CENTRES FOR EXCELLENCE IN MATHS

Exploring the use of technology and teacher confidence to develop and support teaching and learning with variation for fluency in 16-19-year-old GCSE maths re-sit learners, within different learning environments

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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 action research report focusses on exploring the use of technology and teacher confidence to develop and support teaching and learning with variation for fluency in 16-19-year-old GCSE maths re-sit learners, within different learning environments. 8 action research teachers from 4 different colleges situated in and around Central and East London worked together from September 2020 to May 2021 to develop their own confidence and skills with using online technologies (in particular Desmos, Whiteboard.fi, Padlet and Century Tech) in different learning environments (face-to-face, remote and mixed delivery). The focus was to identify how these tools could support maths learning on GCSE resit courses in Further Education (FE), particularly surrounding variation for fluency linking into a mastery pedagogy. As a result of the COVID-19 pandemic, classrooms were transferred online, and teachers in the action research group (ARG) did not want to lose the mastery pedagogy that had only recently been developed in their FE settings.

After major positive impacts on teacher confidence and skills from bespoke CPD sessions, teacher sharing sessions, individual reflection and group reflection, as well as consideration of the context and setting, the ARG developed intervention activities on Desmos and Whiteboard.fi. These learning intervention activities were carried out over a period of 3-4 weeks in March 2021, when learners were gradually returning to face-to-face teaching after lockdown. Learners and teachers felt that there was some improvement in learner fluency as a result of these interventions, as well as increased learner engagement.

However, throughout the whole action research project its success depended on the allowance of time for teachers and learners to develop and hone their confidence and skills with the online tools, which would then enable pedagogical progression.

We found through the action research that it is possible to digitise a mastery classroom, but that you do need to recognise the limits that each technology tool has. We also found that teachers felt that being part of action research as a whole had a positive impact on their practice, and that they found inspiration and innovation when taking part in this project.

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Background

Introduction

Following on from lockdown in March due to COVID-19 and the move to online learning of GCSE maths, Newham CfEM and its partner colleges wanted to build on using data and technology to develop a blended learning model to support learner development of mastery in maths both inside and outside the maths classroom. In particular, we wanted to focus on exploring the use of technology to support the development of variation and fluency in maths. The action research that this report pertains to is linked to both technology and data and mastery themes used in the CfEM programme year 2020-2021.

Prior to September 2020, maths teachers and learners within the College and network used (and continue to use) a range of maths applications and websites inside and outside of the classroom. For example, teachers at Newham College set homework using MathsWatch and MyMaths on a weekly basis for all GCSE learners and since January 2020 were starting to implement the use of Pinpoint Learning to create bespoke resources for learners based on their mock assessments. Network partners were also involved with the trials of Pinpoint Learning – with both Lewisham and Tower Hamlets College implementing them this year. Our key network partner – Westminster Kingsway carried out action research into the impact on learner engagement of using Century Tech in 19/20. Having successfully used a range of online learning tools pre- and during lockdown we then wanted to explore the best tools and processes to support learners' maths; in particular how we could support and develop learner fluency and variation in maths within different learning environments. We also wanted to spread the trials to larger numbers of professionals and thus learners in our own organisation and within our wider CfEM network. The colleges involved in this action research project in addition to Newham College were Southwark College, the College of Haringey, Enfield and North East London (CONEL), and Westminster Kingsway College (WKC).

Newham College is a large FE college situated in the London borough of Newham and has one of the youngest populations in the country, as well as a high proportion of BAME residents. In terms of the profile of our learners, there were 540 learners doing GCSE maths in 2020/2021 and 91% of these were BAME. Achievement rates for GCSE Maths in 2018/19 was 96% at Newham College (including 27% higher grades), and for 2019/2020 the achievement rate was 98% (including 35% higher grades). The hopes for this action research project was that it would additionally support the continued improvement in achievement rates as well as the direct impact on individual learners. For the college, CfEM is a beacon that draws together other organisations/institutions who share common aims and values in the sector and allow a platform to draw on best practice and ideas. It is also a platform that is resourced and dedicated to allowing and enabling research that provides tangible outcomes and evidence that can inform sector wide practice. Learners at the other participating colleges come from a wide range of backgrounds, and some of the colleges also include learners experiencing a comparatively high rate of digital poverty.

Our research topic was influenced by both the situation regarding COVID-19 and also our desire to build on teachers' pedagogies; including mastery, and learners' experiences in this field. Teachers and learners of maths within the College and its network are used to using a range of online tools for setting/completing homework and to support in class learning. To meet both local and national needs, learners leaving post 16 education will need to be proficient in mathematical and IT skills. This is supported by Newham College's own vision

“To give our students the confidence, skills and qualifications that employers need, and that will support local people to get great jobs.”

During lockdown we noticed a range of learner responses to online learning; including some more positive responses from learners who have previously lacked enthusiasm for maths or who had been poor attenders. With this in mind, we wanted to explore further blended learning models that could support these findings but also would allow the development of the use of IT within the classroom too.

This action research also built on the wider work we had undertaken within the centre and within our network to develop mastery – in particular, variation and fluency. Having undertaken a range of mastery CPD sessions on topics including conceptual and procedural variation, and fluency, we would go on within this action research to develop this further and include in our GCSE maths blended learning delivery models.

Overarching aim: To explore the use of technology and teacher confidence to develop supporting teaching and learning with variation for fluency in 16-19-year-old GCSE maths re-sit learners, within different learning environments

Our target group was learners aged 16-19 in GCSE maths resit classes at Newham College, Southwark College, CONEL and WKC. We involved 8 teachers from the 4 colleges, 3 at Newham, 2 at Southwark, 1 at CONEL and 2 at WKC. We hoped that a minimum of 200 learners would be exposed to the trials and teaching interventions, however due to class sizes being limited and issues surround attendance during a year so heavily affected by COVID 19, the actual number of learners was up to 138.

Research objectives:

1. To explore literature to support the rationale and findings for the research
2. To identify possible barriers to access and delivery using IT
3. To develop staff confidence and knowledge of using technology for teaching maths - what interventions will work for which teachers
4. To research and plan interventions, that focus on variation and fluency, collaboratively as a maths team and trial with learners.
5. To investigate how learners respond differently to different teaching interventions and strategies - what interventions work for which learners.
6. To compare and contrast findings between learners in different settings.
7. To collect and use teacher reflections on ease/usefulness of each intervention.
8. To share best practice and findings internally and externally

Key terms

See below the definitions of some key terms used in this action research report:

Blended learning environment/mixed delivery environment – where some learners are in attendance to class remotely and some are online.
Remote learning – learners access the class entirely online.
Learner efficiency – a learner is able to choose the most appropriate strategy for solving a problem in the quickest manner possible.
Learner accuracy – a learner is accurate in their working out, they can recall facts well and they double check their answers.
Learner flexibility (maths) – a learner is able to use different methods of solving a problem.

Literature Review

Introduction

When preparing for our action research (AR) project *Exploring the use of technology and teacher confidence to develop supporting teaching and learning with variation for fluency to 16-19-year-old GCSE Maths re-sit learners, within different learning environments*, we undertook a literature review of prior research, articles and theories relevant to our research aim and objectives. In order to do this, as an action research group (ARG), we selected pieces that were relevant to our aims. Whilst our research aim focusses on specific aspects of mastery teaching and learning with digital tools, we found that we needed to draw upon a wide range of sources with commentary on mastery, digital technologies specifically in maths, and commentary on how to approach a project that could have complex and varied associated factors.

