The Benefits and Challenges of Teachers working together on Team Teaching and the use of Manipulatives

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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 learners, embedding related CPD and good practice, and building networks of maths professionals in colleges.

Summary

The focus of the action research (AR) project was teachers working together, both inside and outside of the classroom. Their collaboration ranged from planning the classroom; implementation of the concrete resources; manipulatives; reflecting on how a lesson unfolded; pairing up and team teaching in a classroom. This approach built on the previous year's CFEM findings and aimed to support and develop learner's understanding in key areas of mathematics.

The design of the intervention was iterative. Within each iteration teachers reviewed and adapted their understandings and practices. As such, qualitative and quantitative data was collected and analysed throughout the project.

Overall, the results were positive. Successful use of manipulatives required extending teacher's practice. This was achieved not simply through teachers reading or watching pre-recorded videos on the use of manipulatives. Rather, an outside expert was employed to train, over several months, the AR team in new teaching strategies. This in turn was supported by ongoing informal AR team meetings to review and plan lessons.

Teachers effectively used a range of manipulatives in a variety of topics. The findings indicated that concrete manipulatives provided new ways of approaching a topic and fostered new learner understandings of a concept. Most success was achieved with those learners who were struggling with a specific topic, and also when a small group of learners worked with manipulatives.

The findings also indicated that team teaching was highly beneficial. It helped minimise teacher isolation; supported teacher collaboration and introduced teachers to new strategies. Seeing these strategies in action, rather than simply hearing about them second-hand, helped embed the practices.

Contents

Background

Introduction

A direct consequence of the Wolf Report (2011) was the introduction of new Government legalisation that required, from September 2013, young people who do not achieve a C in maths and English GCSE to continue studying those subjects post-16, until they achieved that grade. The purpose of the policy was to increase the proportion of adults who have functional English and maths skills, and to address the skills-based employment gap (Porter 2015).

The introduction of compulsory resits for mathematics for 16 to 18-year-old learners without a grade 4 - 9 (C - A* previously) has had a huge impact on Further Education Colleges. As exam entries have increased, the proportion of learners achieving a Grade 4 or above has declined (Smith 2017). In his review of post-16 mathematics Professor Adrian Smith discusses how challenges are most likely to be felt in Further Education (FE) colleges, as they take learners with lower average grades than school sixth forms or sixth form colleges, and additionally, where there has been the largest increase in numbers studying maths. As Ofsted discuss in their Research Review Series: Mathematics (2021) the post-16 resit program for GCSE mathematics still lags behind the secondary school achievement rates of approximately 60%:

> *"Almost 180,000 learners had to re-sit GCSE mathematics in 2019. Of these, only 22.3% achieved a standard pass (grade 4) or above."*

College Background

Cambridge Regional College (CRC) is set within this national context. It is a further and higher education provider, offering vocational courses for school leavers, professional training, qualifications, and community courses including English and mathematics. The Centres for Excellence in Maths (CfEM) Action Research projects have enabled CRC to explore ways of improving learner motivation, engagement and, ultimately, achievement. This has involved addressing learners' barriers to learning and as discussed in this report, the use of collaborative planning as a tool for the professional development of teachers. Now in its second year, the research project has expanded to include staff from Bedford College. This college has a broadly similar profile to CRC.

Research rationale

The Collaborative Planning project, 2021-2022, is a continuation of the important and productive work started last year. The groundwork for this year's approach has been laid for us through the conclusions and findings presented in the final report (2020 – 2021):

> *"Collective teacher efficacy has emerged as the key theme describing the impact of the work of the Action Research group on collaborative planning. The safe environment built upon peer support has promoted the development of more open and honest conversations about teachers' experiences of trialling new resources in their own classrooms. This has led to the empowerment of teachers to take risks and try new formative assessment approaches without fear of judgement by others. In turn, these classroom experiences, and opportunities to share different insights from colleagues have caused teachers to change perceptions of potential learner engagement and capability."*

"CRC to support teacher professional development through the use of team teaching, a natural slow progression from this year's project.

External training providers, funded by the CfEM project, have introduced innovative ways of teaching. Tailored support facilitated by external maths consultant and time to discuss, and experiment is now needed to ensure sustained teacher development."

Building on these key findings we have decided to continue to nurture communities of professional learners in order to advance teacher efficacy and develop teaching skills.

Similar to last year we set two important collective goals:

- To improve the pedagogic content knowledge of our GCSE maths resit teachers.
- To develop more effective formative assessment strategies.

We then decided to introduce two new concepts in order to fulfil these goals. They were:

1. The use of manipulatives.
   The intention being that the use of manipulatives will enhance the learners' conceptual understanding.
2. The fostering of teacher collaboration, both inside and outside the classroom. Teachers were paired up to observe each other and team teach. The aim was that such activities would:

   - increase teacher confidence and resilience when using new concepts
   - improve teacher reflections and so instigate the development of new skills
   - team teaching reduces the perceived risk of introducing new ways of working to learners

The aims of this project were closely aligned to the Mastery and Motivation & Engagement themes that are core to the Centres for Excellence in Maths programme.

This whole process would enable us to answer the main research question: 'In what way does team teaching and the use of manipulatives improve the quality of teaching? In particular, do these strategies provide a more responsive approach to the needs of GCSE maths resit learners?'

The model was employed at our Cambridge and Huntingdon Campus' and at one network college campus. Teachers received 3 hours remission time, funded by CfEM, to enable them to plan, research, reflect and team teach lessons. Manipulatives and materials were made available by the project lead. Teachers were given the opportunity to work with a task design specialist, Dr Sheila Evans.

