



To improve the progress and key mathematical life skills of 16 – 19 year-old maths learners with an entry level of below Grade 3, by using mastery-based approaches.

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About CfEM

Centres for Excellence in Maths (CfEM) is a five-year national improvement programme aimed at delivering sustained improvements in maths outcomes for 16–19-year-olds, up to Level 2, in post-16 settings.

Funded by the Department for Education and delivered by the Education and Training Foundation, the programme is exploring what works for teachers and students, embedding related CPD and good practice, and building networks of maths professionals in colleges.

Summary

The purpose for this Action Research Project was to explore how we can support the progress of students who are obliged to study maths in Further Education, under the Condition of Funding, but who do not yet have a Grade 3.

Statistically these students are unlikely to achieve Grade 4 within a resit year, yet there is a growing trend to move away from the Functional Skills qualifications that they would previously have been put on towards GCSE.

The progress, in exam terms, for this cohort of learners can be very small or non-existent so we knew that we would have to keep our Action Research very tightly focussed in order to identify any marginal gains.

We chose to focus on the topic of percentages because of its wider mathematical connections in terms of Proportional Reasoning. It was important to us to pick a topic that is an important key mathematical life skill as well as one that supports learners to progress towards Level 2.

We believed that the Concrete, Pictorial, Abstract (CPA) approach was not utilised to its full potential within our colleges, so we chose this as the mastery strategy we wanted to use.

Three interventions were planned and delivered sequentially. We collected assessment data before and after the interventions. We collected our students' reflections on the interventions and triangulated this with teacher reflections.

Our results were in line with the existing research which indicates that CPA is an effective mastery strategy and that students find maths that they can relate to, to be motivating and engaging.

In the past, there have been significant concerns within the Further Education sector that our students will not respond positively to using manipulatives. In addition to this, it appears that many colleges do not have the resources or the experience required in order to start to introduce CPA routinely to lessons.

Our Action Research project demonstrates CPA this is a teaching and learning strategy that FE learners respond to well and offer suggestions to how colleges can start to develop a CPA approach.

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Background

Introduction

Since 2015, in England, students with below Grade 4 at the end of Key Stage 4 have had to continue studying Mathematics whilst in education. This is known as the 'Condition of Funding'. While students with a Grade 3 are required to be enrolled on to a GCSE resit course, students with below Grade 3 can either be enrolled on to a Functional Skills or a GCSE course. The decision is made at an individual college level. Nationally "the general trend since the introduction of the Condition of Funding is a move away from Functional Skills to GCSE" (MiFEC – Interim Report 4 2020).

The National Picture and our Local Picture

Three colleges took part in this Action Research. All are based in London and serve economically deprived areas. At both Newham College and City of Westminster College, students with below Grade 3 are enrolled on to a Functional Skills course; most commonly Functional Skills Entry 3 or Level 1. All students aged 16 – 19 years old at Southwark College, the other partner college engaged in this Action Research, are enrolled onto GCSE Maths regardless of prior attainment. Following initial and diagnostic assessment at Southwark, the majority of students who do not have Grade 3 are placed on to an extended GCSE programme designed to last two years, rather than a traditional one-year GCSE resit course.

The aim of this project is to understand more about how we can support the progress of learners in Further Education (FE) who have not yet obtained a Grade 3 at GCSE, whether they are enrolled onto Functional Skills or GCSE maths. Nationally, in 2018 – 2019, this was 56% of all learners required to continue studying maths under the Condition of Funding (MiFEC – Interim Report 4 2020). At Southwark College it is currently 75%. It is likely that this would be higher than the national average if we were comparing two exam years, rather than an exam year (2019) with a Teacher-Assessed Grades year (2021). Historically Southwark College has a higher-than-average number of students who are required to be enrolled on to a maths course, and also a higher number who have not achieved a Grade 3. These figures are broadly in line with those from Newham College and City of Westminster College.

