence base
4 teachers in two colleges
Reflective log, maths assessments, learner questionnaire, professional discussions
Harlow College CfEM

Growth mindsets and independent learning	Evidence base
Issue With such a large curriculum to cover in the available classroom time, some teachers decided to investigate whether a flipped learning approach could help, but this would first require learners to be resilient and engaged enough to be successful independent learners. However, developing a positive mindset for independent learning is a huge challenge for FE maths learners who are demotivated and don't enjoy maths. **Intervention** Teachers reviewed existing research on growth mindset and its application to maths education and considered how it could fit their flipped learning approach and learners' relationship with maths. A learning plan was devised and implemented. Survey results indicated that some students were suitable for independent learning and appeared to have a growth mindset, whereas the majority did not. **Impact** By the end of the year, the majority of learners knew what growth mindset was and what was needed to work independently. Their application of this knowledge needed considerable support from teachers, showing just how hard it is to engage maths resit learners in independent learning outside the classroom. Nevertheless, over the academic year, strategies were implemented that did help more students develop a positive mindset conducive to independent learning.	6 teachers from one large college Data analysis of online maths, learner interviews Leicester College CfEM

6.2 Coaching and mentoring approaches

Evidence gathered from across action research projects on coaching and mentoring approaches suggests positive impacts on learners' maths confidence, experience, ability and resilience. In previous years, projects focused mainly on coaching or mentoring *either* inside *or* outside the classroom by designated support staff and *either* on maths skills *or* pastoral needs, with considerable success and cost. Developing this work further, several of this year's projects focused on teachers' coaching skills, closer teacher-coach working relationships.

Coaching inside the classroom	Evidence base
Issue Disengaged, demotivated and anxious learners at the college were struggling to overcome their barriers to learning. **Intervention** In another example of teacher-coach partnership working where coaching had previously been outside classrooms, teachers and coaches decided to develop a sustainable coaching model. The aim was to equip learners with the strategies to build mathematical resilience, improve engagement and attendance. Employed learner engagement coaches worked full time with the teachers, collaboratively planning and delivering to whole groups in partnership. Both helped create a learning environment where learners were in an 'adult state' and felt safe and able to develop a growth mindset for learning maths. Teachers focused on teaching for mastery through contextualisation and responding to data/evidence, while the coach took a more holistic perspective to building resilience and supporting maths anxious learners.  The expertise of the coaches in educating and supporting these learners to become mathematically resilient was crucial in preparing students for the exam and life. It took several	3 teachers and 3 coaches from 2 GFE colleges Construction and motor vehicle learners at 2 colleges Cambridge Regional College CfEM

years to recruit staff that were retained and trained and became experienced enough to fulfil this role.

Impact
Towards the end of the intervention year, many learners were more willing to publicly ask for support and accept that making mistakes is part of the learning process. 68% of learners said that working with a coach improved how they felt about their maths ability and 88% said having a coach during their exam period had a positive impact on their experience. The team provided specific exam teaching and coaching strategies. Learners were more willing to move out of their comfort zone, including attempting 3- and 4- mark exam questions that they would not have done previously. During the exam period, teachers observed much reduced levels of exam anxiety compared to non-intervention students. Some students were more prepared to proactively take control of their learning.

Maths specialist mentors – outside the classroom

Issue
After a gap in learning due to the Covid pandemic, teachers were looking to boost learner engagement and attainment.

Intervention
Maths Specialist Mentors were employed to work with learners outside the classroom once a week and Maths Peer Mentors recruited from A level maths classes to help within GCSE maths resit lessons once per week. The recruitment, retention, management and the cost of these mentors required considerable resource.

Impact
Half the resit learners being mentored improved their attainment by one grade in GCSE maths between the beginning and end of the project, with teachers attributing the improvement to the mentoring intervention.
The average confidence level for the 76 students increased by 16% and attendance by 8%. The biggest gain was in motivation and engagement. All student felt more motivated and were more engaged than if they were not being mentored.

Evidence base
4 maths specialist mentors and 8 peer mentors supporting 76 students across 5 college sites.
Qualitative questionnaires, lesson observations, attendance and performance tracking sheets.
Christ the King Sixth Form College CfEM

Maths specialist mentors – inside the classom

Issue
Data analysis identified Functional Skills Level 1 and 2 learners consistently struggling with percentages, fractions and decimals. A fresh new approach was needed.