Literature Review

Introduction

The Action Research (AR) project this year was underpinned by two goals: to facilitate team teaching through the development of a trusted community of professional learners and to introduce into the classroom research-informed resources – specifically manipulatives and Century Tech. The intention was to explore the efficacy of these goals within the setting of GCSE resit classrooms. Within this literature review we use the existing research to justify our approach. In order to do this, the action research group (ARG) chose to explore literature on communities of professional learners, then team teaching and finally the new (to this ARG) teaching resources and teaching strategies with a focus on manipulatives.
Note: All five members of the ARG were engaged in reading, summarising, and sharing the literature. This served to bring about a shared understanding of the focus of the action research project.

1. Community of Professional Learners and Team Teaching

Dalby & Noyes (2020) found that teachers gain most through involvement in informal sharing of ideas in teams and CPD that is directly related to their mathematics classroom practice. The CRC ARG research undertaken last year confirms these findings. It has shown clearly to us the benefits of working collaboratively in our decentralised model for maths and English provisions in our FE college. We have developed a teacher learning community (TLC) that has, for example, limited the feeling of teacher isolation and improved teacher agency. As such the findings from last year's action research concur with William's report (2017) that teacher collaboration enables effective change in habits to change teacher practice.

The existing research (e.g., Darling-Hammond 2017), however, asserts that the sustainable development of one's practice needs also to be both content focused and facilitate teacher reflection. Golding (2017) combines the research on teacher collaboration with Darling-Hammond's conclusion by drawing on the work of Spillane, Korthagen and Vasalos (amongst others). Golding explains that conditions for deep and permanent teacher change include a social rather than an individual 'enactment' zone, high-quality materials and rich expert-supported deliberation that is grounded in classroom experience. Moreover, the persistence of teachers in reflective practice brings a host of benefits, including strong feelings of personal security and of self-efficacy in relation to professional actions, better relationships with both colleagues and learners and a higher degree of job satisfaction. All these attributes were echoed in last year's action research project.

Bandura (1997) termed these attributes "*collective efficacy*" and this concept is regarded as many (e.g., John Hattie 2016 cited in Donohoo 2018) as at the top of the list of factors that influence learner achievement. Throughout this action research, we were looking at a different, and previously unused, way of further developing collective efficacy: through team teaching.

The definition of team teaching can vary. Sandholds (2000), for example, explains that

> "…. *although a commonly used term, team teaching has a variety of operational definitions, e.g., the term may refer to (1) a simple allocation of responsibilities between two teachers, (2) team planning but individual instruction, or (3) cooperative planning, instruction, and evaluation of learning experiences*."

Other definitions convey a similar message: "*Team teaching involves a group of instructors working purposefully, regularly, and cooperatively to help a group of learners learn*" (Buckley 2000). The approach used in this research will be an amalgamation of the above definitions and, as Krammer et al (2018) differentiates, will consist of self-selected teacher teams, and not enforced by the project lead.

Although team teaching is not a new idea, there appears to be a scarce amount of research regarding team teaching in FE internationally or more importantly, in the UK. This project aims to go some way to fill that gap. Studies carried out abroad tend to be on a small scale and not maths related. For example, two teachers in a secondary school in Taiwan (Jang 2006) looked at the effects of team teaching on motivation, engagement, and learners' perceptions, e.g., Khoirul Anwar et Al (2019), Simons et al (2020). The findings from these research projects indicated improvements to three factors.

2. Teaching resources

In the first year of this project (2020/21), the professional learner community (PLC) looked at teaching resources and task design with the view of improving learner attainment and engagement. Guided by the research, we aim to foster a "*Culture of Error*"

(Lemov 2015) to progress learning within safe classroom environments. Furthermore, we used multi-choice diagnostic questions (Barton 2018).

> *"The tasks were carefully selected to ensure they had some core characteristics. They were short, open activities that enabled teachers to find out quickly the current level of understanding of their learners. They generally had pre-designed differentiation built in and often included a visual representation. (…) The evidence indicates the tasks facilitated the move towards a more responsive, learner-centred approach to teaching maths. (…) This includes understanding common misconceptions held by learners and how to address them using multiple representations."*
> (2020/2021 CRC ARG)

This year (2021/22), in response to the findings from the previous action research, the ARG continued collaboratively working with the development and refinement of short learner tasks. The tasks, however, will also include using manipulatives as teaching tools to enhance learner's conceptual understanding. This ties closely with the mastery theme currently being implemented in primary and secondary schools in the UK. The age of our learners would suggest a lack of previous experience in using such tools, although it is not unheard of. The ARG also needed to consider the

emerging effect the pandemic has had on teachers and learners. One of the conclusions we can draw from our recent experience with Covid related lockdowns, is that learners had mixed experiences and achievement with online teaching and use of online maths tools. Therefore, we decided to use physical manipulatives rather than existing online ones.

This year's Professional Learning Community's knowledge on manipulatives is very limited (this will be discussed in further chapters). The ARG, first sought to define the term. Laski et al. (2015) provides an explanation of what a manipulative is: *"manipulatives are concrete materials (e.g., blocks, tiles) used to demonstrate a mathematics concept or to support the execution of a mathematical procedure".* Examples of modern manipulatives include Dienes (base-ten) blocks; Unifix Cubes; Cuisenaire rods; Numicon; algebra tiles; number lines; fraction pieces; pattern blocks and geometric solids. In their research, Laski et al (2015) notes that manipulatives have been in use for a number of years and are recommended by educators (The National Council of Teachers of Mathematics, 1989).

