CENTRES FOR EXCELLENCE IN MATHS

How do Maths Teachers respond to interleaving mastery into the vocational areas? How can we make the Maths in the classroom connected to the learners' own experiences; readiness to learn and apply this to more topics.

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OUR PARTNERS

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Department for Education

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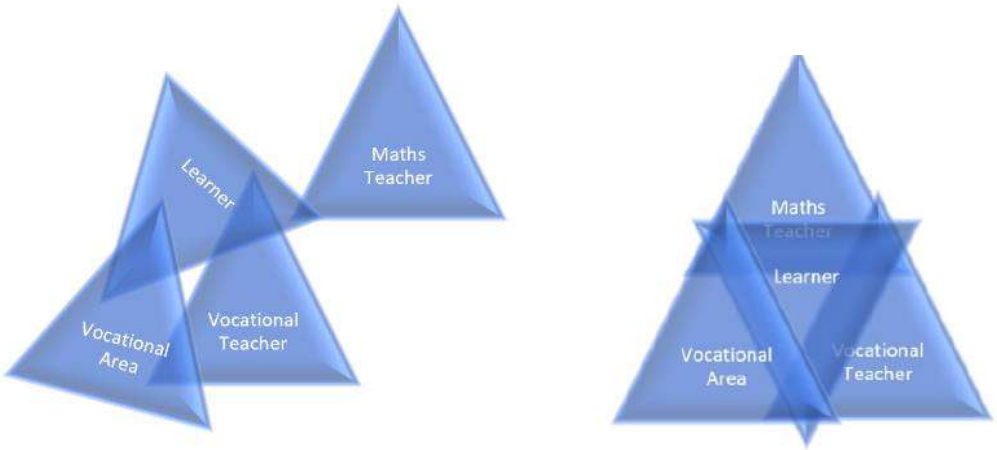
About CfEM

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.

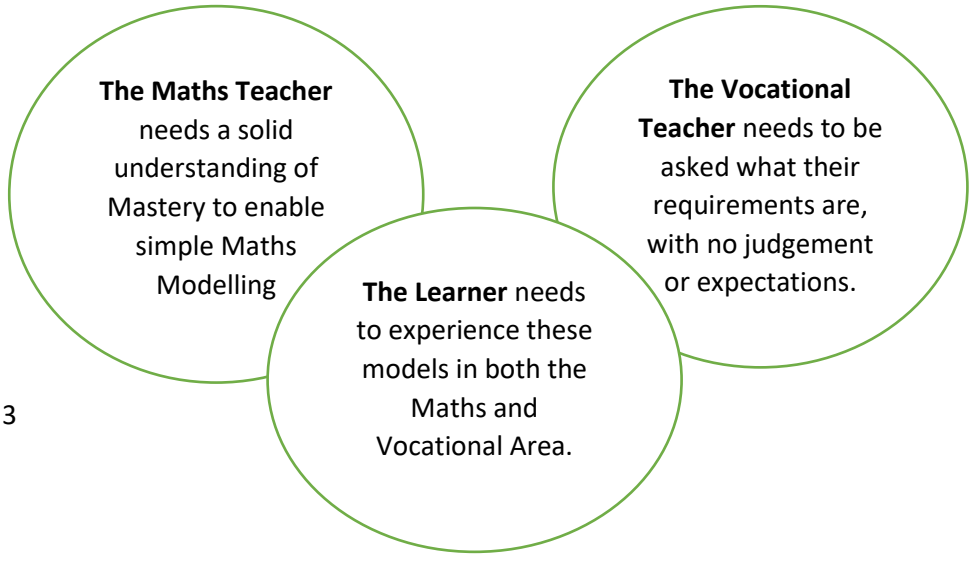
Funded by the Department for Education and delivered by the Education and Training Foundation, the programme is exploring what works for teachers and students, embedding related CPD and good practice, and building networks of maths professionals in colleges.

Summary



This is a project connecting Maths Mastery with vocational areas in further educational colleges, but it is more about how Maths teachers should connect with vocational teachers and then connect vocational teaching into the classroom for the learners. There is a complexity of ideas that we have explored in depth, but which can be represented by the diagram to the left. Here we are left feeling that the Maths teachers are hanging off the learners or trying to inject them with some Maths while they are trying to remove themselves. This research project endeavours to show how through connection and collaboration we can obtain a tight and coherent structure around the learner from each side of the supporting structure.

The connection should not only be between Maths teachers and learners, but also between Maths teachers and vocational areas. The stigma of Maths avoidance amongst teachers and learners permeates across the collegiate centres. Maths Mastery can be drawn together with co-production of the “Vocational-Maths Boards” described here by the Maths and vocational teachers and can form a perfect bond that everybody could work towards. Unpicking the research has cemented our thinking around this topic and do we dare go back? This is how this Action Research Project can be used. The Maths teacher is in the driving seat and needs to understand the various mastery models. The simple Venn diagram below shows that the Maths and vocational teacher can come together to investigate what is required. Every vocational area will be different, every vocational teacher will have different needs. Then every learner will also have their own needs.



Why is this research so important?

We had vocational teachers hiding from the Maths teachers and then feeling relieved as we developed the models together that they could use and understood. This happened on numerous occasions. Once the Vocational-Maths Boards were compiled the vocational teachers shared them with their areas.

Change needs to take place. Three of the 5 colleges involved in the Action Research had negative progression in Maths in 2019.

Employers have been asking for numeracy skills to be improved.

Research as far back as Whitehead (1929) says that learning is not through objective content of inert ideas and scraps of information but through emotions of interest, joy, and adventure.

This research aims to show the need for change, the importance of nurtured support for Maths and vocational teachers over time via continued professional development, the power of the V-M Board and transferring of the learnt skills back into the classroom.

The interventions

The project was made up of three cycles.

1. Cycle 1 starting in September around getting teachers up to speed with Mastery Methods by introducing Ratio tables in Context. Cycle 1 remained in place through-out the project.
2. Cycle 2 was developed after the Literature Review, finding ways of connecting Maths Mastery to the vocational areas. This went in place after October half term and was mostly completed by December, in time for the first data analysis workshop. Some maths teachers continued connecting to the vocational staff.
3. Cycle 3 was the bringing together of those methods back into the classroom and continuing to develop Mastery in the Classroom. This was then completed in March, in time for the data collection and analysis at the start of April.

The Methods

We used teacher and learner interviews using appreciative inquiry and learner questionnaires.

The Conclusions

Maths teachers took time to learn Mastery Approaches, they are developed over time.

The V-M Boards had an incredible impact on both the Maths teachers and vocational teachers. They supported Maths teachers' understanding of mastery techniques including the use of manipulatives in conjunction with the ratio table. They helped the vocational teachers see the simplicity of the Mastery techniques building their own knowledge to try out in the class room, with the particular attention to the structure of the maths and using their VM Board to build their confidence in using this with their own learners.

Co-production of the V-M Board was vital to allow learning on both sides to establish what is required and to avoid misconceptions on either side.

The concrete experiences of teachers and learners help support thinking with straight-line graphs and sequences. Some of the maths teachers were unaware of this link and loved the materials used. Smaller variations are required to underpin the understanding for the learners. This could be achieved via some interactive software such as Geogebra or Desmos with diagnostic questioning.

Contents

Introduction and Background

The Colleges:

The five colleges involved in the Action Research project are mostly white, with a low proportion of ethnic minorities which reflect populations. There are mostly high employment levels within the South-West, but all also have some areas of high deprivation. Weston and South Devon are dependent on seasonal tourism. The maths progression for the colleges is generally improving and from 2017 to 2019, progression data ranged between -0.21 to +0.28. Two of the other colleges taking part in this study showed significantly higher progression than the national average of +0.09. The other colleges were below the national average from -0.6 to -0.21. (If the score is positive students are on average making progress, if negative they have on average achieved lower grades from their entry point). www.compare-school-performance.service.gov.uk/compare-schools?for=16to18

The development of this Action Research Project.

This work followed on from the work we did last year (Cockerton 2021) which highlighted the problems involving proportional relationships, specifically those involving direct proportion. The main findings from last year were that there was a significant improvement of student outcomes on number and the use of the Ratio Table was acknowledged by the teachers. Having created a model we wanted to use this approach and create a model tool that maths teachers and vocational teachers can use in their classrooms whilst developing other mastery approaches, making sure all teachers have a secure understanding of the mastery approaches, so we continued to use the simple model from last year.

In this action research we continued to explore different ways of thinking about and visualising proportional relationships. Ratio tables were introduced as a tool for illustrating different methods for operating on proportional relationships and for investigating the multiplicative nature of these relationships. We then introduced the application of the ratio table to scaffold students to be able to answer questions. Once teachers were confident with this approach, we wanted to see the impact this had on the Maths teachers and vocational teachers.

The Ratio Table

Ratio Table: **Table 1** shows the Ratio table with 1 x 23 as a starting point and then making small variations to one variable (***Variation Theory***) to obtain different answers, building up to 12.2 x 23 = ?

0.02	0.2	0.1	1	2	10	12	12.2
0.46	4.6	2.3	23	46	230	276	280.6

Table 1

Context: introducing a real-life activity such as filling your car with petrol or making pancakes to hook students.

Proportional Reasoning: a multiplicative relationship between two numbers 1x 23 =23 then 10 x 23 =230

RME Realistic Maths Education was originally developed by the Freudenthal Institute in the Netherlands, and is widely used there. It is a way of working introduced by using the above – Context and Proportional Reasoning – and then presenting an open-ended question.

Maths in the Vocational Areas

Keeping in mind our original project title "to strengthen the link with vocational teachers by exploiting opportunities to use the mastery approaches", the Literature Review highlighted a current disconnect between maths teachers and vocational areas and outlined a need for this link to be built. Learners are generally only interested in their main vocational area and any other subjects that are periphery to this are perceived as irrelevant.

There are some materials that have been set up to improve this disconnect including Maths Matters at work, which aims to get learners to engage in maths within their own vocational area by using a worksheet. The need to strengthen the ties between the maths teachers and vocational areas is clear.

The Literature has also outlined the need for a substantive change of pedagogy. Central to this shift in pedagogy is allowing learners to gain agency in the application of Maths. Taking this idea further, the literature matches with the six principles of Andragogy (2020):-

1. Adults need to know why they need to learn something
2. Adults need to build on their experience
3. Adults need to feel responsible for their learning
4. Adults are ready to learn if training solves an immediate problem
5. Adults want their training to be problem focused
6. Adults learn best when motivation comes intrinsically

As the young people are becoming adults then these principles need to be applied: learners' interests; connecting learning to the learners' own experiences; readiness to see a need to problem solve and then gain methods to solve these problems with the application to their vocational subject to create the relevance and motivation to learn.

Pushing the boundaries

Having used the Realistic Mathematics Education (RME) approach in our Action Research in 2020/21, we concluded that using context with a supporting mathematical structure was a crucial part of the learner motivation and their understanding of the mathematical concepts. Our learners' intrinsic motivation increased, and the mathematical concepts made more sense. Our findings matched those of Dickinson (2020) and the action research carried out

significantly impacted the pedagogy of the Action Research teachers. The 8 teachers involved with the project committed to changing their pedagogy in the future.

However, the limitations of our own model developed in 2020/21 was the lack of other manipulatives such as a concrete experience, bar models and double number lines. Although the set of Action Research teachers involved in this project has changed, we have set out to establish the framework for RME and its usefulness in lessons and we have explored the use of the ratio table, double number line and bar modelling. We now want to develop this knowledge further whilst sharing these ideas with vocational areas.