Intervention
Maths Subject Specialist Mentors (MSSMs) were employed for Functional Skills learners as part of a Maths Hub approach, supported by technology. These learners were transitioning back to onsite delivery post-pandemic and received weekly interventions for 6 months from October to March. Learners were introduced to and asked to work with a maths mentor as well as receiving mastery teaching and learning in class and provided with maths software activities to complete

Evidence base
One Functional Skills maths lecturer and four Maths Specialist Study Mentors.
Learner diagnostics, written work and questionnaire. Staff focus group.
New College Stamford

Impact The first cycle suggested there is a place for MSSMs in the classroom to support learning through having a maths dialogue with the teacher and learners and being an additional adult able to answer queries. Having MSSMs in the classroom also promoted a more meaningful collaboration with the college's centralised Study Centre staff who work with learners wanting extra tuition. For example, because MSSMs and maths lecturers planned and delivered Functional Skills together and MSSMs also worked in the college's centralised Study Centre, the sequencing of maths learning is now standardised across the college. It should be noted that, in general, learners were much more willing to find time for additional in-person, college-based sessions than to access the software independently.	

6.3 Engaging learners in problem-solving and multi-mark questions

Several action research groups prioritised developing learners' strategies for making problem-solving questions accessible to learners, and encouraging them to gain at least some marks on multi-mark exam questions. These worded problem solving and other multi-step questions can overwhelm resit learners who skip them when teachers felt that they had potential to pick up valuable marks. Learners would have to develop the resilience to attempt and stick at these questions, have strategies for breaking down these long questions into their component parts so that they could address one step at a time, and the maths skills and understanding required at each step.

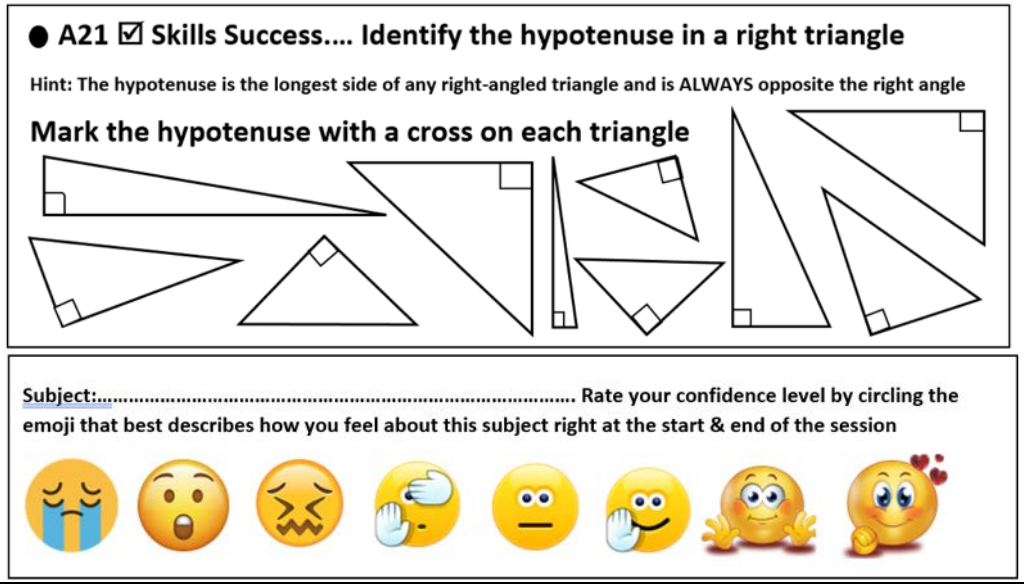
Goal-free questions	**Evidence base**
Issue These teachers investigated how they could increase the willingness of their maths learners to engage with multi-topic, goal-free, AO3 problems. The aim was to increase the self-confidence of learners who have low self-belief, a fixed mindset and potential maths anxiety. **Intervention** Over four weeks, learners were given the same carefully and collaboratively designed goal-free questions. Goal-free questions were used because they were open self-differentiating questions, which allowed the learners to focus on their effort as opposed to answer-getting pressures and achieving a certain number of marks. Once all learners had applied as much maths as they could to a given problem, they were given a red pen and the teacher led a discussion-based review of the problem. Learners could annotate their work, tick or cross out their working and add to their notes. **Impact** The intervention demonstrated an improvement in willingness and outcomes, which suggested the goal-free problem intervention would ultimately increase resilience.	6 teachers from 4 colleges Pre- and post-intervention A03 and confidence assessment, teacher observations of effort Newcastle and Stafford College Group CfEM