The research conducted in UK schools is currently very limited and none were found for FE settings. We thus widened our search of the literature to other countries and found a meta-analysis research on the efficacy of using concrete manipulatives (Carbonneau et al. 2013) where the researchers state the contradictions between the benefits of using manipulatives:

> *"…revealed moderate to large effects on retention and small effects on problem solving, transfer, and justification in favour of using manipulatives over abstract math symbols. (…) These contradictions may exist as a result of systematic factors. For instance, the level of instructional guidance, type of manipulative, age of learners, and other characteristics of a learning environment may impact the effectiveness of the intervention. (…) However, these results cannot be used as evidence that manipulatives are beneficial for learning when making comparisons to other mathematic instructional strategies."*

Other research viewed manipulatives in a more positive light. Johnston-Wilder & Mason (2004), for example, cite John Holt, who in 1964 had shown that only learners who already understood base and place value could effectively use blocks to solve problems. Furthermore, some researchers, e.g., Durmus & Karakirik (2006) believe that learners *"should be given an opportunity to play with manipulatives"* and that just a *"demonstration by a teacher is not sufficient to realize their full potential."* Moyer-Packenham (2001) advises the need for learner fluency in the use of manipulatives plus the feeling of being comfortable with it so that the learners can use it naturally as a problem-solving tool. Researchers recognise, however, that using a manipulative in a lesson doesn't guarantee that a learner will understand the concept and will be able to move on with their understanding of the problem (Clements & McMillen 1996).

The secondary focus of our research is regarding formative assessment tools using an online platform, Century Tech. This resource is relatively new to Cambridge Regional College and has the potential to enrich lessons and support learners' learning. The platform highlights for learners and teachers their acquired skills and

gaps in knowledge. This in turn can guide their revision of learnt material and provide a different look at the same topic. The tool could be of particular use in response to the Covid pandemic. The whole nations' education was forced online for part of 2020 and 2021. As remote learning in some form is likely to be with us for some time, exploring how AI based technology can support learners with their education is timely.

The current research on the effectiveness of AI is mixed (Tuomi 2020). Although some research in mathematics has shown improvements to learning, it is also clear that learning benefits cannot be achieved simply by introducing new tools in a classroom. Indeed, an indirect, but important benefit can be that teachers become more skilled in the use of general technology in the classroom (Benedict du Boulay 2019). This perspective was confirmed in the following quote:

> *"…the learning outcomes do not depend on technology. It depends on how the teachers can use technology in pedagogically meaningful ways. An appropriate approach, therefore, is to co-design the uses of technology with teachers."* (Tuomi 2020)

Another research on the use of AI, this time in higher education, by Zawacki-Richter et al (2019) points out: *"…we should also always remember that AI systems "first and foremost, require control by humans. Even the smartest AI systems can make very stupid mistakes."*

Finding research into AI within FE has proven unfruitful. We have, however, looked at one of the newest CfEM projects conducted by Kimeng (2021). The purpose of this action research was to explore the effect of using technology in the online teaching and learning of mathematics for GCSE resit learners. The aim was to re-engage and motivate disengaged post-16 FE learners in the learning of mathematics, which strongly resonated with us. One of the findings of that project is the fact that working independently is a big challenge and there needs to be a way to make the transition to using online tools from the classroom to independent use of maths learning platforms outside the classroom. Within our ARG we will collaboratively discuss ways of tackling this issue.

3. Teaching strategies

In last year's research, *"there was also an acknowledgement that occasionally, when learners were struggling, they lacked alternative approaches to help them overcome barriers – they simply drew on their own experience of being taught that particular subject."* (2020/2021 CRC ARG)

To remedy this situation, and help teachers develop their practice we intended to use manipulatives as a tool to implement formative assessment strategies and well proven practices of 'formative assessment' (Black & Wiliam, 1998) guide how manipulatives were used in the classroom. Within professional development sessions, teachers drew on their own skills and experiences to collaboratively work out how best to integrate formative assessment strategies both when using

manipulatives and when teaching their 'everyday' classes. The aim was, for example, to maintain learners' 'agency and authority' of the mathematics, even when they are struggling. In doing so, learners' identity as 'doers' of mathematics will be enhanced (Schoenfeld, 1989). Furthermore, the short manipulative tasks will be carefully designed to expose learners' mathematical knowledge and reasoning. This will help the teacher monitor learners' progress and provide timely support. Such actions can deepen learners' understanding of mathematical concepts and their ability to solve problems.

To gain the most benefits from using this teaching strategy, literature suggests *"(…) as only being possible when there is consistent prolonged use of the same or similar manipulatives"* (Martin 2009 cited in Laski et al. 2015).

Based on the research reviewed, overall, using manipulatives appears to have resulted in positive outcomes for learners. However, Nessam (2016) in her review of 5 studies cites Moyer (2001) who claims that teachers often use manipulatives in lessons to add variety or fun without having the knowledge to use them productively. She also discusses Thompson (1992) who cautions against ineffective use of manipulatives and therefore lack of improvement in learners' understandings. Consequently, taking this on board, the new method (for our ARG) required us to undertake a course of CPD to design a series of short tasks in the hope of promoting not just better understanding, but to improve motivation and engagement as well.