To that end we sought to examine how we could adapt our own Maths Matters At Work Table. This should help the vocational teachers and learners recognise the maths in their vocational area, reflect on their confidence level about these areas of mathematics and make plans for developing their mathematical skills (ETF, 2014).

The actual mathematical teaching of the mathematical skills is not shown in the ETF document, although the context has been extracted by the vocational teacher for the learners. The mastery approaches could be added at this point. Not many of the research papers read for this or last year's literature review have looked at linking the mastery approaches to vocational areas, apart from those using the RME approach and that work is limited to the ratio table and teaching and learning percentages (Cockerton et al., 2021).

Our teachers, whilst gaining confidence in the various mastery approaches, were endeavouring to reach out to the vocational areas to establish what their requirements were.
We are also looking to find specific links from the GCSE Maths syllabus to the vocational schemes of learning relating to mathematical concepts. The teachers and learners can extend their knowledge by finding these links and take responsibility for their own learning.

The list of topics created by the extensive research by ETF (2014) identifying the core skills in the workplace have been placed in a table below. The next task was to speak to the vocational staff and ask them independently which areas of focus they required.
Vocational Area ……..

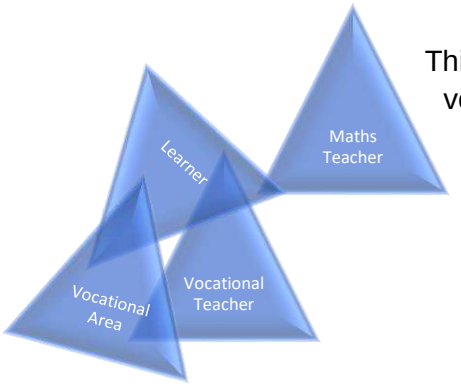
Workplace	**Mastery approach**
Mental arithmetic	Ratio table fluency
Calculate percentages	Ratio tables and bar modelling
Converting between measures	Ratio tables and double number line
Error checking estimation	
Fractions, decimals and ratios	Ratio tables double number lines and bar modelling

The Research Objectives for this project emerged from the literature and thinking summarised above:

- How do Maths teachers respond to interleaving mastery into the vocational areas?
- How can we make the Maths in the classroom connected to the learners' own experiences; readiness to learn and apply this to more topics.

The Vocational - Maths – Learner Model

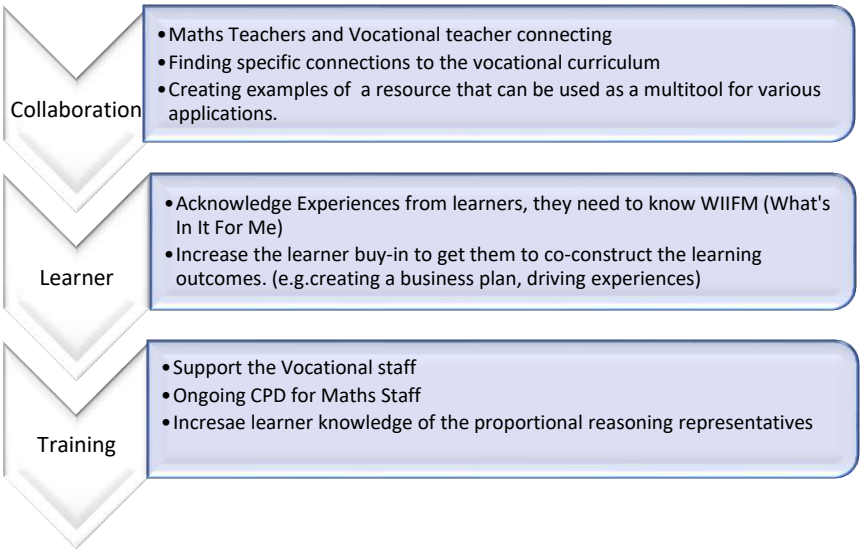
This literature review sets out to establish what the current picture in the FE Sector looks like, what it could look like and how this might be achieved. From the outcome of the literature review it was possible to summarise the literature and establish a model.



This diagram shows what the current scene of Maths, in the vocational areas. The connections between the functions are fragmented with each areas working independently with no real or relevant connection aside having to go to a Maths lesson or timetable a Maths Lesson.

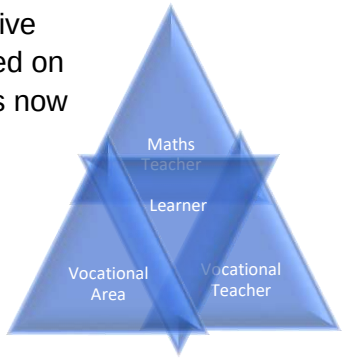
The literature suggests ways in which the Maths and the vocational areas can work together developing connection and collaboration. The outcome of this gives a structure that is tight with support that is coherent around the learner from each side of the supporting structure.

This can be achieved by collaboration with the English and Maths teachers, building Learner buy-in, and supporting Maths and Vocational teachers with CPD. Below is a summary of how to achieve this.



The Maths – Learner – Vocational Model (Cockerton 2021)

This Model describes what is required to be able to achieve a cohesive approach: collaboration, training, and the learner. It is our view, based on experience, that everyone needs to buy into this approach and it has now been widely streamed as the Whole College Approach as a part of CfEM.



Actions taken:

This is how we achieved the success of the Vocational-Maths Board

Step 1: Speak to the vocational area or teacher to find out what they need regarding Maths content.

Step 2: Take a Large White Board with attached magnets from Wilco, permanent markers, double sided tape, card, and scissors

Step 3: Adapt their Maths request to a simple mathematical model that can be used repeatedly.

So how did we reach this list of Actions?

The literature review explains how we came to the actions above.

Literature Review

What is the Current provision and policy?

Currently the provision of the teaching of Maths is very much separated from vocational areas in the more academic GCSE exam classes. There is currently a disconnect between Maths teachers and vocational areas. Learners find it difficult to connect the topics between GCSEs and their vocational areas. Dalby et al. (2015) advised that learners needed to be prepared for learning maths in a way that is meaningful for their future lives.

The work ethics in the vocational spaces are high, observed Dalby & Noyes (2015); vocational tutors gave learners a high degree of student autonomy, whereas the Maths provision was very different. However, when they observed mathematics lessons in the same FE colleges, these were teacher-controlled and tightly structured, resembling a school mathematics classroom where students did not make their own decisions about the learning process or take responsibility for their own progress. They concluded that getting learners prepared for the workplace with coherent, meaningful experiences in maths seemed less important to colleges than the minimum academic standard desired by the policy makers. According to Dalby and Noyes, as students transition from school to work, the vocational training phase is characterised by changing values and shifting perspectives from the students, which suggests that all FE classrooms should reflect the values of the surrounding environment that are important to students.

Hyland (1999) found that increasing academic rigour of vocational qualifications, or bringing vocational education into schools, have historically had limited success. Maclure (1991) and Young (1998) said there was a need for an overarching, coherent policy change of educational traditions which have continued to have little success. Robson (2006) noticed the academic strand in FE is in contrast to the practical usefulness valued by vocational areas and argues that there is a need to reflect the vocational context but noted this could cause an uneasy relationship to be taught as part of a vocational programme. Colley, James, Diment & Tedder (2003) suggest that students focus on their vocational area and that the subjects with no clear vocational purpose are peripheral.

Realistic Context and Relevance

Effective Practices in Post-16 Vocational Maths (ETF, 2014) Final Report gives the most recent and substantial research-based findings and recommendations. These include creating a more realistic work context for maths learning, achieved by the learner's construction of own tasks around work scenarios, working together to solve real life problems, using real units of measurement and concrete ideas. This also matches up with the Maths Matters at Work task.

Maths Matters At Work

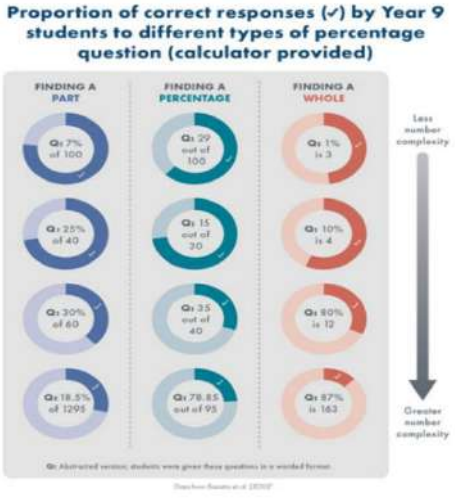
The Vocational Task	What maths was being used?	How confident I feel about doing the maths involved			
		not at all confident, need help	fairly confident but need more practice	confident on the practical side but not confident about the paperwork	very confident, can already do this to the right standard
MEASURING UP FOR FITTING A NEW WINDOW	MEASURING IN MILLIMETRES AND RECORDING THE MEASUREMENTS ON A DRAWING		I'M OK WITH MM BUT GET CONFUSED IF I HAVE TO USE DECIMALS		
Recording somenody's temperature	Reading a temperature scale and recording the reading on a chart			Can read the temperature but am not sure how to put that on the chart.	
Cutting hair correctly	understanding of angles and lengths. Changing the angle for different bits of the cut.	I get confused when a client asks me to "take an inch off". I don't understand inches.			

Relevance

Andragogy is the theory and practice of teaching adult learners. Teaching and Learning percentages (2021), the six principals of Andragogy (2020) and RME approaches (2019), all say that contexts should not be contrived, which has also been recommended by Dalby and Noyes (2015) and ETF (2014).

Smith's (2020) podcast also outlined a need for equipping learners to their own self-worth. His research explained how to equip students with the skills they will need in the workplace not just to gain a GCSE grade. The students got their buy-in and found the tasks relevant and helpful.

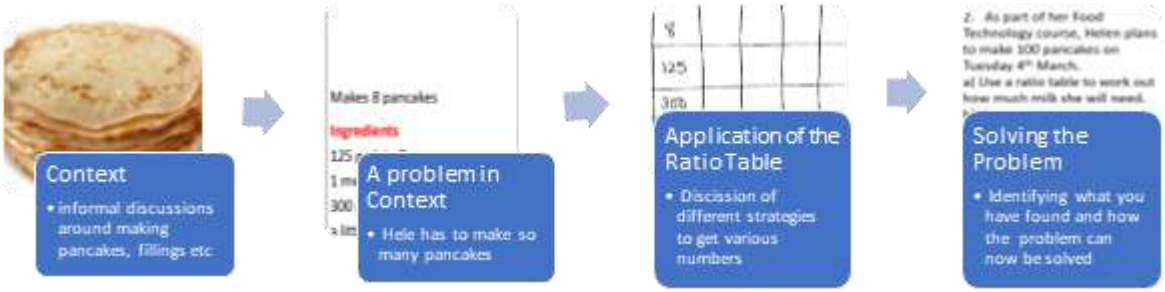
Table showing Teaching and Learning Percentages



Mastery approaches, Realistic Mathematics Education (RME) and representations

The RME Approach was developed in Holland and Manchester Met have done a series of studies on the approach (2019). RME creates a context, creating discussion, (everyone can talk about their favourite pancakes) then an open-ended question is added, such as: here are some ingredients, what else can you find out? This supports any learner to explore the numbers. Then questions can be posed having explored the numbers.

Table showing the application of RME by Cockerton (2021)



The Action Research Group at Weston College (Cockerton 2021) created their own resources using RME (2019) based on the above model, that featured context-filled discussions (at the expense of moving on) and then moving to the applied mathematical content by using informal methods to gain meaning-making and to ensure learners did not lose engagement; in addition the ETF (2014) also recommend the RME Approach. The knock-on effect in using real life scenarios is that it could be relevant to the vocational area and in the learners everyday life which is recommended by ETF (2014), the six principals of Andragogy, and Dalby and Noyles (2015).