We acknowledge the magnitude of our task. "Three out of four students with a GCSE Mathematics grade E/2 at age 16 fail to make progress over the following two years" and 40% "go backwards over the following two years" (MiFEC – Interim Report 4, 2020). With this in mind, we extended our action research project aim in 2021/22 to explicitly include progress in **key mathematical life skills**. We explore both the skills required for GCSE maths and the mathematical skills required for life, as we aim to support our learners to make progress in both.

Since 2014 '**mastery**' in mathematics has become increasingly established in schools in the UK. In 2020 the Education and Training Foundation published "Centres for Excellence in Maths – Maths Mastery in Further Education Handbook" (ETF, 2020). Mastery is still a relatively new concept in FE colleges and even within the schools sector the term "is used to mean multiple different things in research, practice and policy" (Cambridge Espresso, 2019).

Literature Review

The aim of our literature review was to research our aim of improving progress, both towards Level 2 and in key mathematical life skills.

Progress towards Level 2

The existing research in this area focuses heavily on progress towards attainment at GCSE, rather than Functional Skills Level 2. Our assumption is that this is because GCSE Maths is the standard qualification at the end of KS4 and therefore the presumed pathway for most students unless the research is FE specific.

William Emeny shows visually how GCSE topics are connected, in terms of one topic being a prerequisite for learning another. Emeny says that "16 out of the top 20 topics are number and could be summarised as four operations, BIDMAS, place value, rounding, negative numbers and basic fractions." He concludes that "number skills must be mastered early in secondary education if we want to keep the other topics accessible to students at GCSE" and "it shows the importance of good AFL in lessons to establish whether pupils are secure with all the necessary prior learning before teaching them a new topic." ("You have never seen the GCSE curriculum like this before").

Our learners are not in the early stages of secondary education, but the research reviewed, combined with our own professional experience, indicates that it is reasonable to hypothesise that poor number skills might be preventing them from accessing other areas of the GCSE curriculum. The point Emeny makes regarding the importance of establishing the security of necessary prior learning is especially relevant in FE where the majority of students are new to us, and our academic 'year' is closer to 8 months and so requires a highly time-efficient approach.

Several authors and organisations shed further light on aspects of security of prior learning and focus attention on selecting and performing calculations, number sense and skills and proportionate reasoning.

Hodgen *et al* (2020) found that there is no evidence of what they describe as "threshold concepts" which are "particular subsets of mathematical knowledge or skill that unlock future progression". They found that their "research analysis is broadly consistent with a view of low attainment as largely characterised by delay." However, they did discover significant weaknesses in selecting a calculation in the 40% of pupils who they categorise as being unlikely to obtain a grade 4 in maths.

Rycroft-Smith, (2017) writes about number **sense**, which she summarises as "comparing and flexible thinking about number". This extends what we might traditionally think of as number **skills** e.g., calculating, in a way that might be useful for us to consider in this Action Research project. She writes that the available evidence demonstrates that "tests for aspects of number sense correlate strongly with later mathematical achievement" and that "number sense can be improved by helping children make links and move between representations". The term 'Number Sense' is very broad and there is overlap with what is described as 'Proportional Reasoning', with the two often being seen as connected.

Askew (2011) makes the connection explicit "To fully develop children's number sense we need to make sure that they get a rich diet of operating with numbers as relationships as well as quantities"

The Ontario Education Department describes Proportional Reasoning as "the consideration of number in relative terms, rather than absolute terms" which is arguably key to any meaningful sense of number (OED, 2012).

It could be argued that some of what Emeny describes as number i.e., place value, rounding and fractions, and Hodgen et al as an inability to select the appropriate calculation, could also be described as number sense or proportional reasoning.

Progress in key mathematical life skills

For the reasons outlined previously, it is important to us that our research focuses on key mathematical life skills. The Ontario Education Department report, quoted above, concludes that without a sense of proportional reasoning, students are not able to apply the maths they learn outside of the maths classroom. Proportional reasoning is required to "to calculate best buys, taxes and investments, to work with drawings and maps, to perform measurement or monetary currency conversions, to adjust recipes or to create various concentrations of mixtures and solutions" (OED, 2012).