Conclusion

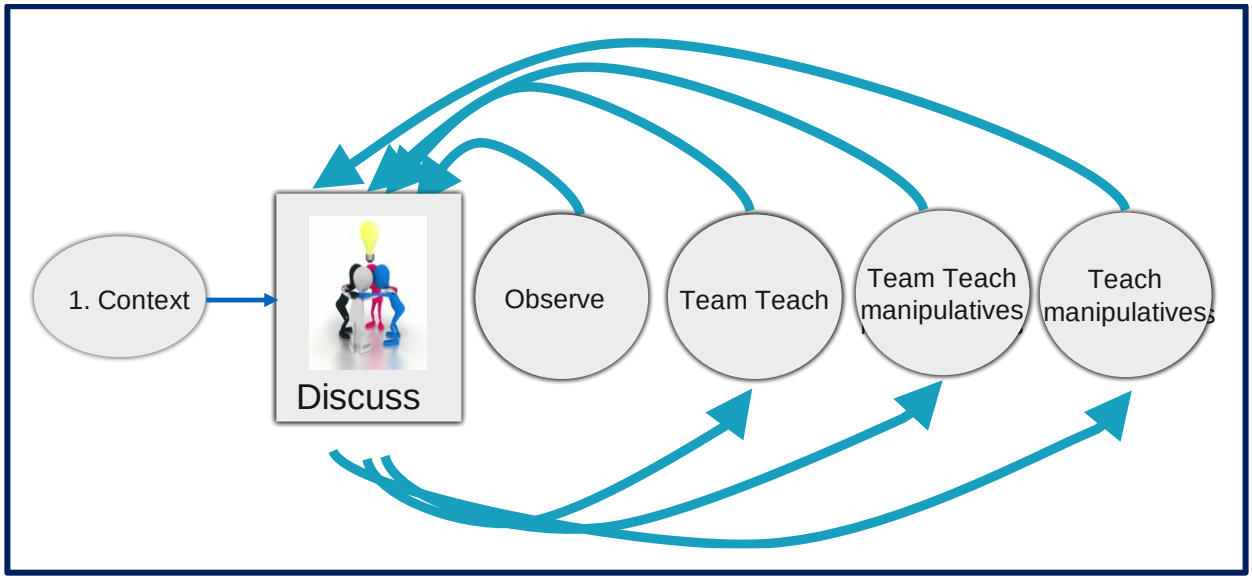
In summary, our work was guided by both the existing literature and the findings from last year's action research. As outlined in last year's report, changing teachers' beliefs is a slow and ongoing process (Swan 2006 and 2007). We followed the relevant processes outlined in the literature, e.g., setting up a PLC (Wiliam, 2016) to give the ARG courage to try new approaches. The ARG with expert guidance will continue investigating the effects of team teaching and the use of manipulatives in our daily practices.

Methods

The Design and Implementation of the intervention

The AR project centred around teachers working together inside and outside of the classroom. Their collaboration ranged from discussing the formal findings of questionnaires', through to planning the classroom implementation of a new resource; reflections on how a lesson unfolded and teaming together to teach the same class.

The project was designed after drawing on the learnings of the literature review. The diagram below shows the five phases of the original research design.



Within the year there were five iterative cycles:

Phase 1: Exploration of Context Learner and teacher questionnaires were completed to establish participants initial perspectives on both the use of manipulatives and team teaching. The information derived from the data collected helped teachers create and refine the intervention.
Type of data collected: (Qualitative and quantitative. No. Sources: Learners (140); teachers (6).

Phase 2: Observe Teachers observed each other and their opinions on this process were captured within a written questionnaire. This activity helped organise the team teaching and resolve any perceived teacher concerns.
Type of data: Qualitative and quantitative. No. Sources: Teachers (6).

Phase 3: Team Teach Teachers had the opportunity to plan, and team teach together.

Phase 4: Team Teach Manipulatives: Restrictions due to Covid prevented this phase of the design from taking place.

Phase 5: Teach Manipulatives: Guided by formal training and informal teacher discussions, teachers planned, taught, and collaboratively reviewed several lessons using different types of manipulatives. Teachers' opinions on the use of manipulatives were established using a questionnaire.
Type of data collected: Qualitative. No. Sources: Teachers (6).

Unfortunately, because of pressures of time and Covid issues the use of Century Tech was constrained. As such no data was collected regarding its use as a formative assessment tool to check conceptual understanding of topics in which learners had been exposed to manipulatives. Limited data was collected on learners' perceptions of the Century Tech platform (Learners:50).

Data was captured from the six participating teachers discussing the impact of the intervention. In pursuit of robust results, all the qualitative data was thematically analysed using a coding system. The non-neutral position of teachers was recognised, and inbuilt biases were minimised by a system of independently checking the coding at all stages.

The two ethical issues considered were the rights of the learners and teachers participating in the interventions, and the use of the data collected from the interventions. All learners were given background information about the project and their rights and signed a form agreeing to participate.

Results

The Intervention

The table below describes the key activities of the intervention. All the activities supported the building of a robust community of professional teachers.