We explored literature surrounding the key themes of using technology in a mathematics classroom, uses of technology for the teaching of variation and fluency, and the evolving nature of a blended learning and delivery environment. However, when exploring these themes, we found that whilst there were a number of formal studies and projects related to primary and secondary teaching (or the equivalencies in different countries), as well as digital tool usage at university level, there were very few projects that involved our specific aim of GCSE re-sit learners aged 16-19 regarding the use of digital tools to support teaching and learning in a mastery-based pedagogy. Indeed, a recent review of literature and research surrounding digital technologies to transform mathematics teaching and learning by Hoyles (2018) refers to a large number of studies, most of which take place in primary or secondary settings, and a smaller number of which take place in higher education settings, but there is no mention of any having been carried out in the landscape of further education. Thus, we have attempted to review formal research projects that, whilst it is not set in our specific setting, will highlight relevant theories and practices across the wider remit of mathematics education research.

However, in recent years, and particularly since March 2020, due to the need to transfer to online teaching settings, the general discussion and research surrounding the use of digital technologies in Further Education has increased significantly. Small pockets within the FE sector have been adopting remote learning strategies and focussing specifically on the outputs for Level 2 English and maths. For example, Basingstoke College of Technology, through the use of “creative and collaborative digital approaches” (Bravo and Hayden, 2020, p. 66) have been developing remote and blended learning delivery models, particularly with the use of Artificial Intelligence Technology (AI tech), to improve outcomes for their learners and found positive effects: “students used AI to help revise for their maths GCSE resits for as little as ten minutes a week improved their results twice as much as the national average.” (Bravo and Hayden, 2020, p. 69). Thus, it is clear to see that digital technologies can be used to great effect when supporting Level 2 maths learning in the FE sector.

The usage of technologies should not just be a short-term, temporary measure as necessitated by the pandemic. There is call for longer term successful use of technology across the board - “blended learning done well may be a longer-term choice to consider rather than just a lockdown solution and a fantastic opportunity to truly engage all learners whilst ensuring no one gets left behind” (Laverick, Heywood and Hollier, 2020, p. 65)

We hope to be contributing to a more formal output of research literature focussing on specific aspects of mathematics teaching with technology – in our case the teaching of

specific aspects of mastery in an online classroom. We also hope that our project findings will not just be useful for the here and now of mathematics teaching under a pandemic, but that our findings will support the use of technologies for variation and fluency in years to come.

Key factors to consider when using digital technologies to support teaching and learning

The literature surrounding using digital technologies for education and for maths teaching generally discusses the following factors to be mindful of when approaching a research project such as this: the digital divide; the teacher's role; CPD needs for the teacher; technological support for both the learner and the teacher; factors such as time; creating a community of practice (Dreher and Kuntze, 2015; Hansen, Mavrikis and Geraniou, 2016; Hoyles, 2018; Bakker and Wagner, 2020; Dobson, 2020; and others)

Within FE in general, and for the colleges involved in this project (Newham College, Southwark, CONEL and Westminster Kingsway), both the colleges themselves and learners suffer with the concept of the digital divide. The combination of a general lack of investment in IT infrastructure in FE (Dobson, 2020, p. 9), and the estimation that "5% of learners do not own their own device" (Dobson, 2020, p. 11), has meant that moving to a remote or blended learning model, whilst benefitting a majority of learners within FE, can pose the risk of learners being left behind. This informed our intervention design, focussing on interventions that ensured the teaching approaches, and support that the technology can offer, were accessible for all the learners involved in the four different colleges and settings that we have. Not only could this be an issue for the learners who don't have their own devices, but it is also an issue for those who do – "with millions of people suddenly using online platforms, crashing software or poor access is all too common" (Bakker and Wagner, 2020, p. 2).

Teachers have needed to change their practice rapidly, they are faced with "a very steep learning curve when it comes to using digital tools and finding creative solutions to practical problems" (Bakker and Wagner, 2020, p. 4). There are parallels between introducing new digital technologies into teaching and trialling a new pedagogical approach, such as mastery, within the classroom. The literature that we have read indicates that in both instances, teachers should be supported with adequate CPD and a community of practice. In the final report of a MiFEC project carried out from 2017-2020, it is commented that there is a disparity in the amount of CPD involvement for teaching staff, and this may depend on factors such as finance and regulations surrounding staff recruitment (Noyes and Dalby, 2020, pp. 26–27). One can go further and say that in some cases there will be a conflict between pedagogical tools and digital tools in the race to catch up post-COVID. The NCTM has stated that "all schools and mathematics programs should provide students and teachers with access to instructional technology…together with adequate training to ensure its effective use" (2011). This applies vice versa, that "teachers' professional development can be enhanced through the co-designing of virtual resources in communities of practice" (Hansen, Mavrikis and Geraniou, 2016, p. 206). In the write up of a research project for Cornerstone Maths, they highlight that "teachers implementing the innovation need time and support to make the innovation their own, to reshape it, and to use it to create novel strategies as well as new epistemologies for themselves and their students" (Hoyles et al., 2013, p. 1066). This study was not just looking at the simple use of digital technologies in a maths classroom, but rather for "how to enhance mathematical thinking [using digital technology] rather than simply reiterating current practice" (Hoyles *et al.*, 2013, p. 1057).

Additionally, to consider scaling up our interventions across wider areas of the sector, we would also need to ensure that there would be adequate time for training and support for

those using any digital resources or tools to support the teaching of variation and fluency. Clark-Wilson *et al* concluded that in the process of scaling, it is necessary that the teachers' PD needs resonate with the project aims, teachers have a supportive relationship with colleagues, teachers are empowered and given time to contribute to the revision and development of schemes of work to take account of the project, school interpretations align with the overarching aims of the project and that senior colleagues actively lead the way. They also stress that the institution must "buy in" with technological support (Clark-Wilson et al., 2015). As we were working with 8 teachers across 4 different colleges, we needed to be mindful to ensure that we had the proper support, time and "buy-in" not just from us as ARG teachers, but from our teams, leaders and learners.

We also needed to be mindful of the additional strains that the pandemic was and still is putting the sector and individual teachers under – Bakker and Wagner raise concerns surrounding the ethics of asking teachers to set aside time for research when "their first priority is to care about their local circumstances" (2020, p. 2). However, they go on to say that certain types of research are necessary in light of the pandemic, and that past events such as World War II or prior pandemics have sparked major change and discoveries (Bakker and Wagner, 2020). By setting our AR in our current practice, we hoped to find the balance between using up precious time with contributing to improvements for the way we were working, as well as influencing future practice.

Where digital technologies are becoming central to transforming the teaching and learning of mathematics, or to enhance pedagogical practice, teachers should be "part of the transformative process as co-designers and teacher researchers" (Hoyles, 2018, p. 15). During this AR, we hoped that our teachers would take the next steps, not just using pre-designed digital resources for the purposes of supporting fluency and variation, but that we ourselves would be working together to design the digital resources, and potentially contribute to the discussion around improving the tools themselves. We would be looking to analyse certain tools as replacement tools – i.e. tools that can replace elements of classroom practice, some tools as pre-designed tools and resources, and some tools as transformative tools similar to those that Hoyles describes.