The ability to unitise is part of proportional reasoning and "being able to 'unitise' is fundamental in handling money and in understanding place value" (NCETM, 2019). Further, "Percentages are used extensively in the real world and across the curriculum. Percentage is integrated into the broader concept of proportion and proportional reasoning, the challenges of which have been widely reported and learning should be embedded within these wider ideas" (NCETM, 2019).

There are many more articles making connections between proportional reasoning and 'real life' maths. As Lanius and Williams (2003) write "proportions may be the most commonly applied mathematics in the real world. Sometimes, for a given mathematical topic, a teacher may have to search for applications outside mathematics but not with proportionality."

The available literature strongly suggests that by planning interventions where we seek to improve students number sense with a focus on proportional reasoning, we should be able to have a positive impact on their progress both towards their maths qualification and towards developing key life skills.

Engagement

Another interesting element that came out of our reading of the literature relating to key mathematical life skills was the impact that this can have on engagement. Disengagement is a very real problem in FE. This is confirmed as a national issue by the CfEM Handbook: "A number of recent studies have highlighted the issue of poor engagement and low motivation among low-attaining students studying GCSE or Functional Skills maths post-16". Out of the five key principles for increasing motivation and engagement outlined in the handbook, two relate most directly to our project. The first is Principle 2 – Student Interests. The handbook states that

"Research with FE students shows that they find maths more relevant when there is an immediacy of usefulness for them personally. Once they understand the relevance of maths to their own lives and interests, they become more motivated and engaged. This may involve making meaningful connections to their lives that demonstrate the actual use value or simply showing how maths is a part of life outside the classroom".

Principle 5 – The Importance of Maths. The handbook says that

“Research has shown that it is possible to increase students’ motivation by showing that maths: is useful in itself and not just as a qualification; has direct relevance to students’ daily lives; is of immediate, not just future, use”.

In terms of delivering maths that students find of personal value, Realistic Maths Education (RME) is probably the most well-known pedagogy which has this embedded as an essential component. It is Dutch in origin and research from both the Netherlands and other countries and, in the words of the maths teaching and learning website Espresso, “suggests positive effects of RME on both learners and teachers, including: greater interest in and valuing of maths; development of mathematical competence; improved informal strategies and problem-solving skills; enhanced performance in number; increased class discussion and meaning making; and using context as a tool to motivate students”...

Of particular interest is a study of RME methods on GCSE resit students in the UK, which “found that students receiving a short Realistic Mathematics Education (RME) intervention showed improved attainment on post-test performance in Number” (Majewska, 2019). Further, “qualitative script analysis of Number post-tests revealed the impact of the RME intervention in terms of:

- use of the bar and ratio table models to find a route to a solution
- allowing some students to re-engage with informal sense making strategies
- providing a structure within which to organise and record thinking
- encouraging flexibility and creativity” (ibid.)

These areas are interesting as they fall within the area of number sense and proportional reasoning.

The available literature seems to suggest that if we make the maths in our interventions as immediately relevant to the students’ interests as possible, then we may also maximise engagement.

Methods

Focused research aim:

Deepening understanding of percentages with students below GCSE Grade 3: using Concrete Pictorial Abstract approach and real-life examples.

Following our Literature Review, we decided that we wanted to focus on students' understanding of percentages. This is a significant topic in both the Functional Skills and GCSE specifications so success would support our aim of progress towards Level 2. We also felt that it would allow us plenty of scope to work with 'real life' examples, highlighted in our literature as having a positive impact on motivation and engagement, and also have the potential to affect key mathematical life skills.

Research Design

Prior to any interventions we wanted to get a snapshot of who this group of learners might be. We wondered if EAL or SEN students might be overrepresented and whether this may have any implications for our intervention design. Students were given a quantitative profiling questionnaire.