List of Key Topics Identified as Core Skills

The ETF (2014) has created a list of topics that are identified by the CBI as core skills in the workplace. These include mental arithmetic without a calculator, to interpret quantitative data, calculate and interpret percentages, work with fractions, decimals and percentages, estimating to check for errors, odds and probabilities. Teaching and Learning percentages (2021) offers researched skills in these areas required by the workforce that match RME and the Mastery approach giving learners opportunities to move flexibly between representations such as the bar, ratio table, double number line, and their own representations of percentage.

Embedding Maths into Vocational courses

Embedding maths into vocational courses may reduce learner drop-out rates. One study, by Casey et al. (2006), suggests that learners were less likely to drop out of courses when maths teaching was embedded into vocational learning at level 2. For the sample chosen, there were up to 20% higher achievement rates when comparing fully embedded approaches with those that were not embedded.

Stone (2005) corroborates the findings from ETF (2014) and Dalby and Noyes (2015) that partnerships between the teachers of vocational subjects and of maths benefited both

parties and led to mutual respect and professional learning. This matches with a small case study by Abingdon and Whitney College (2010) which found that teachers were initially reluctant and found it difficult to relate mixed vocational classes to their vocational areas but when they did they found it led to increased retention. ETF (2014) go on to say that incentives could be given for collaborative working between maths teachers and vocational teachers.

Conclusion

The literature is conclusive. It lets us know that the research says:

1. Key topics of core skills are crucial for the workplace
2. Once learners experience this then they can see the relevance
3. Maths teachers need to find the relevance in particular vocational areas
4. RME approach will support this using mastery and manipulatives from the concrete examples.

Next Steps

1. Connect to vocational teachers with a Vocational Maths Board to identify core skills required by Learners
2. Create a Vocational Maths Board, made up of manipulatives, enabling the vocational teachers to show the structure of the proportional reasoning with the learners related to their vocational area
3. The Maths teachers will continue to work with the learners to create experiences in the classroom that are concrete to support relevance for learners and to help learners to relate to graphs based on Boaler (2021), Making Sense of a Data-Filled World.

Methods

The Students and Teachers:

Table 4 shows the number of students in the Action Research project, their levels at outset and their teachers.

Colleges	GCSE grade U-2	GCSE grade 3	FS level 1
Weston College	**1**	**21**	
Gloucester College	**3**	**5**	
Heart of Worcester			
Yeovil College			
Totals			

emailed teachers for their data

Table 4

The Cycles:

We conducted 3 cycles of collaborative planning, teaching, gathering evidence and reflection, based on our research. We practised and made sure we had mastered the techniques before teaching the lessons to our classes. It was vital that we were all confident so we could address any misconceptions or problems which may have arisen. During face-to-face lessons we took photos of students' work and the Action Research Lead observed some lessons being taught. After delivering the lesson we reflected on the lesson informally in the shared workroom and formally in writing and discussion. As part of this process, we discussed how the lesson could be improved for next teaching.

Appendix A shows the lessons developed over Cycles 1 and 3.

- Cycle 1 Teachers mastering Mastery Approaches. We used the Ratio Tables using the RME approach.
- Cycle 2 Connecting with vocational areas. We asked teachers what they needed to teach an essential area of Maths in their Area.
- Cycle 3 Further developing Mastery Techniques in the Classroom. Using Concrete representations whilst teaching graphs.

Collecting Evidence:

As well as collecting examples of student work in the lesson, we conducted interviews with the students to establish what they thought of the approaches using appreciative enquiry. We also used the same technique to gather evidence from the teachers (see Appendix B). Throughout the process we used the thinking environment as a collaborative meeting process. Care was taken so that all teachers could speak freely and share their experiences.

We recorded the interviews with the teaches and learners which have been coded (see Appendix C).

Informed Consent Form sent to all students can be found in Appendix D.

Data Collection templates can be found in Appendix B.

Adverse circumstances:

Covid: Teachers from some colleges were stretched and were unable to meet up at various occasions. Learners often missed their lessons due to isolation or symptoms of Covid. The Cohort was extremely weak, with Grade 3 learners struggling as if a Grade 2 learner.

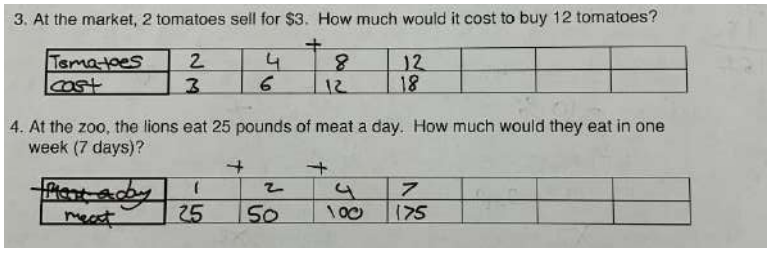
Other: 2 teachers left the Action Research group due to personal circumstances.

Results

Cycle 1 Understanding Mastery

The purpose of Cycle 1 was to get teachers to experience some mastery. Some teachers had experienced the Ratio Table within RME Approach. Appendix Cycle 1 Last Year's Action Research, however we wanted to get all of the teachers up to speed with this technique if we were going to take mastery into the vocational areas.

Teachers and learners completed *Activity 9 Appendix A* so we could all experience the ratio table.



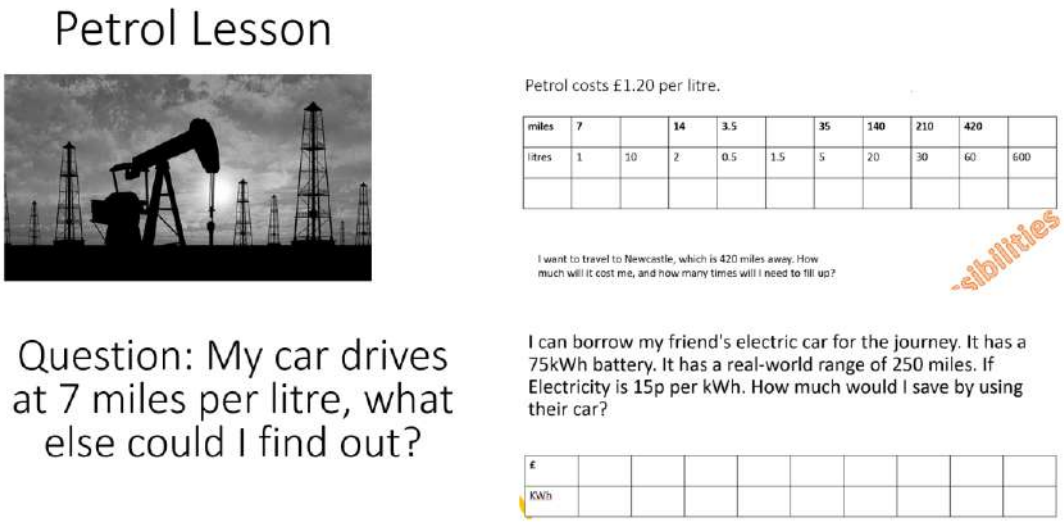
3. At the market, 2 tomatoes sell for $3. How much would it cost to buy 12 tomatoes?

Tomatoes	2	4	8	12			
cost	3	6	12	18			

4. At the zoo, the lions eat 25 pounds of meat a day. How much would they eat in one week (7 days)?

~~Meat a day~~	1	2	4	7			
meat	25	50	100	175			

Teachers delivered the Petrol lesson Appendix A which was developed from the Action research last year [13.-Weston-College-Using-Contextualisation-and-the-Ratio-Table.pdf (et-foundation.co.uk)]



Petrol Lesson

Petrol costs £1.20 per litre.

miles	7		14	3.5		35	140	210	420	
litres	1	10	2	0.5	1.5	5	20	30	60	600

I want to travel to Newcastle, which is 420 miles away. How much will it cost me, and how many times will I need to fill up?

-sibilities

Question: My car drives at 7 miles per litre, what else could I find out?

I can borrow my friend's electric car for the journey. It has a 75kWh battery. It has a real-world range of 250 miles. If Electricity is 15p per kWh. How much would I save by using their car?

£									
KWh									

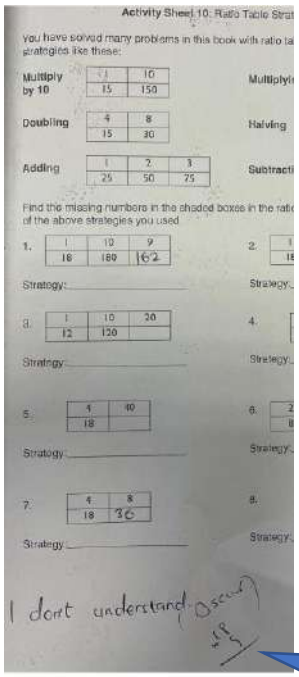
Teachers' Initial responses (November) from interview Appendix B

What the teachers said in November	Out of 6 Teachers
Limited by Time	4
Limited by having to teach the learners new methods	6
Teachers found their own ways to make it work	6
Teachers lack confidence in using the mastery approaches	5
Learner Engagement improved	3
Learner understanding improved	3

- Most of the teachers found learning the new methods challenging but found their own ways to overcome this.
- All 5 teachers who had not used ratio tables in the past will be using them more in the future.
- Most teachers had a low level of understanding of mastery approaches at the start of the project.
- Three of the teachers said they felt their learner's engagement improved in lessons
- Three the teachers said they felt their learners had a better understanding of proportional reasoning

Learner Responses

Example of Learner Work with Teachers and Learners Responses



"Why can't all lessons be like this?"

"Using closed questions meant that learners of higher ability just answered the questions and did not want to explore ways of finding it. "

"Can I have some homework on this?"

"I am going to use it for starters for every lesson next year"

This learner could use ratio table to find 18 x 9 but he said he preferred his own method, however he was unable to work it out his way.

Cycle 2 Introducing the Vocational Maths Board to support the Vocational Teachers understanding Mastery.

Intervention:

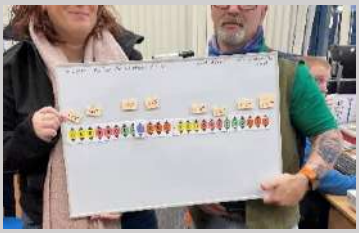
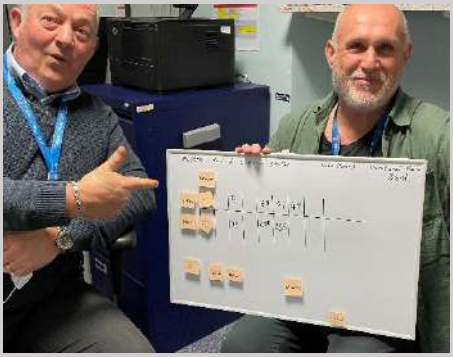
Having completed the Literature Review and having had enough practise with the ratio tables, AR Maths teachers were now more confident in some mastery approaches. We were able to introduce the Vocational Maths Board to the vocational areas.

- AR teachers spoke to the vocational areas to identify a particular topic the learners in that area struggle with.
- AR teachers made up a board using the movable magnets
- AR teachers presented the board to the vocational teachers to show how it can be used and adapted.

The creation of the board took approximately 45 minutes.