Activity	Date	Key Outcomes
Designed learner and teacher questionnaire and organised their completion.	Oct 2021 – Jan 2022	Teachers understanding of learner and fellow teachers' perspectives grew. This in turn improved the implementation of intervention and collaboration with colleagues.
Teachers paired up to observe each other. The activity was then discussed with wider AR group.	Oct – Dec 2021	Positive experiences emerged from the activity. This encouraged teachers to team teach.
In team-teaching pairs, teachers planned, taught a class together and reflected on the activity. At this stage teachers used no new resources. They then discussed their experiences with wider AR group.	Dec 2021	Positive experiences encouraged teachers to team-teach using a resource relatively new to them – manipulatives. Developing Covid restrictions curtailed this activity.
In two PD sessions ARG teachers shared ideas on the use of manipulatives. After using them in the classroom, reflected with the wider AR group, on how the lessons worked.	Jan-Feb 2022	Teachers shared ideas, successes and failures and so supported each other's understandings, practices, and motivation.
All AR teachers attended four sessions on manipulative training. External professionals ran the sessions.	Mar-May 2022	Teachers learned new ways of teaching a range of manipulatives across a variety of mathematics topics
Teachers reflected together on their use of manipulatives in the classroom. This reflection occurred with three PD sessions.	Mar-April 2022	Teachers shared ideas, successes and failures and so supported each other's understandings, practice, and motivation.
Final informal, but structured AR discussion, on the whole of the AR project.	April 2022	Teachers shared ideas, successes, and failures – helped support each other's understanding and motivation.

Findings

Using a grounded approach, four distinct themes emerged from the analysis of the data. Guided by these themes, the results are described below.

Theme 1: A Community of Professional Teachers

All teachers were positive about the informal meetings organised to reflect on their ideas and share ideas.

Nature of Talk	Teachers were particularly pleased that the meetings occurred on a regular basis as this enabled them to get to know each other, develop trust and talk honestly about their experiences in the classroom. From the data, it was clear that strong relationships developed between teachers.
Tackling Isolation	Some teachers commented that, unlike more generic training sessions, it was good to work with just fellow mathematics teachers who understood the challenges of working with resit learners: "…. *you share the same challenges that I also experience. So, you feel that you're not actually isolated, you're not alone. You know, we've all got those same challenges."* *Other teachers mentioned that they often do not get the opportunity to talk to other mathematics teachers.* *"…. teaching is quite a lonely profession. We might be in a room full of people, but do those people do the same type of job we do day in, day out? Can they relate and understand what we're doing and what challenges we're facing and having someone else, who knows? … That's what I keep from this project and that helped me learn and help me develop"*
Sharing Risk	All teachers recognised that embedded within the introduction of a new resources was an element of risk. Learners, for example, may not immediately appreciate the benefits of manipulatives and not respond as hoped. Moreover, teachers may not initially fully understand the pedagogical approaches required and so there was further risks that they would not teach it well. The potential for behavioural issues to emerge was ever-present. Knowing that other teachers are prepared to take these risks helped to sustain teachers: *"…. we are free to not succeed with something that we do because we are trying it and we are sort of pioneers that … go try it, do it and then we come back in here and we share it. And when someone else says that, oh my God, that didn't work for them. I feel it wasn't only me …. I feel validated that what I've done"*

Theme 2: Teacher Learning

Teachers reported on their own learning. This learning can be categorised into three distinct areas:

Training Sessions	Feedback from training was mainly positive. Teachers appreciated the remission time granted to take on new ways of teaching. Many teachers reported that the training added a 'new dimension' to teaching, and they

	had learnt useful, new teaching strategies in a variety of topics such as translations, averages, and ratio. For example, one teacher reported:" *I wouldn't have thought to have used them for sequences at all, and that certainly did help some learners this morning.*" Moreover, some teachers stated they were now able to adapt the use of manipulatives to contextualised learning such as a childcare setting. Teachers also reported a heightened awareness of the importance of using the relevant vocabulary. The data suggests that this appreciation of the training was strengthened by their own initial attempts to use manipulatives in the classroom. These occurred before the training sessions on manipulatives, and many teachers reported challenges and recognised there were gaps in their pedagogical content knowledge
Collaboration Outside the Classroom	All teachers viewed the informal meetings outside the classroom as key to the project. These provided opportunities to share ideas, listen to different perspectives and so extend their pedagogical and mathematical knowledge. For example, one teacher stated: "I like to steal ideas and copy ideas from colleagues, another stated: "someone else sees it differently".
Collaboration Inside the Classroom (team teaching)	Teachers who participated in team teaching appreciated how much they learned 'in action'. New ways of teaching were identified as well as new ways of handling attitude and behaviour issues. Witnessing how topics were broken down, for example, was seen as useful and provided "another message of how to solve problems".

Theme 3: Team Teaching

Teachers reported on the successes and challenges of team teaching. These are outlined below:

In the Classroom	**Successes:** Several teachers reported that team teaching allowed them to feel more relaxed in the classroom. Any issues concerning learning or behaviour management could be tackled by two teachers instead of the usual one. As such the stresses of teaching were reduced. Indeed, some teachers reported that it was a fun lesson – they were able to relate better to both learners and their fellow teacher. Another teacher mentioned that this safety cushion allowed them to try new ways of teaching without too much worry. **Challenges:** Teachers expressed a few concerns about team teaching. These were largely around the initial phase of 'getting used' to a colleague in the classroom. One teacher was worried that "that one teacher overshadows the other teacher during the lesson". Another was concerned about the flow of the lesson – when to talk and when to listen: "*Knowing when to step in to talk to the whole class and not disrupt the flow of the class*". Another reported on the challenge of talking to learners who did not know them, and of not knowing the learners' needs.
Collaboration	Teachers highlighted the need to plan lessons together as this helped establish roles and clarify the learning intentions of the lesson:

	"…. thinking out loud often helps me clarify my own ideas about what I am going to do – if I can explain it to someone else, then it is clear enough to work with a group!" Other teachers stressed the need to have a post-lesson review in order to express concerns and overcome problems. Others reported how they enjoyed collaborating in the lesson *"Two teachers collaborating together during the lesson – we did things 'together' and were adding more examples or something that we individually thought was necessary and the other teacher hasn't done."*

Theme 4: Teacher Strategies for Manipulatives

Overall, teachers were very positive about using manipulatives in the classroom. It gave them more options when teaching: 'it's another way to tackle the problem. I could transfer to manipulatives' Furthermore, being able to see from the learners' perspectives and providing opportunities for learners to explain their methods were highlighted as big positives; 'gives an insight into how different learners work'

This theme considers the practicalities of how teachers used manipulatives in the classroom.