This literature review has also shown us that the teacher's role is essential in both the use of digital technologies and developing mastery within a mathematics classroom – even though this has not yet been analysed fully. Hoyles states that "early design research with computers reveals rather little detail of the role of the researchers and the teachers, although teacher scaffolding of mathematics learning was certainly recognised as critical" (2018, pp. 14–15). Dreher and Kuntze argue in their introduction to their study on the teacher role in multiple representations in the mathematics classroom (a form of variation) that although there is ample research into learners' learning using multiple representation, there are few studies looking into the role of the teacher in the teaching and learning. (Dreher and Kuntze, 2015, p. 90). Thus, through this project, whilst the literature has shown us that both elements of mastery and the use of digital technologies can have a large impact on learner outcomes, there was still a place for more research surrounding the teacher's role in the incorporation of aspects of mastery and digital tool usage in maths teaching and learning. Hoyles goes further to state that "the mere presence of digital technology or even the ready access to data makes little difference to student learning outcomes" (2018, p. 16) – thus implying that it is how the teacher and learners use the technology, similar to how a teacher might use a pedagogical framework, that truly impacts the progress of our learners.

Outside of the teachers control however, a barrier to research projects with regards to digital technologies in FE in general could be that "infrastructure within FE has suffered from a lack

of both investment and strategic alignment between IT and the organisation" (Dobson, 2020, p. 9) – and so whilst a number of practitioners and institutions have been using digital technologies for teaching and learning, this area of research specific to mathematics has not been prioritised until recent years. This could also explain why, whilst there has been research into using digital technology for mathematics education in FE, there has been a lack of specific work on transformative technologies within FE, or reviews on how specific pedagogies that work within the face-to-face classroom (such as mastery) could work in a different classroom environment.

The debate over what the technology should be used for/how to analyse its impact

Whilst it would be interesting to compare how effective technology is for teaching mathematics vs not using technology, the situation at the time in the pandemic meant that we would be unable to have a control group of non-technology usage. Indeed, the literature shows that a mixed picture approach works when using technology, and when using technology for aspects of mastery teaching. For example, Loong reviews a number of research studies into physical or virtual manipulatives: "Terry (1995) found that a combination of concrete and virtual manipulatives helped students make significant gains compared to students using only physical manipulatives or only virtual manipulatives. Takahashi (2002 cited in Moyer, Salkind & Bolyard, 2008) similarly noted that students benefitted from instruction from both physical and virtual geoboards" (2014, p. 3) – this point is particularly pertinent as similar commentary and review was also provided by Suh and Moyer (2007). This would in turn guide our project aims – we did not need to focus on whether it is a better way of teaching and learning, but we knew that a combination of digital technologies and face-to-face teaching could be an improved way of teaching and learning. We would, however, touch on this and review the use of technologies specifically in the FE environment and for specific pedagogical purposes.

When discussing and using digital technologies it was imperative that we as an ARG recognised "that the potential for transformational change depends utterly on how the digital tools are used and the support offered by teachers on their use: the availability of hardware or software is a necessary, but far from sufficient, condition for transformational mathematics teaching" (Hoyles, 2018, p. 2).

Our aim was to look at how best the technology could be used to support variation and fluency, and whether we as teachers could take the next steps to using digital technologies to transform our mathematics teaching and learning. In December 2020, of the three technologies we were looking to use, whiteboard.fi, Desmos and Century Tech, it seemed as though Desmos could be most suitable to the needs of being a transformative technology to support teaching with variation and for fluency in our learners (see results and discussion, Cycle 1).

Key features of mastery teaching relevant to us as practitioners

As part of our ARG discussions and analysis we have identified key pedagogical features already established in literature that arguably form an intrinsic part of mastery within the maths curriculum. What is interesting is that several elements of mastery as identified below also form key parts of digital technology usage in a maths classroom.

Learner discovery

Learner discovery (or active learning) of the mathematics is key to a mastery pedagogy, asking and encouraging learners to make their own connections, recognise on their own key mathematical concepts with the guidance of a teacher. Dawson and Wang argue that a

mastery learning sequence “must be designed in a way that actively reveals the connections that the teacher wishes the students to make” (2019, p. 12). The element of learner discovery is also argued to be necessary when using technology for mathematical understanding. The underpinning theoretical framework that Hoyles uses to analyse the proposed six categories of digital tool usage is based in the necessity of a “constructionist environment” (2018, p. 2), the idea of active learning and learner ownership is key. Certain types of tools, particularly those that outsource processing power, should also have an element of learner discovery such as “TEBOs, through which different layers of structure could be revealed in the control of the user” (Hoyles, 2018, p. 7). We hoped that the technology we used could bring out this element of learner discovery, as it is a key underpinning feature of conceptual and variation in the mathematics classroom.

Discussion and mathematical fluency

Similar to the importance of learner discovery, discussion and collaborative learning environments are also key to developing mathematical fluency and using technology to its best potential. An article for NRICH proposes that you “can't do maths unless you talk maths”, but that the discussion must give learners the “opportunities to use those higher-level skills of comparing, explaining and justifying” (McClure, 2014), and that this is one of the methods we can use to develop number fluency in learners. However, Foster argues for his study into the use of certain activities that there is further need for classroom data and research into the concrete role that discussion plays, and whether it is preferable to traditional learning exercises (2018, pp. 137–138). Similarly, literature surrounding digital technology discusses the importance of a collaborative learning environment, where learners can share their knowledge with peers and teachers, when using different types of technology for different mathematical educational purposes (Hoyles, 2018) – for example to “increase students' access to information, ideas, and interactions that can support and enhance sense making, which is central to the process of taking ownership of knowledge” (National Council of Teachers of Mathematics, 2011).

Combining an element of mastery and technology, Suh and Moyer included discussion as an element in their intervention with physical and virtual manipulatives in order to develop learners’ higher order thinking (Suh and Moyer, 2007, p. 163). In a study regarding implementing mastery in a SEND setting, Williams also highlighted the importance of mathematical discussion or communication and the justification by pupils of the maths to be used in different situations in order to deepen conceptual understanding and mathematical fluency. This was the case even when the mathematical discussion took the form of pictorial representations where learners did not have the language skills to communicate (2019).

As teachers, we have found that the constraints of the pandemic classroom diminished our opportunities for these discussion rich ways of learning maths and developing mathematical fluency. Our research would try to navigate this element of discussion in light of our new classroom environment, in the hopes that the tools we would use could provide a better platform in which learners feel safe to contribute and work through their mathematical thinking. We could also learn lessons from a Cornerstone maths project where teachers were required to work in an online community in order to scale up research design – they found that “it proved challenging to spark productive conversations on the online community” (Hoyles *et al.*, 2013, p. 1067). If difficulties arose to spark discussion with teachers in an online forum, when working with GCSE re-sit learners, we would be mindful of the challenge to ask them to engage in online discussion forums.

Manipulatives and multiple representations

We assert that the use of manipulatives and multiple representations form a key component of any conversation around mastery and variation, and indeed, during our literature review, we found that a number of studies were analysing the use of manipulatives and/or multiple representations to use variation and support mathematical fluency of learners (Suh and Moyer, 2007; Loong, 2014; Dreher and Kuntze, 2015; Hansen, Mavrikis and Geraniou, 2016; Williams, 2019). The literature also states that both physical and virtual manipulatives as different representations of the mathematical concept (Loong, 2014, pp. 3–4).