Results

Cycle 2 The V-M Board

Vocational Area	Boards	Voc Teacher Responses	AR Teacher Responses
Electrical		The board helped me show them how to work standard form to the level 1 learners and they all passed their assessment on standard form.	It was interesting to create this and I have now developed more resources on size matters looking at place value in the Maths Classroom and how it works.
Hair and Beauty		The vocational teachers were very happy and felt more confident about showing how to do % discounts. One teacher said she would now be able to do 15% discount.	One of the teachers was hiding from us due to her fear of Maths. After the meeting she said she could do it.
Plumbing		The vocational teachers said the students found the runoff calculation difficult to show students. The teachers were really pleased with the way the VM Board helped.	When I went back into the vocational area I could see the VM board being used.
Music		In music students need to learn know how the decibels in a certain type of venue affected the number of people allowed. I feel overwhelmed over how helpful this has been. All the other teachers are using it now.	I was surprised to find something that needed these Maths skills.

- 4 out of 5 AR teachers who introduced the VM Board said that it had a positive impact on the vocational teachers and their learners.
- 4 vocational areas welcomed the VM Board and said they would use it
- In the fifth case we came to understand the importance of co-production in addressing the maths anxiety of the vocational teachers. Vocational teachers were hiding from us and found it difficult to articulate their needs.

Cycle 3: Continuing using Mastery in the Classroom based on Vocational Teacher requests and further Literature Review. Understanding Graphs.

Mini Literature Review:

Some of the Level 3 vocational teachers highlighted that a large proportion of learners could not understand graphs. Appendix E Data shows this, collected by one of the AR teachers. Teaching the Straight-Line Graph was also featuring in most teachers' Schemes of Learning. We wanted to give the learners a concrete experience of the Mathematical concepts associated with graphs by using the Human Number line before hand-plotting any straight lines, then using a CAME Resource (Cognitive Acceleration Mathematical Enhancement Program) Adhami, Johnson., Shayer, 1998). This resource connected the topics to develop thinking. Also Boaler (2021) Making Sense of a Data-Filled World described how young people had to be numerate in a data driven society. Jerome Bruner's model recommended moving from concrete experiences to pictorial to symbolic to algebraic and Adhami (1998) connecting the topics to develop learners thinking. Whitehead (1929) said it was fruitless to teach without engaging learners in concepts through experiences.

How can we make the Maths in the classroom connected to the learners' own experiences; readiness to learn, and apply this to more topics?

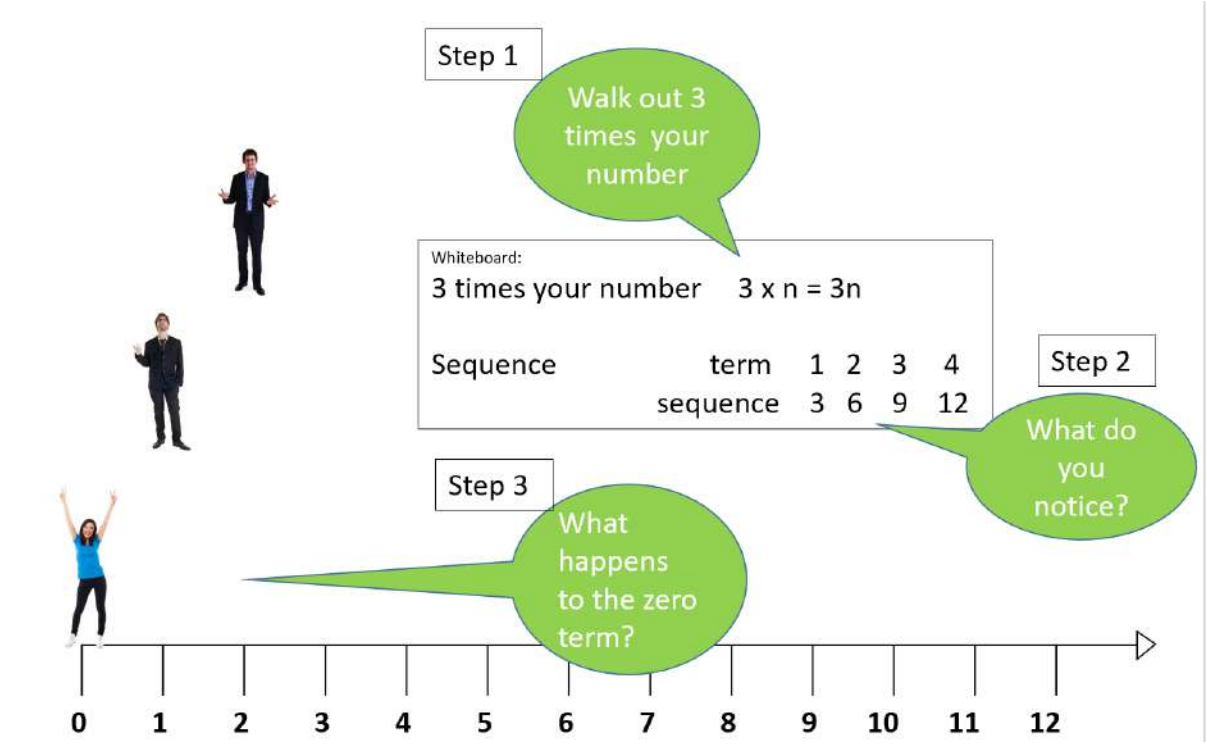
Intervention Cycle 3 Appendix A: Using a Human Number line to help learners understanding of straight-line graphs, whilst grouping together the topics from the CAME resource.

A descriptive lesson was shared with all AR teachers. The AR Lead demonstrated the lesson together with the Action Research teachers.

- Students stood on a number line given each a number 0-5 in order (depending on number of students. Facing the teacher Right to Left
- Teacher directed the student to take that number of steps depending on the instruction.
    - 2 times your number
    - 3 times your number
    - 2 times your number add 1 etc
- After each instruction the teacher would write on their own white board that instruction 3 x n
- The teacher would ask each student to say their new number. The teacher would write down the numbers underneath their number creating a sequence on a whiteboard that the students had called out.
- The teacher would ask what the students had noticed.
- The teacher would pay particular attention to the person who was zero. Asking them to describe their movements.
- The students and teachers tried this several times.
- Students asked what would happen if you multiplied by negative 1. This showed that the learners were inquisitive and engaged about their understanding of the topic and they were able to predict what would happen to the learners position when asking that question.

Here is the visual sent to all the teachers as a reminder of what to do.

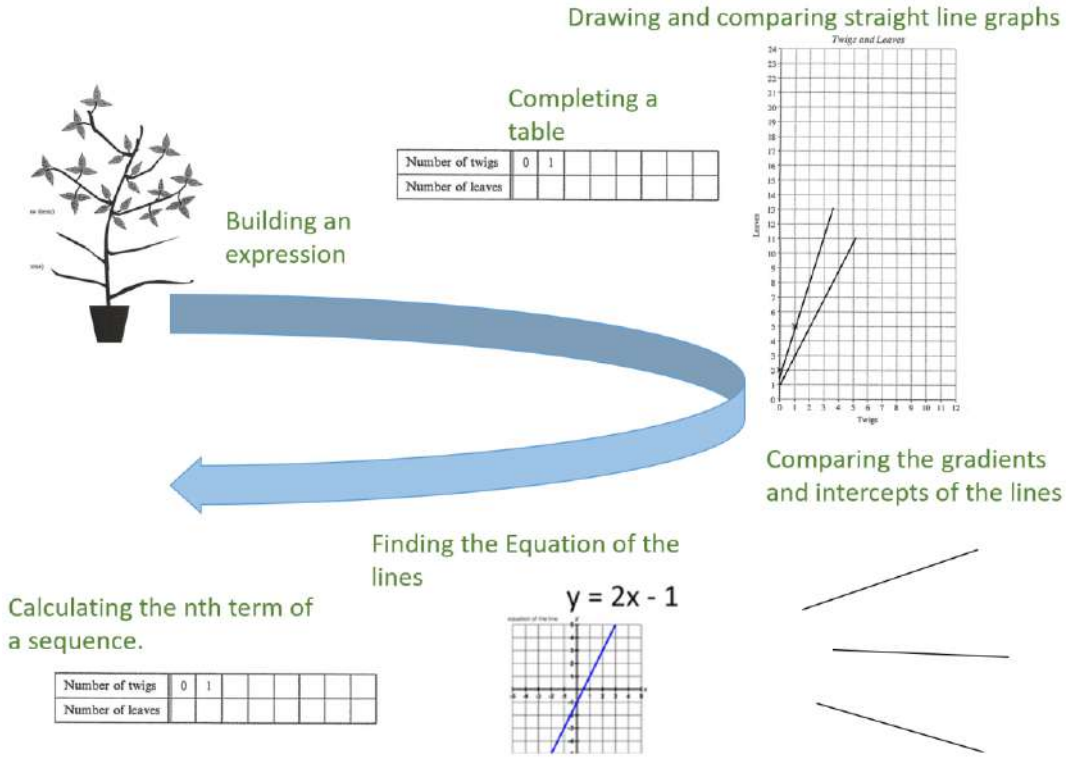
Students have to start by standing on an imaginary x-axis. The teacher gives them each a consecutive number starting at zero.



The Photo shows the learners stepping out from the wall.

Step 2: Introduction of the Two stage relations resource from CAME Appendix A Interventions

Below the diagram shows the journey that the learners take whilst working through the worksheets. By the end of the lesson learners are able to see the connections between these topics. This is shared with learners at the beginning and end of the lesson so they can recognise the connections made. The resource takes learners on a journey to understanding the pathway: pattern - writing an expression - finding an equation- making a table of values – drawing a straight-line graph and comparing differences and similarities, which we have extended to sequences – and to finding the nth term.



The table shows the Journey that the students will take whilst understanding sequences and graphs.

This was then followed up with other rich resources in Appendix A Interventions Cycle 3

Completed Results from Cycles 1, 2 and 3 based on the final interviews
Appendix C Raw Data: March 2022

From Learner feedback forms we found that: The data collected from the forms were muddled between learners who had completed the intervention with those who had not. We decided to ignore this data. A better process would be to use a couple of diagnostic questions to assess learners starting points and misconceptions and not make these anonymous so we could compare the data.