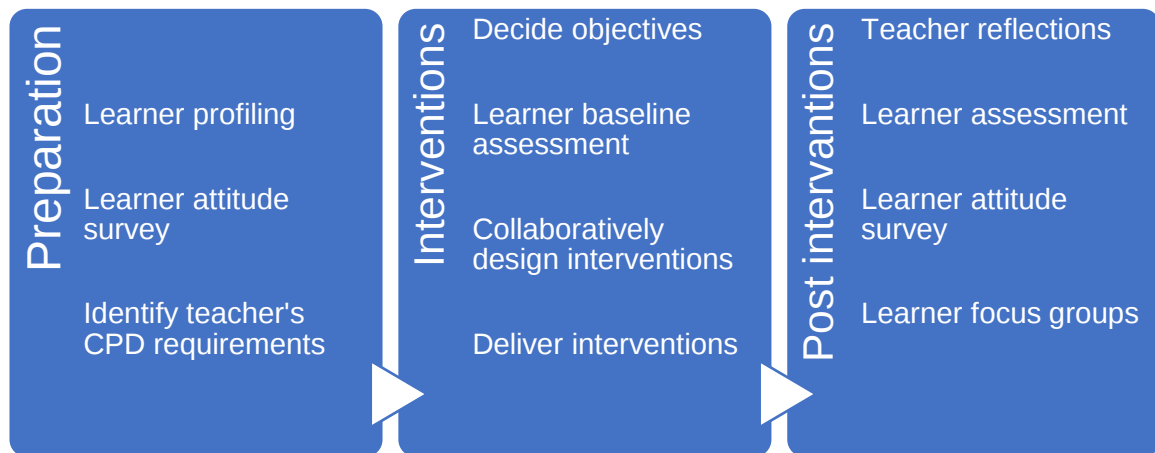
The impact of poor motivation and engagement came out of our literature review, and we wanted to hear more about this from this group of learners. We wanted to know how students felt about maths and their lessons generally. Alongside the profiling questionnaire we gave the learners a mixture of quantitative and qualitative questions seeking their opinions.

Clearly, we hoped to see mathematical progress over the course of our research. To capture this, we gave students a quantitative assessment before and after our interventions. This comprised of mathematical questions, and we also asked students to rank their confidence levels in the areas we were assessing. Our classes at this level have quite high mobility rates, so we asked students to provide their names in order to focus our analysis on the learners who took both assessments. We assured anonymity and that no participant would be identifiable.

Given the progress that this group of learners typically make, we knew any mathematical gains could be extremely marginal. Hence, we decided that we needed to design our research to capture a holistic picture. We wanted to know if using examples from 'real life' was something that our students had an opinion about. Similarly, we wanted to know how our students felt about CPA. The evidence demonstrates that this is an effective mastery pedagogy. But we did not know if teenagers would feel comfortable using manipulatives that they might not have used before, or at least for a period, due to COVID restrictions. There was concern amongst the teachers that the students might perceive manipulatives to be "childish" and that this might impact motivation and engagement negatively.

To complete the triangulation of our data, we collected teachers' responses to the interventions after they delivered each one and their reflections at the end of the intervention cycle.

The timeline of our project became as follows:



Participants

There were five teachers in our Action Research Group. This student cohort is relatively mobile, and the numbers involved fluctuated throughout as follows:

Data Point	No. of learners
Learner profiling	97
Learner attitude survey – pre-intervention	56
Learner baseline assessment	83
Post intervention assessment	66
Learner attitude survey – post-intervention	68

Results and Findings

Learner Profiling

Our learner profiling questionnaire (Appendix 1) showed that across the three colleges, the students in this cohort were typically 16-18 years old and enrolled on a L1 or L2 study programme.

Approximately 60% were previously educated in the UK, 30% educated outside of the UK and 10% educated in both.

30% had GCSE grade 2 as their highest mathematics qualification. 15% had Functional Skills Entry 3 as their highest qualification.

63% considered English to be their dominant language.

13% had an Education and Health Care Plan, however, 57% reported receiving support in maths classes at school.

We also asked questions relating to confidence, motivation and feelings about lessons (Appendix 2). When we asked students how confident they felt at mathematics, 69% answered slightly or very. 85% said they were either slightly or very motivated to work hard in maths.

We asked students open questions about what motivated them in maths and the predominant themes were to pass their exams, to get a job they wanted or their teacher.

The main theme that emerged when we asked students what they liked in their lessons was that they like maths to be relevant or useful – either for passing an exam or in their daily life.