Dreher and Kuntze place large value on using different representations as "doing mathematics relies on using representations, since mathematical objects are not accessible without them (Duval 2006; Janvier 1987; Mason 1987)" (2015, p. 90). However, they go on with caution writing that "Multiple representation plays an ambiguous role for learning mathematics: on one hand they are essential for the construction process of mathematical understanding and the ability to deal with them flexibly is key to successful mathematical thinking and problem solving (Acevedo Nistal et al 2009; Lesh, Post and Behr 1987; Stern 2002; Zbiek, Heid & Blume 2007). On the other hand, multiple representations can function as an obstacle for learning mathematics, since interpreting them, recognising their connections and changing between them are challenging tasks (Ainsworth 2006: English & Halford, 1995; Janvier 1987)" (Dreher and Kuntze, 2015, p. 91). This in turn would inform our intervention and resource design – we needed to ensure that, if we were to use multiple representations and online manipulatives for the purposes of supporting teaching with variation, the teacher would be properly supported to guide learners to navigate any obstacles that multiple representations may create.

Key terms and definitions

Whilst researching the key terms in our project aim, we found it very difficult to pin down one specific accepted definition of blended learning – rather that blended learning has become an "umbrella term" (Hrastinski, 2019, p. 564) and that "all types of education that include some aspect of face-to-face learning and online learning is described as blended learning in the literature" (Hrastinski, 2019, p. 564).

Even amongst ourselves as teachers, we have struggled to come up with an agreed definition of blended learning, rather preferring our term *blended learning environment*. We found that by adding in the key word *environment*, this encompassed both *blended learning* – i.e. the use of both online and face-to-face teaching and learning methods when your learners are in the traditional face-to-face delivery model, as well as *blended learning delivery* i.e. where you are in a different delivery environment to the norm – some learners could be online, and some in class, at the same time. This second definition seems to be becoming the new definition of blended learning – whilst some would call it a mixed delivery model, others, including leadership in our colleges, are using the term *blended learning* to describe the situation when some learners are logging in remotely. Thus, the term *blended learning* post-COVID is now becoming somewhat muddled. Where we have learners attending a class completely online, this will be called *remote learning*.

Gaps in literature

Whilst commentary exists around online learning in a range of contexts, less exists around the mixed or blended environments we found ourselves in with learners attending a class remotely and in person simultaneously. This is particularly the case for the teaching of maths at GCSE level as before March 2020, most of these classroom environments would have been face-to-face. We found a number of studies that assessed the use of digital tools to

supplement mathematics teaching within the classroom, or as supplementary tools to feed into classroom activities (Suh and Moyer, 2007; Hoyles *et al.*, 2013; Loong, 2014; Lin, Tseng and Chiang, 2016; Roschelle *et al.*, 2016; Childers and Lu, 2017; Hoyles, 2018; Pulham and Graham, 2018; Adelabu, Makgato and Ramaligela, 2019), but we struggled to find research which assessed how digital tools can support the teaching of fluency and variation when you are not able to have the class physically in a room together. Thus, our research activities would hope to review how best to use the technologies for this new setting of a *blended learning environment.*

In addition to this, we found research that has taken place in primary or secondary settings using elements of the mastery pedagogy with digital tools, such as the use of virtual or physical manipulatives (Suh and Moyer, 2007; Loong, 2014; Hansen, Mavrikis and Geraniou, 2016, 2016), however we have struggled to find specific research exploring the use of these digital tools for GCSE re-sit learners – an arguably niche group of learners that have struggled with mathematics learning through primary or secondary, or who have come to the UK late on in their educational journey.

Conclusion & justification for our research

Having pulled together a wide range of influences from academic literature, we have focused our research on several key themes including:

- Teacher support and confidence when using technologies for pedagogy-based teaching
- The barriers for both teachers and learners in an FE specific context, specifically within our own teaching contexts
- The usage of these technologies within mixed delivery and blended learning environments within an FE maths classroom
- Following through using certain technologies to cultivate the use of variation and fluency in the new classroom environment we find ourselves in

However, working through the different stages of this project we would need to be mindful that this type of AR project can be quite complex – delving into how to use technology to support or transform our teaching and learning, particularly when it comes to data collection and analysis of data. Hoyles argues that whilst there are now multiple frameworks through which digital technologies in mathematics can be analysed, “this multiplicity of frameworks brings new challenges not least to compare and contrast research and to build a cumulative picture of results” (Hoyles, 2018, p. 15). Thus, as an ARG, we would need to have clarity and purpose of how we were to measure our research against the aims that we set out.

Our AR will also sit in a wider area of research, especially as there is widespread agreement that the use of digital technologies in mathematics education requires further research, and in particular, that the teacher must be involved in the research and resource design phase (as mentioned previously). Bakker and Wagner also argue that in light of the pandemic, there is now a need for further research in mathematics education and that we need “to curate lessons that people have learned or are going to learn about the current situation, for the benefit of future crises and times of stability” (2020, p. 4). We hope that our AR will not only contribute to the immediate discussion and problem-solving of teaching mathematics during a pandemic, but to a longer-term discussion surrounding how to best use digital technologies for mathematics teaching regardless of the worldwide situation.

Methods

Overview of research design

Following on from our literature review, we decided to take a cyclic approach to our research design, splitting it into roughly 3 cycles. Throughout all the cycles, and data collection, we ensured that we had the informed consent from respondents, allowed for anonymisation and held non-anonymised data in a secure fashion according our colleges' data protection policies. Learners were made aware that the activities completed were part of the AR project, and participants were given the opportunity to opt out of taking part in the project.

Due to COVID and additional factors such as time pressures from the TAG process and assessment, we needed to adapt our cycles in January to April – we were able to still continue with most of the research, but the interventions were in a mixture of remote, mixed delivery and fully face-to-face settings, based on when the individual colleges opened up for face-to-face learning. This also meant that whilst we had planned to do an additional AR cycle in the latter stages of our project, to swap the tools AR teachers were using and to refine the activities used, we were unable to do this. The TAG process and assessment windows for the different colleges also affected the quantity of data we could collect in cycle 3. Additionally, some data from cycle 3 was lost due to a migration of IT services in one of the colleges. We adapted our final data collection methods to attempt to counteract this data loss.

Cycle 1

In our first cycle, from September to December, we focussed on exploration of the chosen aim and establishing our current thinking and practice. We completed our annotated bibliography and literature review as a group to identify general barriers and approaches for digital technology with mastery relevant to FE. We also explored on a more specific level the tools that we had used ourselves as teachers, and that we felt would be appropriate and applicable to use for mastery activities; particularly those supporting fluency and variation. We gathered qualitative opinions through discussion and the use of a Padlet board (see Appendix 1), which Martin Newton then summarised into a piece of analysis (see results and discussion), and we found that Century Tech, Desmos, Padlet and Whiteboard.fi would be the technologies that we would focus on.

Cycle 2

Our second cycle, from January to the beginning of March, was a combination of establishing a baseline level of tech usage for both learners and teachers within a mastery setting, teacher confidence with AR, mastery and technology, and then building on these baseline levels with teacher development and collaborative design of the interventions for cycle 3. We used mixed qualitative and quantitative approaches to data collection during this phase and gathered the perspectives of both teachers and learners.

At this stage, we invited teachers and learners to complete initial questionnaires (see Appendices 2 and 3) to ascertain the types of technology they were using, the apps and technology they had used already, their experience of different learning environments for teaching and learning and for teachers and their experience related to CPD they had already undertaken with regards to remote or mixed delivery.

In this cycle, teacher development was a focus, as we knew from our literature review that this could be a key barrier to making pedagogical advancements. For teacher-facing interventions, we decided that there would be three strands: bespoke CPD/support,

individual and collaborative reflection, and sharing our practice. For the bespoke CPD and support sessions, teachers requested either one to one or small group support sessions on the technology tools they had self-identified as being less familiar with (Desmos and Whiteboard.fi in particular), and these sessions were delivered by Martin Newton – largely focussing in on how to use the technology tools for maths teaching, with a small amount focussed on ideas for fluency and variation.