The table below summarises the final teacher and learner interviews

Teachers / Interventions	Improved Teacher and Student Understanding	Improved Engagement	Improved Teacher and Learner Motivation	Needs further refinement	Teacher resistance on asking the Vocational areas	Impact (all teachers who asked VOC areas had very positive responses)
5 teachers / RME and Ratio Tables	4	4	4			
5 teachers / VM Boards					3	4
4 teachers / Human Number Line and Graphs	3	4	4	3		

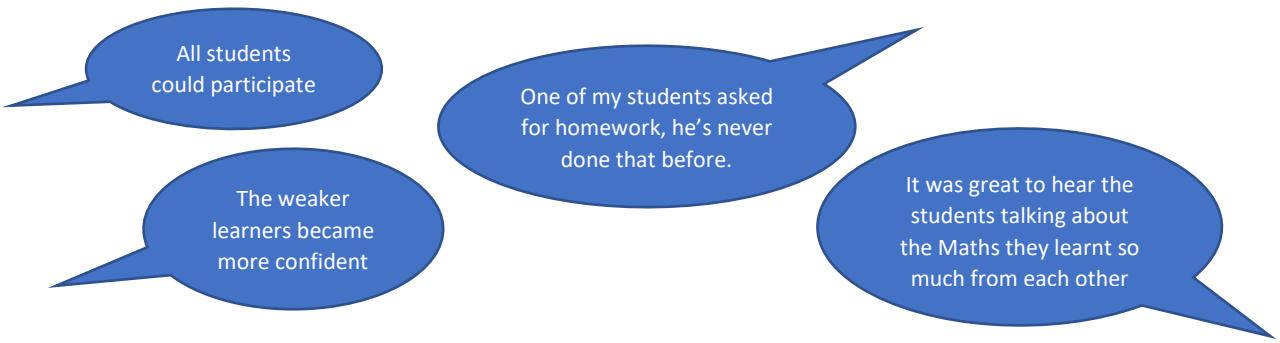
The table shows a summary of the teachers experiences of using the interventions throughout their teaching year. Teacher interviews Appendix D

From Teacher Interviews we found that:

The Ratio Table:

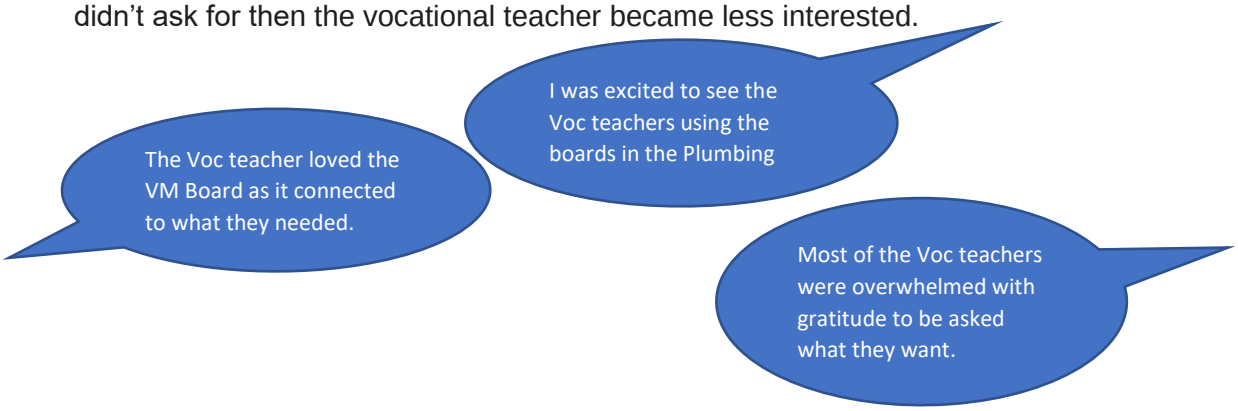
Most teachers said it improved understanding

- Most teachers said it improved engagement of learners
- Most teachers found both teachers and learners took more interest in the Maths, increasing motivation in teaching and learning.



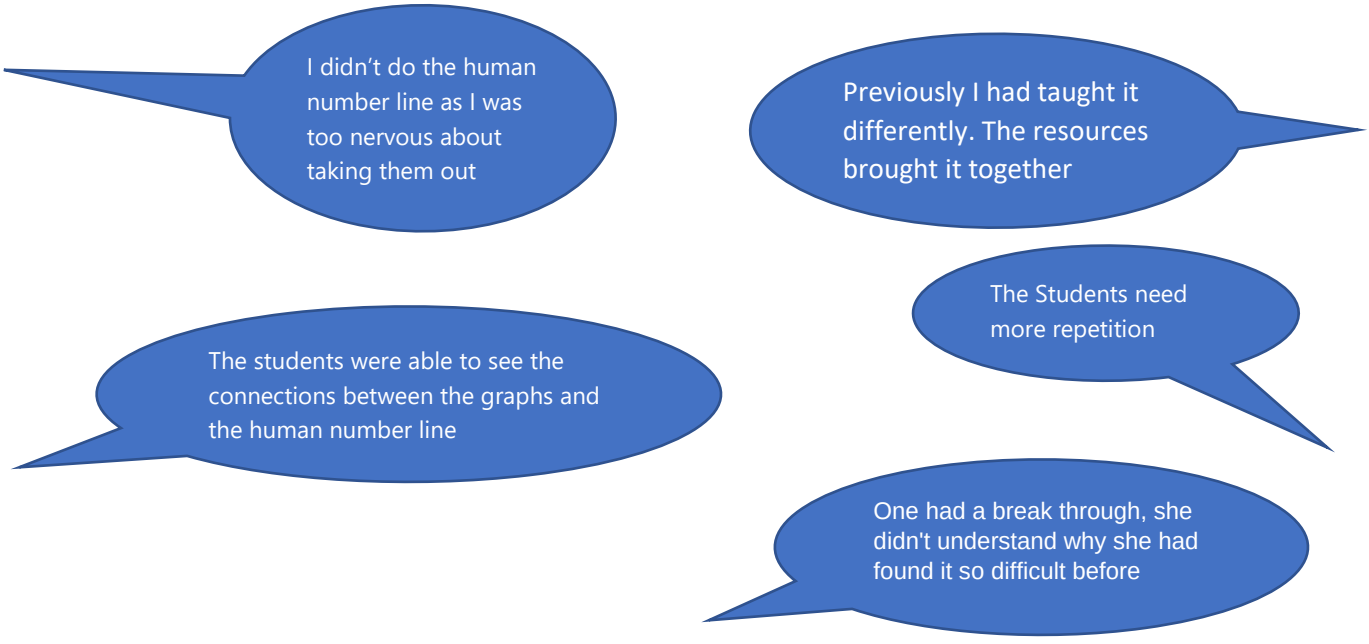
The Vocational Maths Boards:

- Mostly a positive impact on the Maths teachers and the vocational teachers who presented their Maths Boards.
- Some Maths teachers were initially apprehensive to connect to the vocational teachers.
- Some teachers found that if vocational teachers were presented with something they didn't ask for then the vocational teacher became less interested.



The human number line:

- Only 3 out of 4 teachers did this intervention.
- All 3 teachers found that the learners were more engaged than usual in the lesson and they said that learners found it memorable.
- All 4 teachers found that they would use the activities again
- 3 out of 4 of the teachers were not initially confident in taking the learners outside.
- There was a better understating of connections between sequences and graphs.



Discussion:

The 3 Cycles were distinct and overlapping and produced rich overlapping data.

The final results based on the final interviews given by the teachers give a mostly positive review of the resources used and show an improved understanding and knowledge of the ratio table as the project ran on throughout the different cycles for both teachers and learners. Teachers had to be brave to ask vocational teachers that they may have not met before about what could help them in the vocational areas. The co-production of these resources was essential to engage the vocational teachers. Maths teachers initially needed time to assimilate the resources and once they did, they used them with rigour and this informed their own pedagogy.

The human number line was a concrete experience for learners who were able to relate back the outdoor activity with ease. The resources used afterwards would need to be utilised more carefully. Some teachers found that the learners preferred the standard method of teaching straight-line graphs and didn't used the human number line at all.

Conclusions and Recommendations

Conclusions

1. The Ratio Tables were an essential part of the project and can be utilised in all areas in the FE Setting.
2. Teachers were surprised about the use of the ratio table and the human number-line and the impact of using relevant context in lessons and in the vocational areas.
3. It takes teachers time to embed new teaching methods and learners also need time to understand them and how they can be used.
4. Learners are more engaged in lessons and more motivated to learn with lessons that have context that is relevant to them with purposeful work set according to the context.
5. The ideas developed in the vocational areas can be further developed in the maths classroom.
6. Learner “experiences” help provide the learners with something concrete to then inform their future work.
7. Students found lessons more relevant and engaging when the ratio table was introduced with relevant context or the learners were gaining a concrete experience.
8. Teachers saw an uplift in student proportional reasoning especially students with lower attained grades.
9. Teachers found that the students quickly forget newly learnt methods, so persistency in delivery is required to embed the methods.
10. It is important to take Maths avoidance seriously with the vocational staff.

Recommendations

1. Use relevant context that the learner can relate to and then continue to work through. For example How much could I be earning? How much does petrol cost? This could depend on their vocational areas but not necessarily.
2. Continued high quality CPD can upskill staff on how to use ratio tables, the use of manipulatives and RME approaches to allow a meaningful connection with vocational areas. Sue Hough’s webinar CfEM teach meet – Contextualisation CPD session (on24.com) was a good starting point and creating spaces to enable teachers to reflect with other teachers.
3. Co-production of the VM boards can increase confidence in both Maths teacher and vocational teacher in Mastery Approaches.
4. The Vocational Maths Board was perceived as a perfect gift for the vocational teachers to support the teaching of Maths in the vocational areas.
5. Use the V-M Boards in the Classroom as well as the vocational Area
6. Develop a SOW to incorporate our research findings across the academic year in conjunction with the vocation teachers.

7. Create starting activities allowing learners to experience something new,
   hook students - model the ratio table - let students articulate their work - ask problem solving questions. - develop the abstract.
8. Further develop a positive maths cross college culture, “It’s Everyone’s Business”.

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Appendices

Appendix A Interventions

- Intervention Cycle 1
- Appendix Intervention Cycle 3

Appendix B Processes

- Teacher interview December 2021
- Learner Form
- Teacher interview March 2021

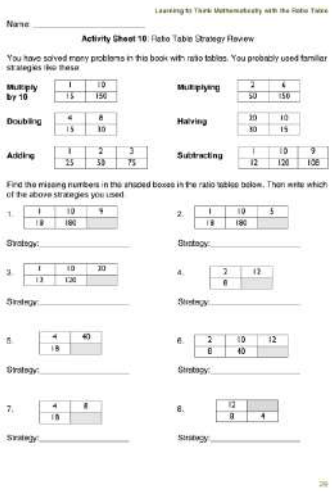
Appendix C Raw data

- From Teacher interview December 2021
- Learner Form raw data
- From Teacher interview March 2021
- From Learner Forms

Appendix D Informed Consent

Appendix A intervention Cycle 1

Learning and Using the Ratio table and the Petrol Lesson



Learning to Think Mathematically with the Ratio Table

Name: _____

Activity Sheet 10: Ratio Table Strategy Review

You have solved many problems in this book with ratio tables. You probably used familiar strategies like these:

Multiply by 10

1	10
15	150

Multiplying

2	4
50	150

Doubling

4	8
15	30

Halving

30	10
30	15

Adding

1	2	3
25	50	75

Subtracting

1	10	9
12	120	108

Find the missing numbers in the shaded boxes in the ratio tables below. Then write which of the above strategies you used.

1.

1	10	9
18	180	

Strategy: _____

2.

1	10	5
18	180	

Strategy: _____

3.

1	10	30
13	130	

Strategy: _____

4.

2	12
8	

Strategy: _____

5.

4	40
18	

Strategy: _____

6.

2	10	12
8	40	

Strategy: _____

7.

4	8
16	

Strategy: _____

8.

12	
8	4

Strategy: _____

4. At the zoo, the lions eat 25 pounds of meat a day. How much would they eat in one week (7 days)?

5. At the same zoo, 50 visitors are allowed into the monkey exhibit each hour. How many visitors can see the monkeys in a day? The zoo is open for 8 hours each day.

6. It costs $12 per student to get into the zoo. How much would it cost for a group of 21 students to visit the zoo?

7. Every 4 hours, the doctor sees 8 patients. How many patients does the doctor see after 11 hours?

Hours									
Patients Seen									

28

Petrol

Discussion

- Does anyone here drive? Do you have a car, a motorbike, or a scooter?
- How much does Petrol cost?
- How far can you travel with one litre of petrol?
- Are there alternative to using petrol for your car or bike? What are they?

Question: My car drives at 7 miles per litre, what else could I find out?

Question: If my car drives at 7 miles per litre, what else could I find out?

miles	7								
litres	1	10							

Question: If my drives at 7 miles per litre, what else could I find out?

miles	7		14	3.5		35	140	210	420	
litres	1	10	2	0.5	1.5	5	20	30	60	600

My car has a capacity to take 60 litres of petrol.