Mathematic Topics	Teachers expanded their knowledge of the use of manipulatives in topics from negative numbers to volume, sequences, place value, averages, collecting like terms and equations. The types of manipulatives used ranged from counters to multilink cubes to algebra tiles and Cuisenaire rods. Teachers recognised that some concepts developed using manipulatives could then be applied across different topics. For example, zero pair, a concept introduced using counters to develop learners' understanding of negative numbers, can be drawn on when learners were working on linear equations or simultaneous equations. Similarly, teachers used the same manipulatives across different topics. Double sided counters, for example, were used with negative numbers, averages, and sequences. Some teachers recognised that the manipulatives allowed learners to learn a topic, but in a different way.
Group Size	Most teachers decided to use manipulatives just with small groups (about 3 or 4) or one to one support, rather than with the whole class. One teacher stated: "*I found they [manipulatives] were a helpful device for one-to-one support when he was struggling with evaluating a single expression with different values of the variable and when it became apparent, he held some misconceptions."* The decision on group size often stemmed from the unsuccessful use of manipulatives with a whole class. However, one teacher specified that some topics may be appropriate for whole groups e.g., side elevation. Another teacher was able to work with the whole class, but that was because there were only six learners in the class.
Length of Task	Some teachers initially devoted a substantial part of the lesson to the use of manipulatives – the success of this depended on the learners' prior

	knowledge. SEND learners, for example, benefitted from spending nearly an hour when they used manipulatives. Many other classes were exposed to short 10–15-minute tasks with some teachers preferring to draw on manipulatives as and when appropriate. Other teachers, however stated that the pressure of time constraints was problematic when using manipulatives: "*it takes a long time…. I feel a bit squeezed*"; "*manipulatives are quite a time-consuming process*".
Move to Abstraction	All teachers recognised the importance of moving away from concrete manipulatives to more abstract mathematics. Some teachers used online platforms such as Century Tech to check learners abstract understanding. Others considered that the move could be a slow process for some learners and stressed the importance of not rushing it. One teacher sought to switch between abstract mathematics and concrete manipulatives at different points in a lesson: *The idea was to see both method and have a deeper understanding. Learners' reactions were mixed, they found the concrete method more complicated."*
Prior Learning	On the whole, teachers believed that learners with weak prior attainment benefitted the most from the use of manipulatives. Using them improved both their confidence and their understanding of mathematics. Those learners with stronger prior attainment were sometimes less engaged when using manipulatives. One teacher for example quoted a learner's response to the idea of using manipulatives "*Are you serious? I thought this is something for primary school".* As such, the data revealed that teachers tended to select those learners who were struggling with a topic: *"I selected a small group of 3 learners that were struggling with that topic. The goal was to be able to add to negative numbers and extend it to the context of simplifying Expressions."* Once a group had been selected, teachers tended to use manipulatives with the same learners in order to ensure continuity and exposure to manipulatives. A teacher reported, for example, after a second lesson *"Learners were very comfortable with using manipulatives."*

Theme 5: Learner Experience

In contrast to teachers' concerns, most learners were initially positive about using manipulatives.

The table below focuses on the key findings of the learners' experiences:

Learner Attitude and Behaviour	In general, the activities involving using manipulatives were well received by learners even if was simply to *"provide a change of focus".* Indeed, for a number of learners, manipulatives helped improve attention, reduce anxiety, and improve confidence. For example, one teacher reported: *"The most important thing was what it did to his [learner] confidence, which was really, really nice to see, … he normally he hates coming to maths obviously because he's really, he is really, really weak and yet he went out that week and with a big spring in his step because of what he'd achieved and understood ".*

	Another stated that one particularly unconfident learner needed the one-to-one support of the teacher in order to overcome his initial concerns. Manipulatives also helped slow down the learning processes and supported learners to adopt a more considered approach when solving problems. Although most teachers reported increased learner engagement when using manipulatives, there was some disruptive behavior, for example, learners throwing manipulatives. One teacher reported that learners felt that using manipulatives close to exam time was not the best use of their time. As such they did not engage in the activity. The use of manipulatives did not often promote learner collaboration, however there was some evidence of learners helping each other.
Learner Learning	There was some evidence of learners improving their understanding through the independent use of manipulatives, with learners with lower prior knowledge benefitting the most. A follow-on assessment showed more improvement than expected. It is, however, not clear yet if there could be a long-term impact on results.
Century Tech	The main finding was that learners struggled to receive immediate feedback when their answers were incorrect. Learners were impressed, however, on the extensive Mathematical content of the platform and found the performance data useful. Some learners cited that there could be improvements to ease of access and often struggled to find a particular topic.

Discussion

The two overarching aims of the project were to develop a community of professional teachers and concurrently develop new pedagogies for working with manipulatives. Integral to these aims was the development and understanding what influenced and constrained the success of the intervention.