Throughout January to March, teachers also completed an individual reflection log (Appendix 4) in order to reflect on how they were using technology in their remote, mixed delivery and face-to-face GCSE maths lessons, as well as any issues and how the tools could be used in the future more effectively. We also paired teachers together to carry out lesson visits to see learner and teacher confidence levels from a different perspective, and to gain another perspective on the impact of using the tool in GCSE maths learning – we were aiming for 2 visits per AR teacher, but this was reduced to 1 per teacher due to COVID restraints. The pairs then discussed their visit reflection logs (see Appendix 5), and a summarised version was sent for analysis. In the two sharing sessions, 1 AR teacher per each of the 4 tools delivered a small segment on how they were using the tool in their classes already, and how it had affected their practice. Questions were answered, and we then had a mini-group discussion on how each tool could be used specifically for fluency and variation.

During the second cycle, and using learning from the reflections, bespoke CPD sessions and sharing sessions we then also collaboratively designed our interventions for cycle 3 during this time (see Appendices 6, 7, 8 and 9 for learner activity plans and intervention activities). These intervention plans detail how each activity has been carefully created by the teacher and the group to support teaching with variation for fluency. We honed down the intervention activities to be solely delivered using Desmos (free) and Whiteboard.fi (including additional subscription version).

Cycle 3

In Cycle 3, March-May, we carried out the learner-facing interventions in remote, mixed delivery and fully face-to-face classes over the space of 3 weeks. 5 teachers (1 Newham, 1 Westminster Kingsway, 2 Southwark, 1 CONEL) carried out interventions on Desmos with their classes, and 3 teachers (2 Newham, 1 Westminster Kingsway) carried out interventions on Whiteboard.fi with their classes. After each intervention, teachers and learners completed an intervention activity review (see Appendices 10 and 11), which asked teachers and learners to comment on the impact on aspects of learner fluency (efficiency, accuracy and flexibility), as well as ease of use, access issues, and comparing the activities to the “normal” classroom activity style. Teachers held these locally so that the interventions could be adapted from one week to the next, and ARG meetings were held in these weeks to discuss any adaptations recommended to new activity plans.

In May, we then asked learners and teachers to complete final questionnaires (see Appendices 12 and 13). The learner questionnaire focussed on measuring the impact of the tools on learner fluency, the experience of using the tools impact on their learning and whether they would like to do those types of activities again. Likewise, the teacher questionnaire had a similar focus in order to triangulate our findings, but with the additional aspect of reflecting on the impact of the action research on them as teachers, as well as in their teaching practice.

Summary table of data collection cycles, methods and respondents

	Cycle 1	Cycle 2				Cycle 3				
Data collection methods	Padlet summary	Initial Teacher Questionnaire	Initial Learner Questionnaire	Teacher reflection log summaries	Teacher visit reflection log summaries	Teacher Intervention activity review	Evidence of learner work	Learner Intervention activity review	Final Teacher questionnaire	Final Learner questionnaire
Number of AR teachers responding	8	8		7	7	33 responses from 7 out of 8 AR teachers	Examples given by 8 AR teachers		8	
Number of additional teachers responding	2	6								
Number of learners responding	N/A	N/A	140					154 responses over 3 weeks		86

Results and Discussion

For our results, we discussed and analysed the data collection chronologically and per cycle ensuring that the results could inform and impact our action research on an ongoing basis.

Cycle 1 – exploration of mastery and honing down the technology

Teacher Padlet - Reviewing software

During the first cycle, the ARG teachers reviewed different software and presented their findings on a Padlet (https://padlet.com/elizabeth_hopker/ARG1Tech) to enable a decision as to what software to use during the initial software trial stage.

Software reviewed by ARG teachers on the Padlet were, Desmos, Century tech, H5P, Padlet, MS forms, Quizlet, Whiteboard.fi, Geogebra, Teams Whiteboard, MathsBot, OnMaths, EEDI, Edmodo, Quizizz and Phet Colorado. From the review, four different software, Desmos, Whiteboard.fi, Century tech and Padlet were chosen for ARG teachers to trial in phase one of ARG with the purpose of becoming fluent with the software ready for intervention into using for fluency and variation in phase 2. Teachers commented on ease of use of the different software, but also commented on how the tools can be beneficial pedagogically. In our discussions as an ARG, we found that the four technologies offered the chance to explore synchronous and asynchronous learning, as well as flip learning opportunities (particularly for Century Tech). In addition, the instantaneous nature of Desmos, Whiteboard.fi, Padlet was something that we as a group hoped would enable the responsive nature of a mastery pedagogy, so that we could tailor the fluency and variation activities on the day to our learners' needs. Other key aspects such as manipulation of graphs or drawings, pacing and individual feedback for assessment for learning were felt to be key to enabling the planning and delivery of fluency and variation activities. Whilst each technology also had some negatives noted by teachers, the four technologies seemed to suit our action research purpose the most at the time.

In phase 2, it was decided that all ARG teachers would use Desmos and Whiteboard.fi. Those with Century tech would use it and those without would use Padlet. For these four online tools, Martin Newton then summarised the responses from the Padlet into the table on the next page. As an ARG we then read through and discussed this summary, to lead into our explorations of using Desmos, Whiteboard.fi, Padlet and Century Tech in Cycle 2, and to contribute to our intervention planning during Cycle 2.

Software	Positives	Negatives
Desmos https://www.desmos.com/	• Students can interact by writing, drawing, card matches, ordering activities manipulating shapes and graphs. • Teaching can see student responses in real time. • Teacher can control the slides by pausing and pacing. • Tracking and evidence of each student in real time. • Individual feedback can be given to students. • Can be used individually, in groups or whole class. • Can be used easily with MS teams. • Can be used with login or without login. • Students input can be used on later slides. • Could be used for procedural and conceptual variation	• Individual feedback comments can be time consuming. • Some aspects such as large card sorts will not work well on mobiles. • To get full facility students need to be registered and logged in.
Whiteboard.fi https://whiteboard.fi/	• Students have an individual whiteboard and the teacher can see each board in real time. • Good for questioning and discussion due to instant view of students work. • Can be used individually or a small group sharing work. • Could be useful when trialling procedural variation as it allows students to show different methods and representations. • Free version easily accessible and easy to use. • Facility for writing with basic maths type • Subscription account **Basic:** teacher account, invite co-teachers, upload PDFs, higher resolution **Premium:** basic features plus permanent room URL, Library for saving whiteboards, feedback where teacher can draw and write on student whiteboards	• To get full facility you must purchase. • When pushing out work to students it will replace what they have on their screen, so work is lost.
Century tech https://www.century.tech/	• Substantial learning platform based on learning science and artificial intelligence • Useful for initial assessment and flipped learning • Century tech nuggets can be modelled on curriculum delivery • Can provide synergy between what is delivered and e-learning	• Subscription basis only at a substantial price.
Padlet https://padlet.com/dashboard	• A simple way to organise multimedia content via a web-based platform with no password needed • Padlet links can be shared via college systems by text messages • Easy to administer by teachers • Works well on mobiles • All students and teachers can contribute to the wall and share ideas and instantly publish them • Many different resources can be shared on Padlet • Good for discussion	• Only three Padlets can be used for free, more than three is subscription only • Padlet itself might be difficult to use on a number of maths problems

Cycle 2 – becoming fluent with the software and finding the baseline

During Cycle 2, we developed our teacher skills through CPD, bespoke CPD, sharing sessions and lesson visits, and we also collected more data on the baseline levels of teachers and learners alike, with technology, and applicable pedagogical or learning experience views.