Possibilities

- I can borrow my friend's electric car for the journey. It has a 75kWh battery. It has a real-world range of 250 miles. If Electricity is 15p per kWh. How much would I save by using their car?

£									
kWh									

Petrol costs £1.20 per litre.

miles	7		14	3.5		35	140	210	420	
litres	1	10	2	0.5	1.5	5	20	30	60	600

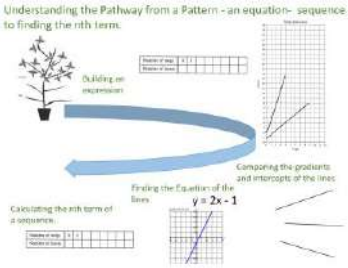
I want to travel to Newcastle, which is 420 miles away. How much will it cost me, and how many times will I need to fill up?

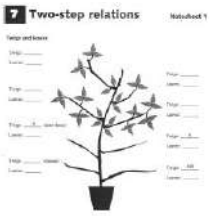
Possibilities

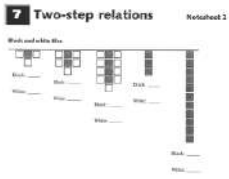
Appendix A intervention Cycle 3

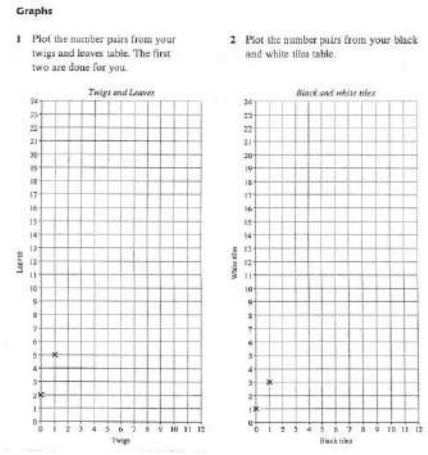
Using the human number line to support graph questions.

Connection straight line graph with patterns, nth term gradients and the intercept





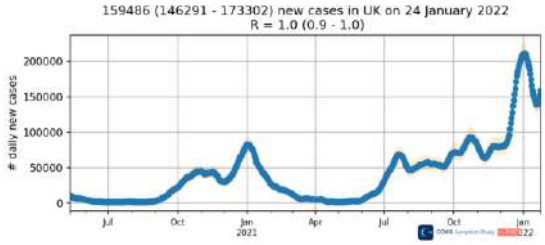


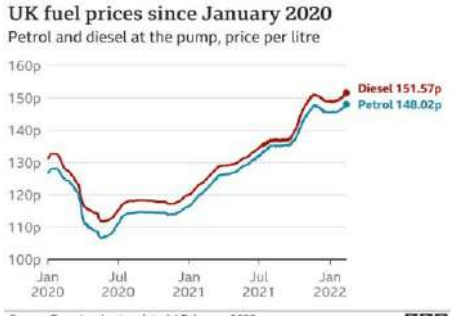


Matching graphs with gradient nth term

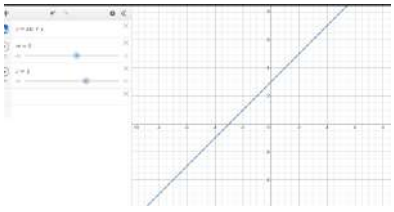
Graph	Coordinates	Intercept = c	Gradient = m	Y=mx + c	Sequence for $n=1, n=2, n=3, n=4$	Nth term
	x: -1, 0, 1, 2 y:	Intercept =	Gradient =		2, 4, 6, 8	
	x: 0, 1, 2, 3 y:	Intercept =	Gradient =		1, 3, 5, 7	
	x: 0, 1, 2, 3 y:	Intercept =	Gradient =		-2, -4, -6, -8	
	x: -1, 0, 1, 2 y:	Intercept =	Gradient =		4, 8, 12, 16	
	x: 0, 1, 2, 3 y:	Intercept =	Gradient =		-1, 1, 3, 5	
	x: -1, 0, 1, 2 y:	Intercept =	Gradient =		-2, -1, 0, 1	

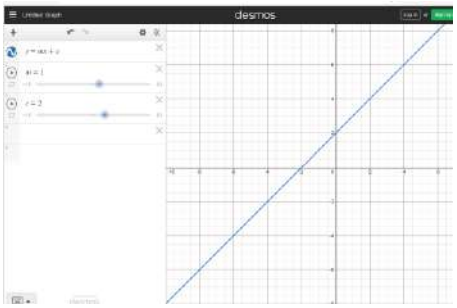
Using graphs from the news or other areas to extract information.





Using interactive software in the classroom





Pricing up a job

Motor Vehicle	Pricing a job: To buy and fit a tyre Cost of the tyre = Time taken to fit = Your hourly rate = Total Price =
	Pricing a job: To buy and fit new brake pads Cost of the pads = Time taken to fit = Your hourly rate = Total Price =
Carpentry	Pricing a job: To buy and fit a door Cost of the Door = Time taken to fit = Your hourly rate = Total Price =
	Pricing a job: To buy and fit 3 metres of skirting Cost of the skirting = Time taken to fit = Your hourly rate = Total Price =

Plastering	Pricing a job: To buy 24kg of lime plaster and cover 3 metres square of wall Cost of the plaster = Time taken to skim the wall = Your hourly rate = Total Price =
	Pricing a job: To buy 24kg of basic plaster and cover 5 meters square of wall Cost of the plaster = Time taken to skim the wall = Your hourly rate = Total Price =
Bricklaying	Pricing a job To buy and fit a front step Cost of the slab = Time taken to fit = Your hourly rate = Total Price =
	Pricing a job To buy and build a 1 metre square wall Cost of the bricks = Time taken to fit = Your hourly rate = Total Price =

Appendix B Processes

Teacher interview December 2021

Name:	Vocational Area:
1. Which interventions did you use with respect to mastery approaches?	
2. What happened when introducing the intervention that you chose?	
3. What have been the most interesting discoveries you have made while working on the project?	
4. What have been the best moments?	
5. What has been the most difficult moments?	
6. How would you use what you have learnt in the future?	
7. What would you do differently?	
8. How dd learners responded to the new methods?	
9. What did students say or do differently?	
10. How Confident do you feel about using the methods?	
11. How have you felt about teaching some of the mastery approaches?	
12. What were the reactions of the Vocational Staff to the VM Board? What did they say? what did they do?	
13. What would you like to do next?	

14. **What else do you think or feel?**

Teacher interview March 22

Teacher notes Interview a Colleague

- Please record the interview in the AR Team General which will auto transcribe the interview. This would have the most impact when presenting our findings. Jot down memorable episodes to help collection of data.
- Time taken could be 20 minutes
- Have on display the interventions to remind colleagues. Attached
    - AR1: Ratio table, Barvember, centicubes, ratio with bar modelling (AO3 Questions?)
    - AR2: Ratio Table, Petrol lesson Human Number Line, Twigs and Leaves, matching activity. (Separate questionnaire needed for the Voc Teachers with the V-M board)

Evaluation

Read to Colleagues: Please be as honest as you can and remember there are no right or wrong answers. All responses are really valuable to help me to understand your experiences. The recording will only be shared with permission from you. Anything said will be anonymised.

1. *Think about how we have taught Maths this year. Try to remember a time in classes when you were most positive about your teaching.*
   In your own words, tell me about that time.

Follow up Questioning on the responses.
What happened in the lead up to this moment?
What were you feeling?
What were others doing that helped?
What were you doing that helped?
What was happening at/during the moment?
What made it a positive experience?

2. *Are there any other positive examples you would like to tell me about?*

3. *Have you shared any of these interventions with other colleagues.*

Prompt Questioning on the responses.
What happened in the lead up to this moment?
What were you feeling?
What were others doing that helped?
What were you doing that helped?
What was happening at/during the moment?
What made it a positive experience?

4. *Are there any other positive examples you would like to tell me about?*

5. *Thinking about your teaching in the future. Which ideas from the interventions this year do you think might be useful to you?*

6. *Is there anything you would wish to have been different?*

7. *Is there anything that anyone could do that might help you develop your ideas in maths that could help you this year?*

8. *Is there Is there anything else you would like me to feed back?*

Ending the interview

- *Thank you for taking part.*
- *May I share the notes and recordings with our colleagues in the research program and other teachers?*
  (May I share just the anonymised notes with our colleagues in the research program?)

- *May we have your permission use your story anonymously in a report about the programme?*

- *Is there anything you don't want me to write up or things you don't want me to share with other people anonymously?*
- *Thank you very much for letting me interview you.*

Colleague to sign
I give permission for you to share the anonymised notes of me and recordings of me

Yes / No

I give my permission for my story to be anonymously included in the report.

Yes / No

In the report I do not want you to include comments about

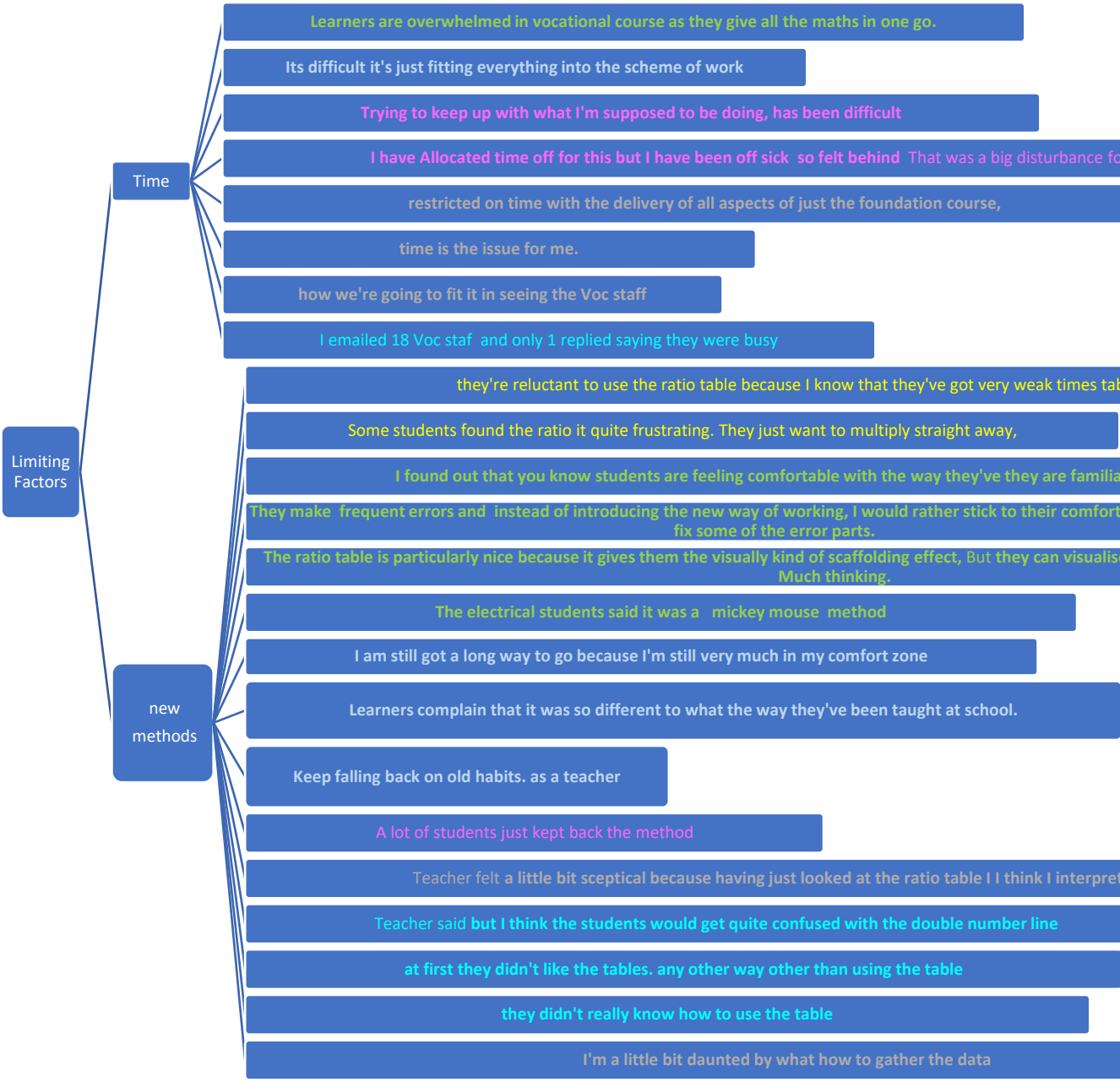
.....