Interventions

We aimed to have three sequential lessons that covered the objectives relating to percentages from both the Functional Skills and the GCSE specification. Following CPD, we identified bead strings and Deines blocks as the manipulatives that we wanted to use at the Concrete stage and bar models at the Pictorial stage.

We worked collaboratively to identify themes and the order of the objectives, and then in pairs to design individual lessons. Our Action Research consultant, Emma Bell, worked with us guiding and advising as necessary. We considered the lesson design process to be a crucial part of this project. We wanted to ensure that our students benefited from high quality lessons based on evidence led pedagogy. We also want to participate in a process that could be repeated and scaled as necessary in the future.

Our lessons (Appendix 3) were quality checked by Emma Bell. They were deliberately designed to be extremely comprehensive so that teachers would feel supported in the use of the CPA approach. However, we decided that they could be adapted as needed to meet the needs of classes and individual learners. We wanted them to be seen as a floor, rather than a ceiling i.e., to fully support, without restricting the individual teachers' delivery. The CPA approach ran throughout, as did reference to real life examples.

At Southwark College the lessons were delivered to students on an extended GCSE programme. At Newham and City of Westminster Colleges they were delivered to Functional Skills students. However, all students had prior attainment of less than a Grade 3 at GCSE.

All lessons were delivered face to face.

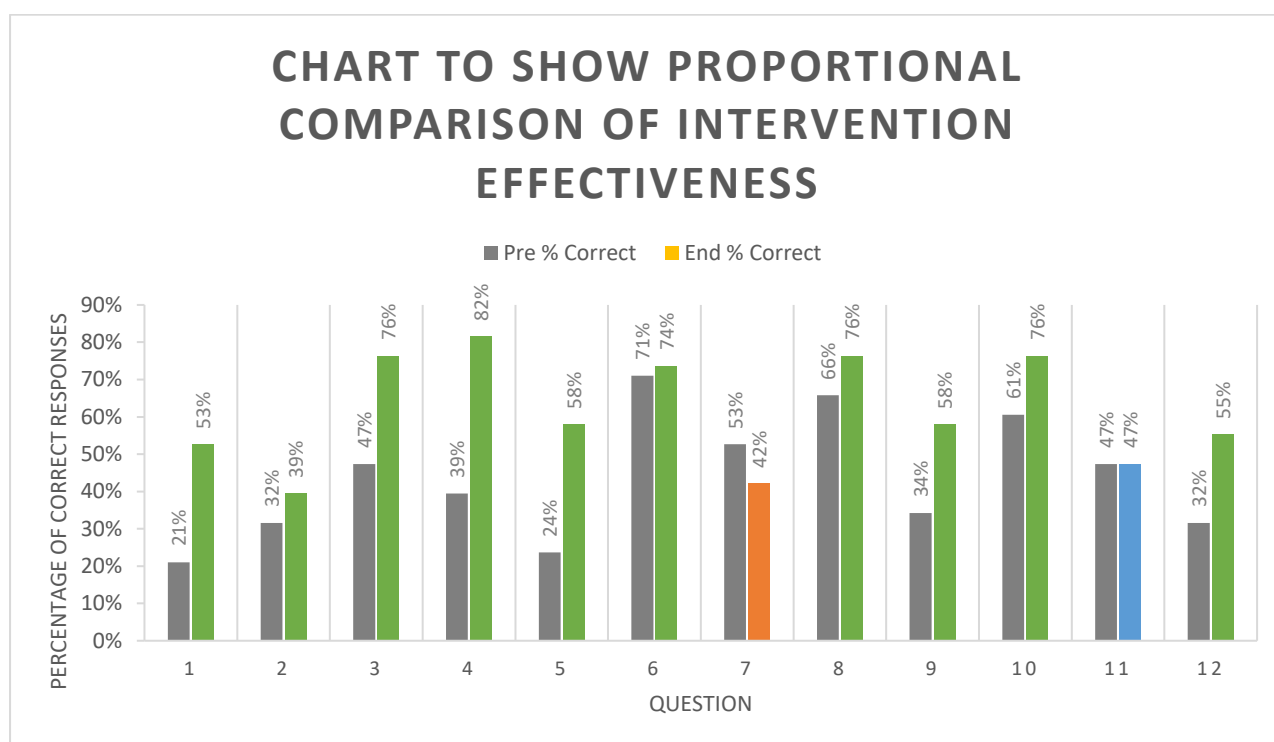
Assessment Results

Before and after the interventions we asked the learners ten questions from Craig Barton's Diagnostic questions website. We asked:

1. Which picture shows 1%?
2. Which of the following does not represent 40%?
3. Write 0.6 as a percentage
4. Write 0.09 as a percentage
5. What is 1.2 as a percentage?
6. What is $\frac{4}{10}$ as a percentage?
7. What is $\frac{4}{20}$ as a percentage?
8. Calculate 20% of 300
9. A coat costs £200. It is 25% off in the sale. How much is the sale price?
10. Find 30% of 90
11. What is £60 as a percentage of £120?
12. A computer costs £700. Its price increases by 20%. What is its new price?

As previously mentioned, mobility is high with this cohort of students. In addition, attendance can be problematic. We decided that for this particular set of data it was important that we ensured that we focused our analysis on students who undertook both assessments.

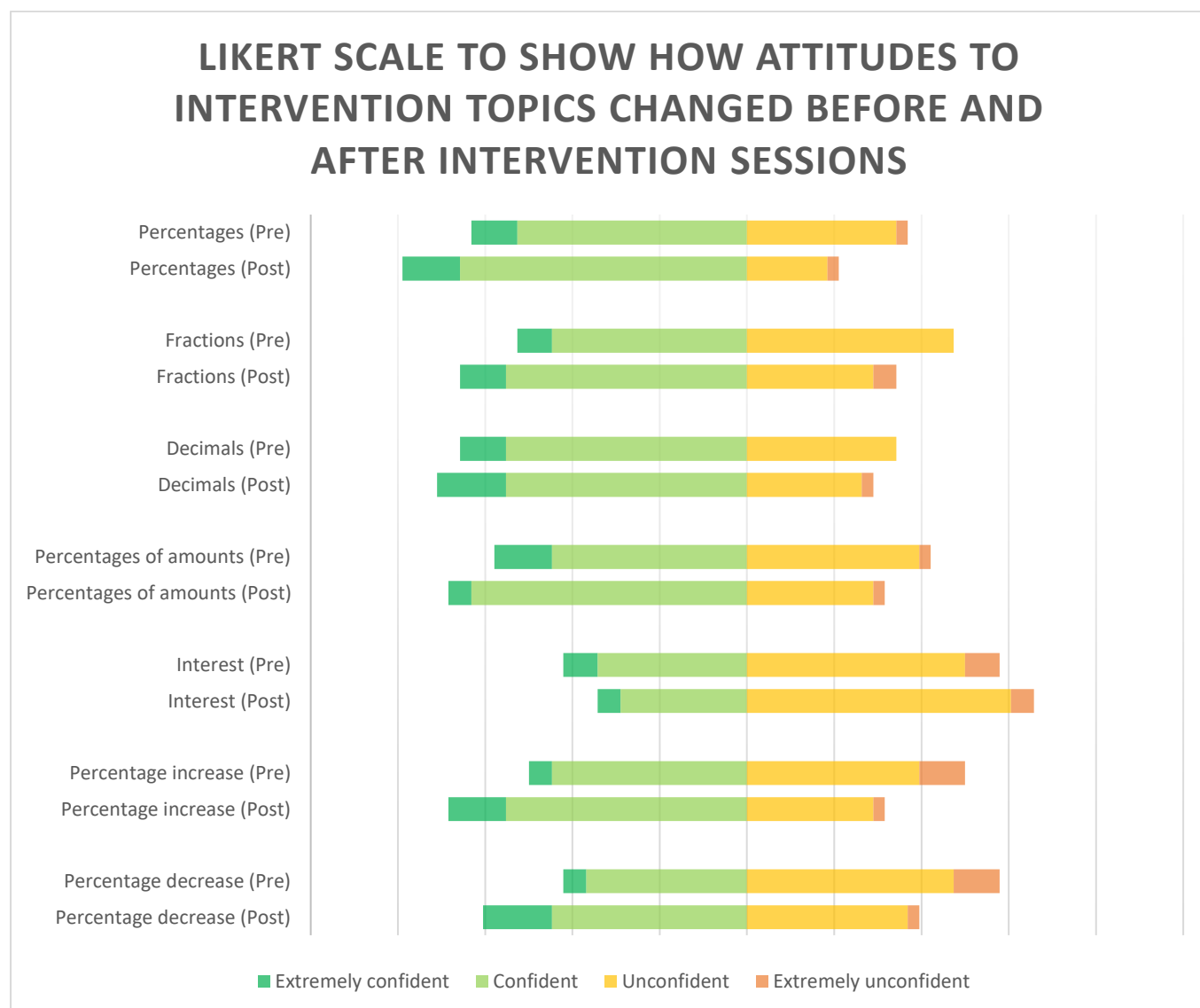
This chart shows the results:



In all areas, except for two, the percentage of correct responses increased. The percentage of correct responses for question 7 dropped and stayed the same for question 11.

Alongside the diagnostic questions, we asked learners about their confidence levels when working with percentages, fractions, decimals, percentages of amounts, interest, percentage increase and percentage decrease.

For data analysis we focused on the students who had taken both assessments. As this chart demonstrates, confidence in all competencies, apart from interest, increased.



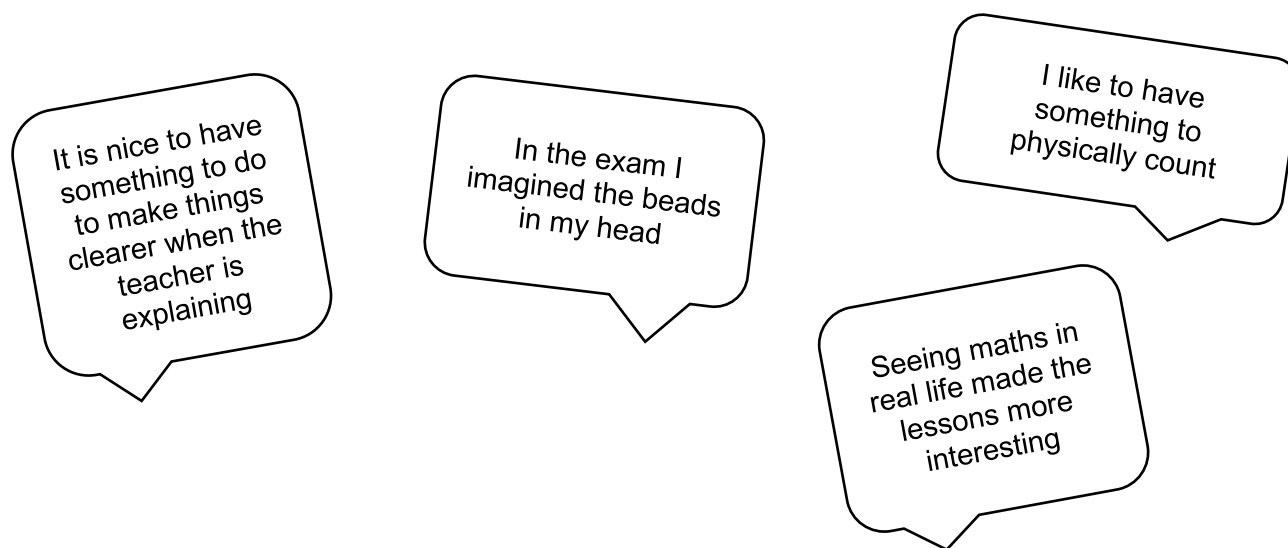
Learner Voice

In addition to measuring attainment, we considered it critical to capture our students' opinions regarding the lessons (Appendix 4). As mentioned previously, motivation and engagement are well documented issues in FE mathematics and we wanted to know learner responses to both the use of manipulatives in class and real-life examples.

83% of students said they felt more confident in mathematics after the interventions. 87% felt more motivated.