Initial Teacher Questionnaire

For the initial teacher questionnaire, we had 8 action research teachers and 6 non-action research teachers responding. Of these, 5 were from CONEL, 4 were from Southwark College, 3 were from Newham College and 2 were from Westminster Kingsway College. 13 of the 14 teachers deliver GCSE maths re-sit for 16-19-year olds, whilst one teacher just delivers to adult learners. Some of the respondents also teach Functional Skills or Core Maths. For analysis, we were able to theme the responses and analysis into barriers related to online teaching and learning (including confidence), the positives of delivering online or mixed delivery lessons, pedagogical differences in the different settings, and initial teacher opinions on CPD relate to online or mixed delivery teaching and learning.

<u>Barriers to online teaching and learning</u>

When asked to describe any barriers that they have experienced to online teaching and learning (Q4), the most common responses from teachers were lack of college equipment/hardware and issues with the internet connection for learners (6 respondents). 11 out of 14 respondents said their college's internet connect/Wi-Fi (Q5) was fit for purpose. When teaching lessons, 12 respondents said they had a good internet connection (Q9). Some respondents also discussed having issues with software such as Teams, lacking in confidence when using technology and barriers to monitoring engagement with online lessons (Q22). In the additional information section, one teacher felt that there was, at the time, a too high expectation of teacher technology skills for online teaching and learning (Q27).

To teach online or mixed delivery lessons (Q6), all teachers said they use a laptop/desktop, and 10 said they use it in conjunction with their phone for monitoring learning/teaching. 5 teachers said they used graphics pads, and other hardware mentioned included use of a tablet, dual screen, a headset, separate camera and external hard drive. In terms of whether they used and how they used different hardware when teaching in college vs at home (Q7), 9 teachers said that they used a different equipment set up at home with only 4 mentioning that they used a college laptop at home. In terms of teacher confidence with hardware (Q8), where teachers were using additional pieces of hardware, they said that they were either confident or very confident in using the technology. Most teachers said they felt confident or very confident using laptops and phones for teaching online.

When asked about how confident teachers felt when introducing a new tool into teaching, this contrasts with the confidence shown on the hardware, where only 7 teachers felt either confident or very confident. Half of the teachers only felt somewhat or a little confident about introducing new tools to learners (Q11). In terms of interactive online tools, teaching and learning platforms or apps used:

- all teachers were using MS Teams
- 10 said MyMaths
- 9 for Padlet and MathsWatch
- 7 for Desmos and Whiteboard.fi

- 4 for Socrative, 3 for Hegarty and 2 for Century Tech, Google classrooms and Kerboodle
- Other single mentions were EdPuzzle, JustMaths, OneNote, Quizizz, Teams Whiteboard, Mentimeter and Kahoot.

Positives of delivering online or mixed delivery lessons

A wide variety of positives were mentioned for delivering online or mixed delivery lessons from teachers (12 out of 14 teachers had some positives to contribute), with the most common being:

- Positive impact on communication between teachers and learners (4 responses)
- Better at enabling learner catch up (through recording or online resource storage) – (3 responses)
- No need for travel and reducing cost
- Positive impact on delivery and learners such as the ability to be flexible with lessons/resources, monitoring learner work, attendance, engagement and behaviour, as well as improvement of teacher digital skills, learner confidence and maths skills.
- Interestingly, only 1 teacher mentioned a positive of being safe from COVID.

Pedagogical differences in the different settings

When asked whether teachers felt that some aspects of face-to-face teaching cannot be put into place in an online or mixed-delivery setting, all of the teachers responding said yes (Q26) **–** however there was a wide variety of reasons given for this: a lack of personal interaction and feedback; more difficult to monitor progress online; you lose the ability to react to learner needs (including reacting to non-verbal clues to engagement); you are unable to demonstrate working as easily; an impact on learner focus; a loss of the classroom atmosphere; inability to use manipulatives or physical activities; an impact on engagement; and group work is not as successful.

Teacher opinions on CPD related to online or mixed delivery teaching and learning

Of the 13 teachers that said they had taken part in CPD related to online or mixed delivery teaching and learning (Q13), 11 teachers responded with positive opinions related to the importance, impact and availability – most notably that the CPD improved their own skills for online delivery, that CPD is necessary or useful and that the CPD improved their confidence. The impact that CPD could have was also recognised to be dependent on the quality of the CPD and time allowed to reflect on the CPD, with one teacher explicitly stating the need for more training, and another stating that the impact is higher in a one-to-one setting.

Learner access, engagement and confidence

In terms of teacher perspectives of learner access, a significant number of teachers said they felt that internet connection and a lack of equipment (11 out of 13) was a technology barrier for learners. When asked to estimate roughly what percentage of learners have access to a stable internet connection, the average of responses came out at 74%. In terms of technology that teachers thought learners were using to access an online or mixed delivery lesson, all teachers said that learners used laptops/desktops or mobile phones, and 11 out of 14 teachers said some learners used tablets (Q24). For printing resources, none of the 14 teachers said they were confident that learners would have access at home (Q25).

The teachers were also asked to reflect on learner experience, engagement and confidence with using the tools and hardware for online learning (Qs 15-21). Only 4 teachers either

agreed or strongly agreed with the statements “my learners engage with online learning as effectively as face-to-face classroom learning” and “my learners have sufficient access to technology”. So, most of the teachers asked felt that learners only somewhat engage as well with online learning vs face to face, and this is in parallel with learner access to technology. In terms of assessment, under half of the teachers felt they were able to assess effectively and give learners effective feedback online or get relevant and useful feedback from learners.

In terms of learner confidence, less than half of the teachers felt that learners are confident with using interactive online learning tools, however, most teachers felt that even though learners aren’t so confident at using new tools, learners do welcome the use of interactive teaching and learning platforms.

So, in terms of learner access and engagement, it seems as though from the initial questionnaire teachers felt that access and the experience of online learning could negatively impact learner engagement with their GCSE resit maths course, but that new tools would be welcomed by learners despite low confidence levels. This justified our plans to use and introduce new tools for variation and fluency, but also supported the literature review findings that whilst online learning tools can have a positive impact, they need to be used in appropriate ways and being mindful of time to ensure learners are familiar with the tools.

Initial Learner Questionnaire

To triangulate and compare the results from the initial teacher questionnaire, we also sent out an online initial learner questionnaire via MS Forms. There were 140 respondents: 64 from Westminster Kingsway College, 32 from Southwark College, 30 from Newham College and 14 from CONEL. We asked learners about their access to remote or mixed delivery lessons, the hardware and software they have used as well as their experience and engagement, and below are some of the key findings.

In terms of learner access and confidence:

- 76% of respondents said their college had a fit for purpose Wi-Fi connection
- 79% of respondents said they had access to the internet outside of college
- The vast majority of learners access lessons using laptop/desktop (75%) and/or their phones (72%), with a small number of learners using a tablet (9%)
    - Most learners (65%) said they are either confident or very confident using their chosen hardware: laptop/desktop – 69%; mobile – 64%; table – 63%.
    - In all cases, a very small proportion of learners said they are not confident using laptop/desktops, mobile phones or tablets (5%, 8% and 8% respectively).