Colleague signature ……

Appendix C Raw data

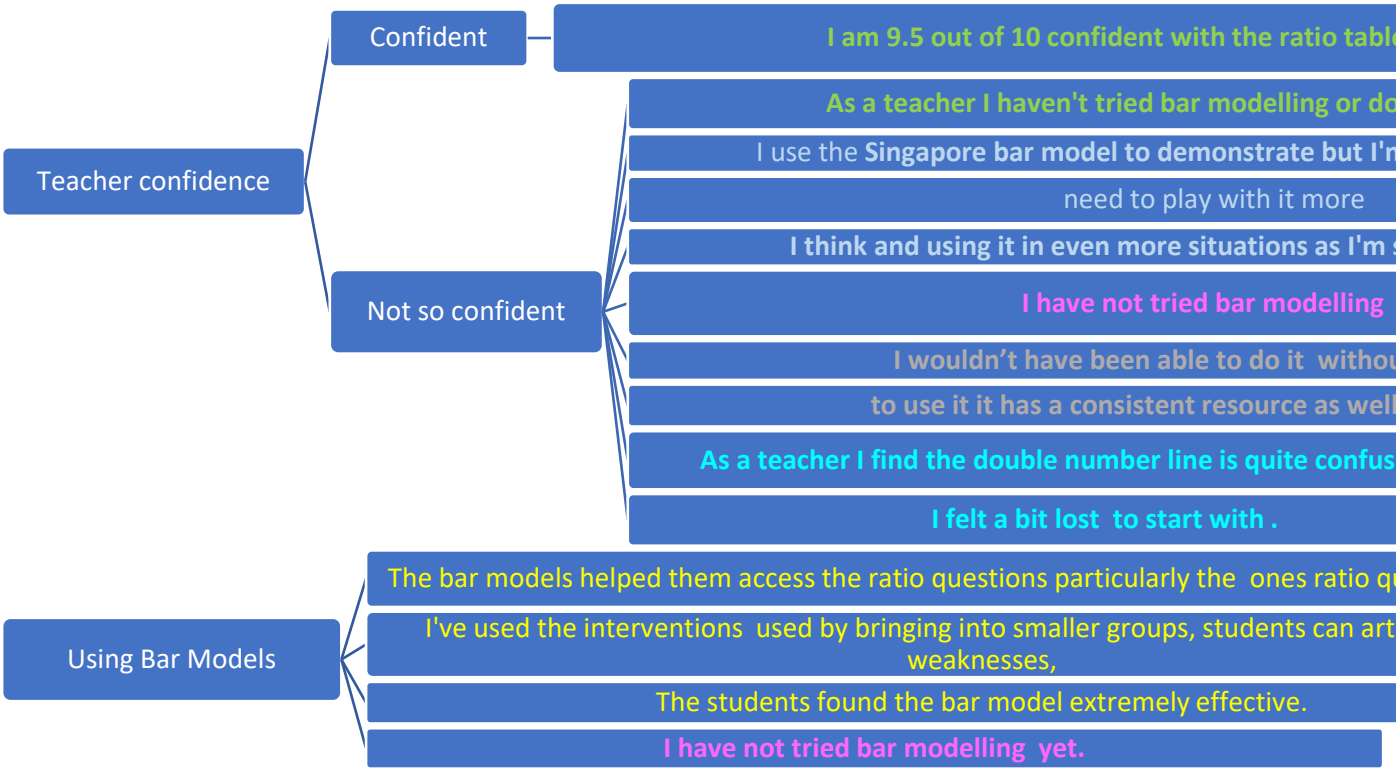
Teacher interview December 2021 Raw DATA

Analytics of the data AR2 Teacher Questionnaire: limiting Factors(Dec 2021)



Teacher Self Efficacy (Dec 2021)

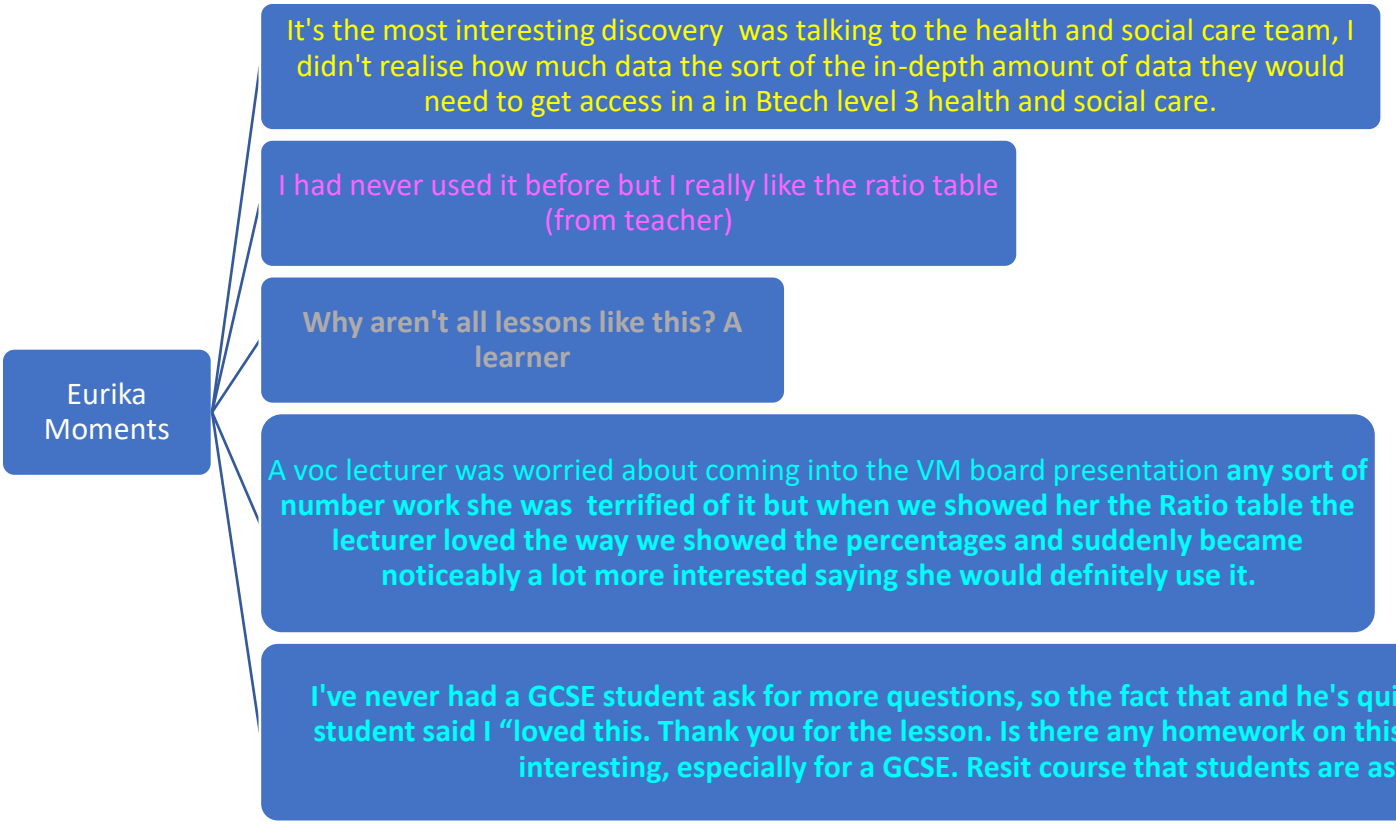
Teacher confidence using mastery and bar models (Dec 2021)




Using Ratio Tables in context
engagement
Understanding
The context of the petrol lesson helped ther
If they can focus on not the end goal, but just what can they do
for them.
Students weak were unable to manipulate their numbers and
table really helpful.
Students finding percentages found it very useful to m
There is a eurika moment when students understand the links
They all battling through it,
they were really engaged with
they were really engaged with
The petrol lesson is not exactly contextualised for this area, bu
STD question and instead of using the triangle we just did it
chart. much easier.
a formula Speed is whatever it is times whatever i
laying it out again in the visual way was much
they could see what the Calculation was, They could
students down beat when introducing the ratio table intially
fitted in.
They enjoyed the petrol lesson, they saw t
As they were discussing it the energy in the class
they liked finding Electrically powered cars and
ratio table has helped the learner to see w
light bulb moments where they say I can actually see what's
the relationship between the nur
with using the ratio table the students were able to iden
A confident student who didn't want to use it said it help
making mistakes and I was going
a very weak student recently with no confidence, very quie
answer the questions
I helped them to be able to unpick th
Some of them liked using the tables and carried on us
After getting quite proficient at ratio tables, go straig
the petrol lesson really stretched
They found it challenging most of them did get to
they used tables ratio tables to work
Using context helps the students to understand that it was a l
can see that it is true.
The student tried 21 times 12 without the table and then th
The table is Easier because they don't have to d
Towards the end the students liked the ratio table especially
became more effective