Breaking learning into manageable chunks	**Evidence base**
Issue Typically, learners working at Entry Level and Level 1 make very slow progress through assessment scores in a linear qualification, spending most of the year within the same grade boundary. **Intervention** After reviewing a range of tools and strategies that aim to develop confidence and resilience, it was decided to focus on breaking down skills that learners saw a need to develop into smaller and therefore more manageable pieces. Teachers demonstrated to learners that they can be successful in maths if they work on one skill at a time. Each skill was presented to learners on separate slips of paper, which accumulate over time and become tangible evidence of success. As well as these Skills Success Slips, teachers investigated what effect confidence slips would	1 teacher working with lower attaining learners with a diversity of high needs Observation, learners' work, learner focus groups Nelson and Colne College Group CfEM

have on resilience. Confidence Slips were a row of emoji's from angry/distressed to very happy, to be completed before and after tasks then looked back on as tangible evidence of changes in confidence. Learners also completed small focussed tasks concentrating on one skill to develop mastery in their approach and could be applied to several subject areas over the year.

Impact
Learners worked individually, giving the opportunity for individual success. The collated Skills Success Slips built back up to the larger multi-part question from which they originated. When approaching larger questions, learners gained confidence from being able to refer back to the slips.

The tools and strategies developed during this action research project are thought to have generally increased confidence levels over the academic year. Measures to increase confidence can counteract lack of self-belief and promote a more positive and arguably more realistic self-perception for the learner, promoting higher gains in achievement and progress.



Problem-solving toolkit

Issue
Teachers had long-observed that many GCSE resit learners find complex 3- and 4-mark problem solving questions very challenging. These questions often seem inaccessible to learners and the teachers regularly find they do not attempt them at all, therefore missing out on vital marks. The teachers also discovered a lack of existing resources suitable for teaching problem-solving to their resit learners.

Intervention
Initial surveys threw up some unexpected and enlightening issues. They identified differences between learner and teacher perceptions of problem-solving questions that weren't previously known. Further, teachers believed a lack of motivation to be the biggest barrier to students successfully answering these questions, but learners indicated that this was not the case. Therefore, teachers decided to collaboratively design a toolkit for learners on problem-solving on the area of measurement. This would be manageable and is a maths topic with good potential for attractive visual diagrams and contextual scenarios. The toolkit was trialled, evaluated, modified and re-trialled.

Impact
Teachers observed learners engaging well with the toolkit and learners confirmed that they were likely to attempt more complex measurement problems due to the intervention. However, learners sometimes lacked conceptual understanding including connections between different maths topics in one question. They also sometimes lacked experience and also the resilience to confidently and independently navigate their way through these questions, which could have been excacerbated by lost learning during COVID lockdowns.

Evidence base
GCSE cohorts of 3 teachers from 3 colleges
Learner surveys, observation, teachers log
GBMET CfEM

Target setting and de-constructed questions	Evidence base
Issue Learners who are overwhelmed by multi-mark questions require strategies for removing barriers to attempt them. In another project focusing on breaking down multi-part questions into their component skills, teachers and learners collaboratively set micro-targets. **Intervention** In an initial survey of attitudes to maths, learners were found, in general, to have positive attitudes, saying putting in effort is worthwhile, which led teachers to believe target-setting would be useful. Also, teachers found out that learners' prior experience of target-setting focused on the end goal, which was too great and distant and therefore hard for learners to plan for, for example 'to get a grade 4'. In preparation for the intervention, teachers de-constructed exam questions, each part being a potential target step or steps. **Impact** Spending time with teachers meant that learners received the positive, personal attention that they wanted and high expectations could be reinforced. Teachers concluded that it is very important targets are classroom-based, target-setting is seen by learners as a process not the end goal, and that it involves mathematical discussions between peers and with the teacher. This micro-target setting process was most effective when learners had time for repeated practice. A low entry, high ceiling strategy was found to be effective when using de-constructed exam questions. Teachers observed learners' sense of accomplishment as they were able to access the activity and got a confidence boost. Learners gradually came to focus on the learning and problem-solving instead of rushing to the solution. 82% of students surveyed at the end of the year said that they should have specific maths targets. Teachers were pleased to find that 57% of learners completed all of their micro targets during the intervention and a further 32% completed at least some.	3 colleges, 6 teachers. Cycle 1 with 370 learners, from which 63 were selected for cycle 2 and 8 for a small pilot for cycle 3. Initial attitudinal survey, observations, post-intervention survey Tameside College CfEM

6.4 Altering the learning environment

Low motivation is an ongoing challenge due to experiences of underachievement at secondary school which negatively affects learners' self-efficacy at college. By changing aspects of the learning environment from time to time throughout the year, learners and teachers have become re-invigorated. Included here is taking groups outdoors to do practical problem-solving lessons, introducing team activities with an element of competition for an enjoyable experience of maths and introducing TikTok-style videos into the learning mix.