In terms of the implications for our action research, and our plans for the interventions, we needed to take into account that 21% of learners who responded don’t have reliable access to the internet outside of college, which could affect their remote or mixed delivery learning experience with the tools and the variation activities for learner fluency. This would also go on to affect the number of respondents and attendance we could have in remote or mixed delivery settings. We also needed to ensure that the tools we would go on to use (Desmos, Whiteboard.fi, Padlet and Century Tech) would be phone compatible as a significant number of learners were using their phones for their remote lessons.

In terms of prior learner experience regarding online learning learners were asked to put into their own words the advantages and disadvantages of online learning.

For the advantages, just under a third of respondents mentioned easy access to lessons and around a tenth discussed no travel as major advantages to online lessons. There were a wide variety of answers given with regards to learning such as positive effects on concentration, flexibility in their learning and pace of learning, independent study, improvements to their maths and digital technology learning, and less pressure on them as learners. More practical advantages such as safety from the virus, positives in terms of timing, improved learner-teacher communication and less impact on lateness or attendance were discussed. Between 7 and 4 respondents mentioned the above.

In terms of disadvantages, which confirmed the responses from the teacher questionnaire, just under a quarter of learners confirmed they have had internet access issues, with some respondents also mentioning technical issues using online tools or equipment access issues. In terms of learning, 22% stated that online learning negatively affected their concentration/provided extra distractions, around 17% of learners stated that online learning has had a negative impact on learner/teacher communication, and 11% of learners stated they felt their mathematical understanding was negatively impacted online. Other disadvantages included negative impact on motivation, a lack of face to face interaction, engagement issues and time limits.

So, in terms of advantages and disadvantages to online lessons, even with a relatively small cohort, a wide array of reasons were given, with some of the reasons stated going for and against online lessons such as concentration, engagement and access. This showed that when using online tools for maths learning, we, as individual teachers within the AR group, had to be mindful of our own group of learners and their individual online learning needs.

In order to ensure that we could plan effectively for the interventions, we also took the baseline of how long learners felt they could focus in an online lesson (just under a half said up to an hour or more), which tools they preferred using for their learning, questions about their confidence, the quality of support and feedback they could receive whilst online and whether they had access to a printer. We also asked learners if they had used the four online tools already: just over half had used Century Tech previously; just over a third had used Padlet; around a quarter for Whiteboard.fi; and a fifth of learners had used Desmos. So, we knew that particularly for Desmos and Whiteboard.fi, we would need to integrate time into our lessons to ensure that learners were familiar with the tools prior to assessing the impact of the tools for variation activities for learner fluency.

Discussion of the initial questionnaires

At this stage we found that our teachers had a fairly accurate awareness of barriers that their learners were facing to remote and mixed delivery learning. For example, on average, teachers identified a similar proportion of learners that faced internet connection issues to what we found from the learner questionnaire. Similarly, teachers knew what types of technology their learners were using to access remote lessons. Teachers were also accurate in their assessment that most learners do welcome the use of interactive teaching and learning platforms – 61% of learners said they welcomed being introduced to new online tools for learning maths, with an additional 25% saying that they somewhat welcomed it.

What was a small surprise to teachers in the ARG was the number of learners who felt they could concentrate up to an hour or more online – as an ARG we thought that the majority of learners would pick a significantly shorter time. We were also pleased to see that learners mentioned a wide range of online tools for their maths learning, though a significant proportion of learners did not mention having used Century Tech (68%), Desmos (93%), Whiteboard.fi (96%) and/or Padlet (90%). This meant that we needed to ensure that, as

explored through our literature review, we would give learners adequate time to become familiar with the tools.

An additional surprise to us as an ARG was the relatively low proportion of learners who said they preferred face-to-face (F2F) lessons (46%) – as a group, we had thought this would be much higher. 15% of learners said they preferred remote lessons for their maths learning, and 32% of learners stated that they preferred a mixture of F2F and remote lessons. So, we then continued our exploration phase in the knowledge that whilst it was still a minority that preferred remote or mixed delivery lessons, it was a larger minority than we had expected. In terms of learner confidence with online learning tools, around a half of the learners responding said they felt confident or very confident, which is higher than the teacher expectations from the initial teacher questionnaire, but as an ARG we still felt that this statistic could be improved upon during the research. Results from the initial teacher questionnaire also matched with our literature review, particularly with regards to CPD for online tool usage – that teachers value the impact CPD can have on pedagogy. We also then took the results from this initial questionnaire and developed the CPD to include both the community of practice as discussed in our literature review as well as a one-to-one bespoke aspect as a direct response to a request from the initial questionnaire.

Teacher Reflection logs

During the second cycle, we also completed our own teacher reflection logs to track which technology we were using in remote or mixed-delivery lessons, any technical and access issues that impacted lessons and adaptations that needed to be made, engagement of learning, pedagogical approaches used and the impact on teachers of learners from the action research or using the tools. We then summarised 7 out of 8 of the reflections, coded the summaries and analysed the results and key findings are as below.

Technology used

During these reflections, teachers initially identified the following main purposes for the main four tools focused on in this action research:

Main purpose	Desmos	Century Tech	Whiteboard.fi	Padlet
Flip learning	✓	✓		
In-class learning	✓	✓	✓	
Remote learning	✓	✓	✓	✓
Delivery platform	✓			
Platform to upload/store work/ resources				✓
Differentiation		✓		

However, as the course of the project went on from January to March, emerging purposes for the technology tools were reflected upon. Please note that where an option is not ticked, this does not mean the tool cannot be used for this purpose, only that the teachers did not specifically mention it.

Emerging purpose	Desmos	Century Tech	Whiteboard.fi	Padlet
Live editing (enabling mastery-based teaching)			✓	✓
Promoting student ownership	✓	✓		✓
Improving engagement	✓		✓	
Improving learner efficiency	✓		✓	
Supporting learning	✓			
Used for learner feedback	✓			✓

Of all the tools, Desmos had the widest range of uses commented on by teachers in their logs.

Technical errors and access issues

In terms of technical errors, Whiteboard.fi was the platform which had the most reported (10) including stability issues and issues arising from lack of familiarity with the tool. These limitations occasionally caused negative impact on delivery, with some learners preferring to use paper. Comparatively, Desmos only had 2 mentions of technical limitations and Century Tech had 1, regarding lack of flexibility as a tool. Mobile phones were also mentioned to be a factor impacting on pacing, but 6 out of 7 reflections commented that using technology generally impacted on pace and timing compared to a normal face-to-face session. In terms of access issues, Whiteboard.fi again was mentioned the most frequently, with 5 mentions, whilst Century Tech had 4, Desmos had 2 and Padlet only had 1. These were also affected by using phones rather than laptops. A stable internet connection and compatible browsers proved necessary to use Whiteboard.fi effectively, which from our initial questionnaires meant that around a fifth of learners could be affected by this. For Desmos, a mixed-delivery environment affected how easily learners could access the tool as the teacher needed to support both in and out of class learners simultaneously with logging on.

Adaptations made

In terms of adaptations made, teachers commented on in-lesson adaptations and ongoing adaptations. The main adaptation which was needed to be made was allowing for more time when using online tools either for logging in/access or completing the activities. Other adaptations related to the hardware being used (such as using Century Tech in landscape), or specific technical adaptations. Teachers did positively comment on Whiteboard.fi, saying that it was able to be adapted to suit learner needs, and Desmos was also used to resolve issues that had occurred within the lessons on other pieces of technology. Finally, teachers discussed that ongoing adjustments when getting used to the new online tools themselves, and for learners, was important to adapt their practice to using the tools.