The findings indicated that, overall, these aims were achieved. By working together both inside and outside the classroom, teachers developed new practices; supported colleagues; sustained their motivation and ultimately improved learner learning.

Although the experiences of team teaching were curtailed, it was clear from the findings that teachers not only enjoyed the process but gained insights into new teaching strategies. The extent to which team teaching was successful, however, depended on the teachers' careful planning of the lesson. Teachers clearly need the space in their timetable to undertake these meetings.

The findings also showed that key to a successful class introduction to manipulatives was the extent to which learners perceive the teacher has faith in the validity of the resource. For learners to fully engage with manipulatives their teacher also needs to be fully committed. To achieve such teacher confidence and commitment requires time before lessons to both gain knowledge and plan. This was achieved in part through the use of training sessions. Key to the success of these sessions was that they were live and interactive. Teachers were able to check their understanding and ask specific questions about teaching strategies for a range of manipulatives. These sessions were in turn supported by more informal discussions with fellow teachers. For CRC this arrangement proved a cost-effective way for teachers to develop their practice.

Given that the majority of resit learners have been exposed to most parts of the GCSE syllabus, the use of manipulatives allowed teachers to move away from the 'same old same old'. Learners had the opportunity to 'see' a concept in a different way. This newness can create a moment that the learner is more likely to remember – a different memory in comparison to just following an algorithm by rote.

In conclusion, most teachers regarded that given the appropriate training, manipulatives are a useful additional tool in their toolbox to draw on when needed.

Recommendations

A range of recommendations have emerged from the findings. These are listed below:

1. Informal and frequent meetings, in which teachers can discuss the issues of teaching and learning that are important to them, can have many benefits. These include improving staff relationships, minimising the feeling of isolation, strengthening knowledge of teaching and of mathematics, and ultimately keeping teachers in the profession.

2. Before teaching manipulatives, most teachers will need to be trained. This training needs to be more than viewing an online video or reading an article. Teachers need live interactive training in order to fully understand the learning potential of manipulatives.

3. It is best to introduce manipulatives at the beginning of the academic year. If they are introduced at a time when exams are looming, learners are likely to be less engaged. Encouraging learners to collaborate can also improve engagement.

4. To achieve success with manipulatives, they should be used regularly throughout the year.

5. Manipulatives can be used alongside other ways of working with a concept. This can help deepen learners' understanding of the concept.

6. Team teaching can support teachers' pedagogical knowledge and promotes collaboration.

References

Bandura, A. (1997). Self-efficacy: The exercise of control. New York: W.H. Freeman and Company.

Barton, C., 2018. On Formative Assessment in Math: How Diagnostic Questions Can Help. American Educator, 42(2), p.33.

Black, P., & Wiliam, D. (1998). Assessment and Classroom Learning. *Assessment in Education: Principles, Policy & Practice, 5*(1), 7-74.

Buckley, F. J. (2000). Team teaching: What, why and how? Thousand Oaks, CA: Sage Publications, Inc.

Carbonneau, K.J., Marley, S.C. and Selig, J.P., 2013. A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives. Journal of Educational Psychology, 105(2), p.380.

Clements, D. H., & McMillen, S. (1996). Rethinking Concrete Manipulatives. Teaching Children Mathematics. Retrieved from https://www.jstor.org/stable/41196500?seq=1

Dalby, D. & Noyes, A. (2020) Mathematics in England's Further Education Colleges: an analysis of policy enactment and pr mifec-interim-report.pdf (nottingham.ac.uk)

Darling-Hammond, L., Hyler, M. E., Gardner, M. (2017). Effective Teacher Professional Development. Palo Alto, CA: Learning Policy Institute.

Donohoo, J., Hattie, J. & Eells, R. (2018) The power of collective Efficacy. Educational Leadership Vol 75 No 6 ASCD

Durmus, S., & Karakirik, E. (2006). Virtual Manipulatives in Mathematics Education: A Theoretical Framework. *The Turkish Online Journal of Education Technology - TOJET (1)*. Retrieved from https://files.eric.ed.gov/fulltext/EJ1102492.pdf

Jang, S.J., 2006. Research on the effects of team teaching upon two secondary school teachers. Educational research, 48(2), pp.177-194.

Johnston-Wilder, S., & Mason, J. (2004). Fundamental constructs in mathematics education. Routledge Falmer in association with the Open University. Retrieved from http://oro.open.ac.uk/642/

Kimeng, V. (2021) To Explore how online platforms can be used to re-engage

and motivate disengaged post-16 GCSE Maths re-sit learners. Centre for Education in Maths (CFEM)

Action Research Project. Retrieved from: https://www.et-foundation.co.uk/wpcontent/uploads/2021/10/27.-Harlow-Technology-.pdf

Khoirul, A., Slamet, A., Rohmy, H. & Asmara, C.H. (2019), 'Learners' Perceptions of collaborative Team teaching and Learners' Achievement Motivation', *International Journal of Instruction,* January 2021 Vol 14 pp325 – 344.

Krammer, M., Rossmann, P., Gastager, A. & Gasteiger-Klicpera, B. (2018) Ways of composing teaching teams and their impact on teachers' perceptions about collaboration. *European Journal of Teacher Education*, 41:4, 463-478, DOI: 10.1080/02619768.2018.1462331

Korthagen, F. A. J., & Vasalos, A. (2009). From reflection to presence and mindfulness: 30 years of developments concerning the concept of reflection in teacher education. Paper presented at the EARLI Conference, Amsterdam.