87% of students said that they felt the use of manipulatives helped them to understand percentages better. 85% said the use of real-life examples helped them.

In focus groups, feedback was similarly positive.



Teacher Reflections

Teachers were asked to reflect on the interventions (Appendix 5). All reported that they would continue to use manipulatives in the future as they believed they had had a positive impact on the learning of majority of the students in their classes.

Four out of the five teachers felt that using real life examples had supported their students learning. The fifth teacher said that they felt real life examples were useful, but more as a technique for engaging students, than supporting learning.

All teachers commented that the process of the intervention development had supported them to either try something new, if they had not used manipulatives before, or to return to pre-COVID good practice, if they had been using them before.

External Feedback

Two lessons were observed by Head of Departments. This was not something we had predicted or planned for. However, the observation feedback in both cases was extremely positive and indirectly referred to the aims of the Action Research.

"Learners made obvious and enjoyable progress. The use of beads really helped students to form concepts that are traditionally felt to be difficult and challenged their (incorrect) beliefs around the scaling up of problems – this was not an easy lesson by any stretch – but the delivery, pace, style and resources used were all superbly delivered – with obvious and meaningful progress made." (Zia Rahman, Newham College)

"This was an excellent lesson, with a focus on one single skill which the learners at this level can understand, process and practise. The familiar and accessible context was motivating as it made the maths 'real-life'." (Cathy Xuereb, Southwark College)

So what?

In every way that we measured, our interventions were successful and supported the evidence documented in the literature review.

It could be argued that given the wealth of research supporting the use of a CPA approach and, to a lesser extent, using real life contexts, this is what one might expect.

So, does our Action Research offer anything of value?

Interestingly, despite the evidence supporting CPA as a mastery strategy, within our Action Research Group, none of the colleges had sets of manipulatives. Three out of the five teachers had not used manipulatives before. Two had, but not in the recent past due to COVID concerns.

There were concerns amongst us that our students might perceive them as 'babyish' and feel patronised. We felt that there was potential for this group of students to feel that they had been identified as not very good at maths and therefore suspicious that they were being given primary resources to play with.

As Action Researchers we were keen to explore CPA with this group of learners. But as a group of teachers we felt at the beginning of the project that we lacked both the experience and resources to get started.

Anecdotally, this seems to be broadly representative of the FE mathematics sector. There is awareness and some use of manipulatives, but they are not used as widely as Pictorial strategies such as bar models.

This Action Research Project has been presented at both at CfEM Live and at the Newcastle College Group (NCG) Teaching Learning Conference. The feedback and questions arising have fallen into two groups:

- Are FE learners willing to engage with manipulatives?
- How can we get started?

Our Action Research Project can answer both of those questions. It has demonstrated that the CPA approach does work for this group of learners who do respond positively to the use of manipulatives. We have shown how you can start to deliver lessons using CPA.

Conclusions and Recommendations

Conclusions

- Our Action Research supports the body of research and evidence that CPA is an effective mastery strategy.
- Our Action Research supports the research and evidence that shows 'real life examples' are motivating for FE students.
- The FE students involved in our project found the CPA approach useful and they responded positively to it and would like to see more of it in their lessons.

Recommendations

Our recommendations for FE settings looking to introduce CPA are:

- Have a shared agreement to trial CPA, with an agreed timeline.
- Keep the objectives focussed.
- Keep the manipulatives simple. We chose to use only bead strings and Deines blocks to avoid cognitive overload for staff and students.
- Have ringfenced time for collaborative planning.
- Prepare comprehensive resources for teachers to use to meet the needs of their classes.
- Hold development sessions where staff can learn about the manipulatives, trial them and become really familiar before they introduce them to learners.
- Allow students a choice.

Our recommendations for FE settings looking to use 'real life examples' are:

- Find genuine examples. Our students enjoyed being able to explore websites that they would use themselves, looking for discount codes. If there isn't a real-life example, don't shoehorn one in!
- Support students to see the connections between the 'real life examples' and the exam questions. What seemed obvious to us, was not always obvious to our learners.

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Appendices

<https://padlet.com/rebeccaatherfold/ARG2appendices>