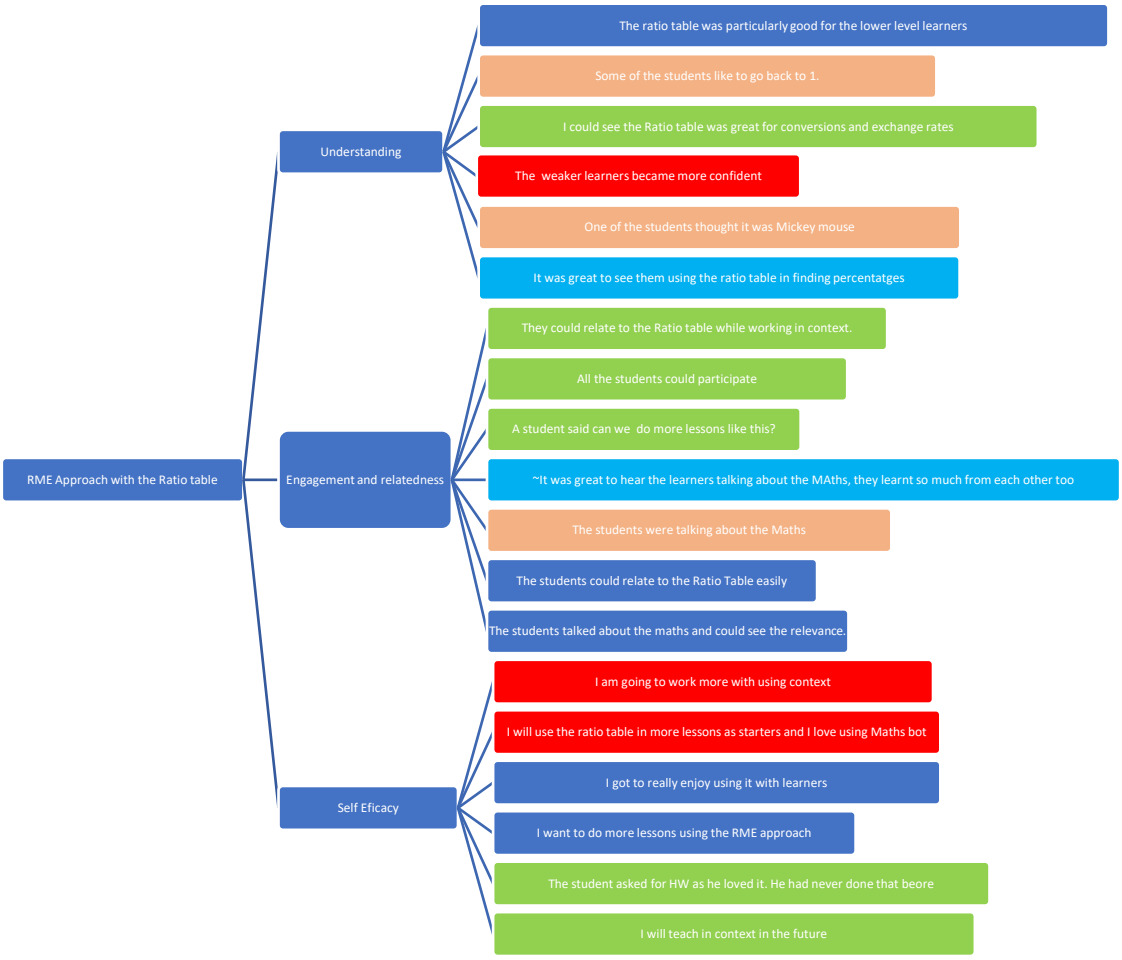
Voc Teacher Responses (Dec 2021)

Eurika moments (Dec 2021)

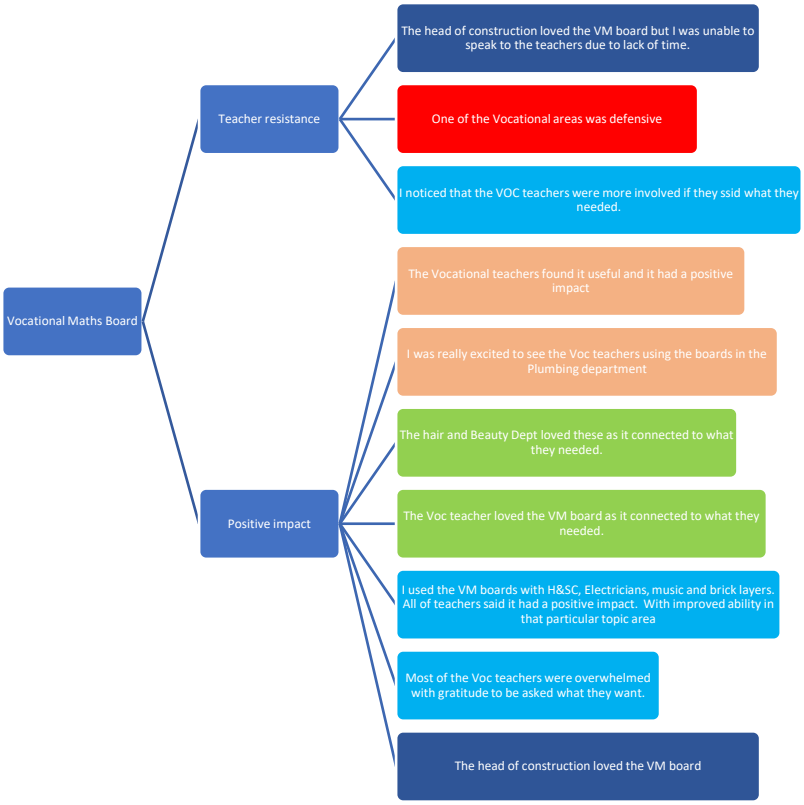


Teacher interview March 2022 Raw DATA

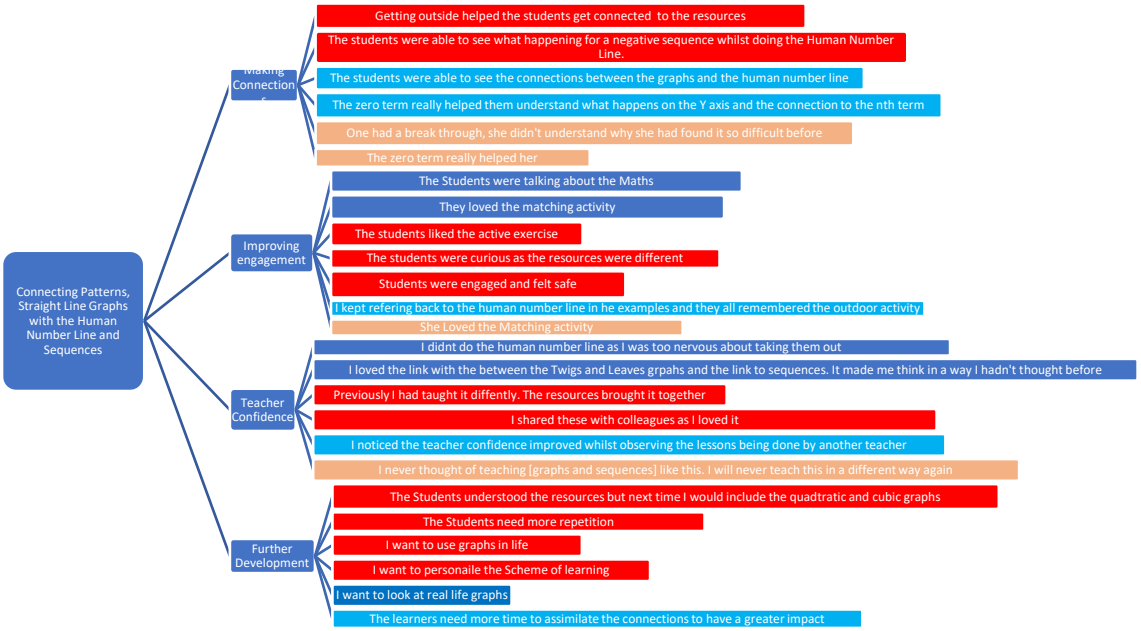
Using the Ratio Table (March 2022)



Vocational Maths Board (March 2022)



Connecting Patterns, Straight Line Graphs with the Human Number Line and Sequences (March 2022)



Appendix D Informed consent.

Centres for Excellence in Mathematics: Action Research Teaching approach
Research Participant (student) Information

Weston College, it's network partners and the Centres for Excellence in Mathematics (CfEM) are funded by the Government through the Department for Education.
The aim of the work is to improve the teaching of mathematics for GCSE learners and the improved progression of all 16-19 learners. As part of this work your maths teacher is taking part in developing innovative teaching in Maths. This will result in your teacher using a number of carefully designed resources with you over the forthcoming year. The research team will investigate the effectiveness of the approach by gathering some data from you. This will involve you being asked to complete short surveys during the year and your Exam outcome data being used for the data collection.
The research team from your College would very much appreciate your willingness to take part in the research. It has the potential to assist generations to come to experience better teaching in mathematics.

Data Protection
Your data will be tracked but anonymized. We will not be sharing your name, only the progress that you as pupil (x) have made.
If you wish to withdraw from participating in the research, you should tell your teacher now and at any time over the next year and complete the form that is part of the participant privacy notice. If this form is submitted at any time all of your data collected to that point will be destroyed and no further data collected relating to you.
We do hope, however, that you are happy to participate given the potential that the research has to inform us how to improve teaching of maths.

Ethical issues
We will ensure your anonymity at all stages and no survey or GCSE outcomes will be identifiable as belonging to you personally. In the case of any use of video for any purposes additional permissions will be sought from you.

If you would like any further information about the work of the CfEM programme in general or of the research programme in more detail please contact Katheryn Cockerton Katheryn.cockerton@weston.ac.uk

Katheryn Cockerton
CfEM Action Research Lead and Maths Lecturer

Appendix E Data collected by one of the colleges

11. What proportion of your students are confident with: interpreting graphs

More Details

All	3
Most	18
Half	15
Few	2
None	0

12. What proportion of your students are confident with: handling data

More Details

All	3
Most	12
Half	19
Few	4
None	0

13. What proportion of your students are confident with: working with fractions and percentages

More Details

All	3
Most	12
Half	18
Few	5
None	0

Remove later

School or college name	Type of school or college	English - number of students	English - progress score	% entering an approved English qualification	Maths - number of students	Maths - progress score	% entering an approved maths qualification
Heart of Worcestershire College ✖ Remove	College	576	-0.22	75.7%	710	-0.21	81.7%
Wiltshire College and University Centre ✖ Remove	College	693	-0.03	81.8%	797	-0.17	81.3%
Gloucestershire College ✖ Remove	College	524	-0.13	74.0%	643	-0.11	82.9%
South Devon College ✖ Remove	College	325	0.03	76.3%	424	-0.09	72.6%
Weston College ✖ Remove	College	533	0.10	76.2%	646	-0.06	79.4%
New College Swindon ✖ Remove	College	303	0.35	76.6%	449	0.23	78.4%
Yeovil College ✖ Remove	College	319	0.16	82.8%	356	0.28	80.6%
England - state-funded schools / colleges		**106083**	**0.14**	**82.5%**	**140556**	**0.09**	**85.2%**

Showing **7** schools and colleges

School or college name	Type of school or college	2017 final	2018 final	2019 final
Yeovil College ✖ Remove	College	0.2	0.27	0.28
New College Swindon ✖ Remove	College	0.33	0.24	0.23
Weston College ✖ Remove	College	-0.06	0.08	-0.06
South Devon College ✖ Remove	College	-0.16	-0.06	-0.09
Gloucestershire College ✖ Remove	College	-0.18	-0.14	-0.11
Wiltshire College and University Centre ✖ Remove	College	-0.21	-0.16	-0.17
Heart of Worcestershire College ✖ Remove	College	-0.38	-0.33	-0.21
England - state-funded schools / colleges		**-0.01**	**0.05**	**0.09**
England - all schools / colleges		**0**	**0.05**	**0.08**

Needs embedding in later discussions According to Whitehead's process philosophy, the stream of experience that forms our life consists of occasions of experience, each of which is a synthesis of many feelings having objective content (what is felt) and subjective form (how it is felt); also, the synthesis of feelings is not primarily controlled by their objective content, but by their subjective form. According to Whitehead's philosophy of education, the attempt to educate a person by merely focusing on objective content—on inert ideas, scraps of information, bare knowledge—while disregarding the subjective form or emotional pattern of that person's experience can never be successful. The art of education has to take into account the subjective receptiveness and appreciation of beauty and human greatness, the subjective emotions of interest, joy and adventure, and "the ultimate motive power" (1929a: 62), that is, the sense of importance, values and possibilities (cf.1929a: 45–65).
1929a, The Aims of Education and Other Essays, New York: The Macmillan Company.

Autonomy is the need to regulate actions in accordance with authentic interests and values. A person acting with autonomy (or with autonomous motivation) feels their actions are volitional, congruent, and integrated; a person acting out of "controlled regulation" experiences being controlled by external or internal pressure. An important aspect of autonomy is the ability to choose actions to meet the other two basic needs. Source: Addressing Mathematics Anxiety through Developing Resilience: Building on Self-Determination Theory (scirp.org)