Laski, E. V., Jordan, J. R., Daoust, C., & Murray, A. (2015). What makes mathematics manipulatives effective? Lessons from cognitive science and Montessori Education. SAGE Open.

doi:10.1177/2158244015589588

Lemov. D., Culture of Error [online] https://teachlikeachampion.com/cultureoferror/ [Accessed 20 Dec. 2021]

Moyer-Packenham, P. S. (2001). Are We Having Fun Yet? How Teachers Use Manipulatives to Teach Mathematics. Educ Stud Math

The National Council of Teachers of Mathematics. (1989). NCTM. Retrieved from https://doi.org/10.5951/jresematheduc.20.5.0498

Neesam, C. (2016) An Evidence-Based Practice Review Report Theme: School Based Interventions for Learning Are concrete manipulatives effective in improving the mathematics skills of children with mathematics difficulties? Review conducted for Doctorate, University College, London

Porter, N. (2015). Crossing the line. Improving success rates among learners retaking English and Mathematics GCSEs. A Policy Exchange Policy Bite. London: Policy Exchange.

Sandholtz, J. H. (2000). Interdisciplinary Team Teaching as a Form of Professional Development. *Teacher Education Quarterly*, *27*(3), 39–54. http://www.jstor.org/stable/23478234

Schoenfeld, A. H. (1989). Exploration of Learners Mathematical Beliefs and Behaviou. *Journal of Research in Mathematics Education, 20*(4), 338-355.

Simons, M., Coetzee, S., Baeten, M, & Schmulian, A, (2020). Measuring learners' perceptions of a team-taught learning environment: development and validation of the Learners' Team-Teaching Perceptions Questionnaire (LTTPQ). Learning Environments Research. 23.

Smith, A., 2017. A review of post - 16 mathematics, London: Department of Education.

Spillane, J. P. (1999). External reform initiatives and teachers' efforts to reconstruct their practice: The mediating role of teachers' zones of enactment. *Journal of Curriculum Studies*, 31, 143–175.

Swan, M., 2006. Designing and using research instruments to describe the beliefs and practices of mathematics teachers. Research in Education, 75(1), pp.58-70.

Swan, M., 2007. The impact of task-based professional development on teachers' practices and beliefs: A design research study. *Journal of Mathematics Teacher Education*, 10(4-6), pp.217-237.

Swan, M. (2008) A Designer Speaks. Educational Designer, 1(1)

Wiliam, D (2006) Assessment for Learning: why, what and how? Edited transcript of a talk given at the Cambridge Assessment Network Conference on 15 September 2006 at the Faculty of Education, University of Cambridge.

Wolf, A. (2011). Review of Vocational Education

Zawacki-Richter, O., Marin, V., Bond, M. & Gouverneur, F. (2019) Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education* 16, 39. https://doi.org/10.1186/s41239-0190171-0

Appendix A – Learner Background Questionnaire

Learner Background Questionnaire

To help teach you better, we'd like to understand better your background and thoughts concerning two aspects of maths lessons. To do this we would be very grateful if you could complete this short questionnaire as honestly and fully as possible. It will take no more than a few minutes.

		Answer
1	Have you used manipulatives in your maths class?	**Yes/No**
2	If yes, • When did you use manipulatives (primary/secondary/college)? • Please describe the manipulatives used	
3	What are your feelings about using manipulatives in maths lessons?	
4	Team teaching is when two or more teachers teach the same class together. Have you ever been team taught in maths lessons?	**Yes/No**
5	What are your feelings about being taught by two teachers in the same lesson?	

Appendix B – Initial Teacher Questionnaire

ARG Teacher Experiences – Initial Questionnaire (November 2021)

For the project to be sustainable and eventually widen out to other teachers, we need to find out what works, what doesn't and what needs adapting – from the teachers' perspective. To understand this fully we need to also get to grips with the context of the project, e.g. are manipulatives completely new way of teaching for the ARG? Is there a lot of concern about team teaching & if so what is the nature of the concern?

To help with this, can you please complete the following questionnaire as fully as possible.

1. How many years have you been teaching? *

Enter your answer

2. How much do you know about manipulatives? *

- ◯ Nothing
- ◯ A little
- ◯ A lot

3. In the last five years, how many times have you used manipulatives? *

- ◯ Never
- ◯ Under 5 times
- ◯ Over 5 times

Appendix C – Reflections on Team Teaching

Teacher Collaboration Project: Reflections on Team Teaching

1. Describe the type of team teaching you experienced (e.g., teachers collaborating together during the lesson, teachers separately teaching different maths etc.)

2. What do you think you've gained from the experience of team teaching? Please explain.

3. Are there any issues with team teaching (from yours or the learners' perspective)? Please explain.

Please email Monika your completed reflections

Appendix D – Final AR meeting questions

Final AR meeting 2021 – 2022: Semi-structured Discussion

1 What are the key things you have learned this year from participating in the AR?
You may want to comment on:
- How this learning has impacted your teaching. Please provide specific examples.
- How you think you'll build on this learning when teaching next year.
- What you enjoyed about participating in the AR.

2. How has the experience of participating in AR differed from other PD?
You may want to comment on:
- Whether these differences are beneficial or not? Please provide specific examples.
- The collaborative nature of the AR, i.e., sharing experiences/knowledge.
- The challenges of participating in the PD.

3. If the AR project continues next year, what would you like it to focus on? Please explain why.