Relating maths to vocational learning	Evidence base
Intervention Informal feedback from maths resit learners highlighted how abstract and unrelatable the GCSE curriculum could be for them. Meanwhile, teachers were finding that available resources for maths contextualisation are often not tailored to vocational areas and real-life situations of 16-19 year olds. **Intervention** Maths and vocational tutors worked collaboratively with the aim of embedding contextualised learning to support progress in maths. Working relationships were established over several months before resources were co-produced by vocational and maths staff.  **Impact** Data gathered from learners and tutors after trials of the contextualised maths resources confirmed existing literature indicating a preference for contextualised approaches in lessons. Learners could relate to the maths so were more willing to engage. Vocational tutors noticed this increased engagement and added that learners were applying their maths knowledge more quickly and accurately to vocational subjects.	80 learners, 4 maths and various vocational staff Pre- and post-intervention learner questionnaire, teacher and learner interviews, analysis of grades over time Leicester College CfEM

Oudoor lessons

Issue
Behaviour within traditional classroom environments had been challenging for some learners and their teachers.

Intervention
Previous years of action research had researched the effects of outside learning on motivation and engagement. A number of practical problem-solving lessons were designed and spread throughout the year. These were suitable to take place in outside spaces in the college grounds. Examples include: murder mystery, game show, escape room, STEM construction kits.

Impact
These outdoor lessons had a positive impact on teachers and learners overall and have led to wider changes in the delivery of maths. Teachers consistently reported improvements in learner behaviour, autonomy and resilience. The more open the space the more open the learner to engagement and learning. Teachers themselves felt a reignited passion and confidence to develop their teaching practice through the freedom to explore new ways of working. Being outside the classroom classroom changed the dynamic and enabled more effective lecturer/student relationships to form. Of the 240 learners surveyed, 92% enjoyed the outside practical maths lessons, 84% reported joining in more than usual and 71% agreed that they support the development of their maths.

Evidence base
3 action researchers working with other lecturers and 204 learners from 3 sites
City College Plymouth CfEM

Using selected gamification approaches in maths lessons

Issue
Gamification is the integration of game thinking and game mechanics into non-game experiences to increase motivation and engagement. In theory, applying selected ideas from gamification into regular maths lesson starter activities could change the dynamic of the class by boosting enjoyment and providing relaxed opportunities for dialogue as well as peer-to-peer support.

Intervention
An activity was collaboratively designed to repeat in a series of lessons where small groups worked in teams to answer either general knowledge, simple or more complex maths questions. Points were awarded by teachers and self-recorded by learners on tables inside their maths books.

Impact
All four teachers commended the points-based system, and cited positive feedback from learners. Counter to much of the literature, learners identified the element of competition as enjoyable, which in turn led to increased engagement. Learners became increasingly engaged in the rest of maths sessions after doing the collaborative and fun game activity. Furthermore, teachers observed increased amounts of dialogue about maths and interaction and support between peers, which was in contrast to a pre-intervention survey where only a small minority of learners said that they helped others.

Evidence base
4 teachers in 3 colleges with 82 learners
Initial learner survey, reflective logs, teacher and learner interviews
Leeds City College

Using short videos to engage learners	Evidence base
Issue Very short and entertaining videos such as those found on the TikTok app are very popular with young people, leading this group of maths teachers to investigate their use to engage learners in maths. **Intervention** The FE maths teachers designed and produced a small range of specially-created very short Tik Tok-like videos. **Impact** After watching the videos, many learners reported enjoying them precisely because they were so concise and succinct. This is of great interest because the maths areas covered were those that data analysis showed learners found particularly tricky, including formulating a linear equation from information given. The videos were also praised by learners for breaking down and explaining exam questions in manageable sections. Teachers decided to continue using this style of video, thinking it a useful addition to their wider mastery approach if kept in balance with other elements and while acknowledging that a few learners are not so positive towards them.	150 learners with 5 teachers in 4 colleges Two learner questionnaire Newcastle and Stafford College Group CfEM

07 Conclusions and Recommendations

For FE maths teachers *by* FE maths teachers

Notwithstanding certain caveats with action research as a research tool (highlighted in section 02), tentative conclusions can be drawn from the consistency of certain findings from across multiple projects and settings:

1. Action research was found effective as a form of continuous professional development.
    - ⇒ Teachers need plenty of CPD and (preferably collaborative) planning time and practice before introducing changes to learners. Similarly, learners need plenty of practice applying new learning to maths problems.

2. Addressing barriers to learning maths is key in addressing the low attainment of post-sixteen resit cohorts. A range of approaches to developing engagement and resilience were found to boost confidence and willingness to participate, with knock-on effects for attendance and progress.
    - ⇒ Teachers should share with learners how the brain works and possibilities of moving from fixed to growth mindsets at the beginning of the year. Learners should then have opportunity to practice using these strategies, with reminders and support, throughout the year. The focus should be on regular self-identification of mindset and use of appropriate ways to improve motivation to do more maths and attempt exam-style questions. Engagement and resilience should be viewed as a prerequisite to FE maths resit learners making progress.

3. Visual representations – double number lines, ratio tables and bar models – were introduced with considerable success for learners who didn't already have a secure method.
    - ⇒ Representations should be introduced early in the year and then regularly demonstrated in a range of maths topics (percentages, ratio, fractions, proportional reasoning, etc.). They particularly support those learners without a reliable algorithm and for learners who already have a one to take on more challenging/varied questions.

4. Manipulatives were introduced to small groups of learners with misconceptions or without secure understanding of maths concepts, for example, double-sided counters for directed numbers, algebra tiles, geoboards for symmetry and nets. Contrary to expectations, 16-19 year olds doing FE maths resits do accept physical manipulatives when introduced appropriately.

5. The project on teaching mathematical terminology is one of four on the same topic done over three years and all arrived at a similar conclusion: improved performance on assessments could be attributed to understanding of key mathematical vocabulary and command words.
    - ⇒ FE teachers should review lists of mathematical vocabulary and command words published by examination bodies, teach the meanings of key words near the beginning of the year. Then regularly draw attention to these words and give learners regular opportunities to practice using this knowledge to answer exam-type questions.

6. FE maths resit learners benefited from teachers contextualising maths topics, making relatable what can otherwise an abstract curriculum, leading to both deeper understanding and engagement.
    - ⇒ Explanations of real-life applications of maths should be integral to FE maths teachers' practice, drawing on ideas of Real Mathematics Education (RME).
    - ⇒ FE maths teachers should establish working relationships with teachers from vocational areas and co-design resources with them.

7. The use of responsive teaching processes were attributed to successful identification and of learners' skills gaps and misconceptions, and addressing these effectively. The central premise

is not re-teaching what learners already know. Successful responsive teaching approaches involved a series of steps that soon evolved into significant changes in practice away from teacher as instructor and towards teacher as learning facilitator.

⇒ Responsive teaching can be planned outside the classroom though can be time-consuming, even with elements of automation, and therefore efficiency is key. However, the use of effective questioning and formative activities within the classroom can be effective in both identifying and addressing learner misconceptions.

8. Coaching and mentoring approaches were found by teachers and learners to improve engagement and mathematical resilience, with one Centre attributing grade improvement to combined in-class and out-of-class mentoring.
   ⇒ Coaching and mentoring is an expense that the vast majority of colleges are unable to sustain without CfEM funding, but action research has shown that teachers can learn and use coaching and mentoring techniques. FE maths teachers have much to learn from using coaching and mentoring techniques that they could use in class.

Further recommendations for maths managers and senior leaders in college

1. Understand and promote action research, with central tenets of collaboration, sharing, valuing others contributions, and focusing on issues important to teachers.
2. Create a more supportive culture – development takes time, teachers need permission from managers to be innovative and regular practical and collaborative maths CPD and joint planning sessions.
3. Spread learning and positive working environment across college.

Further recommendations for DfE and wider sector organisations

1. Evidence-informed to bring in established expertise, with teachers working collaboratively over a sustained period to co-create solutions that are grounded in the particular issues and contexts. be a balance between learning from established expertise, and allowing teachers to co-create solutions to pertinent issues.
2. Core elements of teaching for mastery can be applied effectively to an FE context – especially the use of models and representations that make maths more tangible and accessible to learners
3. Strategies to promote learner engagement and resilience are vital antecedents for progress in maths, and need to be incorporated from the start of the academic year and reinforced throughout.

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