Engagement of learning

Desmos had the most mentions when reflecting on positive impact to engagement of learning, but there were also some negatives: screen fatigue during F2F and mixed delivery environments, and some learners preferring paper-based work in these environments.

Pedagogical approaches

In terms of findings around impact on pedagogical approaches, Desmos and Whiteboard.fi were both recognised to have positive impacts on assessment for learning and enabling mastery pedagogy (such as multiple representations). Additionally, Desmos enabled differentiation and monitoring the progress of learning through the transition from remote to F2F. Whiteboard.fi and Padlet enabled whole class activities to take place online. However, Century Tech was deemed during this reflection phase to not be suited to in-class, teacher-designed activities, and there was also concern with regards to Padlet about too much loss of needed pedagogical approaches.

Impact on teachers

For teachers, in addition to the above, the largest positive impact on using the tools in this cycle came from collaboration with AR teachers, shared planning sessions and lesson visits. Increased teacher confidence and self-esteem came from the use of Desmos, and both the use of Desmos and Whiteboard.fi increased teacher technology skills. Whilst there were strong positives, one teacher noted that Desmos was easier to use F2F, but another

commented that its impact was limited F2F. Using technology tools in general was reflected on as being harder work in a mixed delivery environment.

Impact on learners

From the teacher reflections, Desmos had the largest positive impact on learners, with these additional positives mentioned for the following technologies:

- Positive impact on identifying and addressing misconceptions (Desmos, Whiteboard.fi, Padlet)
- Increased learner motivation and engagement (Padlet, Whiteboard.fi, Desmos)
- Positive impact on differentiation (Desmos, Whiteboard.fi)
- Improvement in reasoning (Desmos, Whiteboard.fi)
- Increased reflection (Desmos)
- Ability for learners to pace their own learning (Desmos)

One teacher did reflect that using online tools can marginalise some learners if they don't have technology access or sufficient technology skills – as identified in our literature review, this was still an issue which we had not yet manage to fully address even with adaptations we were making. In terms of planning for our interventions, we still needed to be mindful of the impact that a lack of hardware or familiarity could have on our learners.

Teacher Visit Reflection logs

After completing our individual reflection logs for a few weeks, we then carried out lesson visits which additionally reflected on teacher and learner confidence, as well as the themes commented upon in the teacher reflection logs. Again, as well as the four main tools, teachers used other technologies to support their learners. The process of analysis was the same as the Teacher Reflection Logs. Whilst some findings such as access and technical issues were similar to those found in the Teacher Reflection Logs, additional findings are below.

Technical and access issues

Like in the individual logs, Whiteboard.fi was the technology which presented a high number of technical errors in lesson visits with whiteboards and learner work disappearing and difficulty using on mobile phones being the most common reason. However, in the visit logs, access issues when logging in to Desmos or when using different hardware were reported at a higher rate. However, one teacher also noted that Desmos helped them overcome technology challenges faced by some learners.

Teacher and Learner confidence

In almost all or all of the visits, Desmos, Whiteboard.fi and Century Tech when used were commented on as being confidently used by teachers. Two thirds of the relevant reflection summaries noted that teachers were using multiple tools confidently in the same session, and half of the reflections stated that teachers were then able to be flexible with using different tools or platforms. One reflection mentioned that teacher confidence improved as the sessions went on, and that low confidence affected the usage of the tools. In terms of negative impacts on confidence, one reflection mentioned that the technical errors experienced with Whiteboard.fi negatively impacted their anxiety levels. Only a third mentioned that learners were confident – reflecting the need for further time to develop the learner skills ahead of the interventions. However, there were also reflections which stated that learner confidence was improved through the use of Desmos and Whiteboard.fi.

Impact on learners

In addition to impact on learner confidence, the positive impact on learning from the feedback capabilities of Desmos and Whiteboard.fi were further highlighted in the lesson visit reflections. Additionally, teachers noticed an improvement in learner digital skills as the result of using multiple tools during one lesson.

Engagement of learning

In contrast to the findings from the individual teacher reflections, Whiteboard.fi had the most reflections commenting that it positively impacted learner engagement, though Desmos still had positive reflections, particularly for the engagement of learners who were struggling with the content of the lesson.

Pedagogical approaches

Some of the reflections commented on how they used the technology with different pedagogical approaches:

- Desmos was used well for increasingly difficult questions
- Multiple tool usage was said to impact on pedagogical advancement
- One teacher used a traffic light system with MS Teams and Whiteboard.fi, and it worked well
- Whiteboard.fi had a mention of increasing learner discussion
- Padlet enabled group activities

Reflection logs discussion

Throughout this exploration and reflection cycle, we met as an ARG to discuss our experiences and reflections, as well as receiving bespoke CPD and taking part in the sharing sessions. From both the individual reflection logs and the visit logs, it is clear to see that these forms of sharing practice and teacher development had a big impact on teacher practice – ratings of teacher confidence and skills had improved compared to the initial questionnaire ratings. Confirming our literature review findings, teachers still felt that having more time and practice to explore tools by themselves and with learners was beneficial for both parties, especially as it gave us as an ARG the opportunities to identify the technological issues posed particularly by Whiteboard.fi, in order to address them for the interventions. Whilst teacher confidence had improved over this period, it still seemed from the lesson visits that learner confidence and skills could be improved for some classes, and so this would have an impact on the carrying out of the interventions.

In addition to the key features of mastery, such as learner discovery and learner discussion, that we had discussed in our literature review, the reflection logs also highlighted that addressing misconceptions, furthering learner reasoning skills and pacing learning would be key to ensuring that we could teach with variation for fluency during the intervention phase of our AR. Likewise, Desmos and Whiteboard.fi enabled the usage of multiple representations, but virtual manipulatives were not focused on at this stage as teachers were still developing their confidence with the tools.

Cycle 3 – interventions

Considering as we went along the findings from the initial questionnaires and the reflective logs, as an ARG we collaboratively designed intervention activities based on variation for fluency using Desmos and Whiteboard.fi (see appendices 7, 8 and 9 for links to these plans and activities). We had found in Cycle 2 that whilst Padlet and Century Tech could be useful for group work, flip-learning and differentiation, they were not suited to the types of synchronous intervention activities that we wanted to trial with the learners. However, for Century Tech, teachers who had access and the ability set tasks related to the topics in the interventions to try to measure its impact as a flip-learning tool. After each intervention, teachers and learners completed mini reviews commenting on the impact of the activity in terms of fluency and variation, as well as technical issues, learner engagement and progress.

Post-intervention Teacher Review forms

Teacher Response count per week and technology type for the interventions

Activity	Week 1	Week 2	Week 3
Desmos Tricky Questions 1 & 2	7 reviews from 4 different teachers	7 reviews from 2 different teachers	6 reviews from 2 different teachers
Whiteboard.fi SSDD	5 reviews from 3 different teachers	4 reviews from 2 different teachers	3 reviews from 2 different teachers

Extenuating circumstances prevented 1 teacher completing any reviews, the number of interventions completed was impacted by assessment weeks necessitated by TAGs at the different colleges.

For the Teacher Review forms, we coded the qualitative responses and then drew out the key findings from the data collected.

For both platforms, AR teachers found that they enabled activities that help learners to develop their fluency using variation. Whiteboard.fi leant itself to the development of aspects of fluency such as accuracy, efficiency and flexibility, whereas the activities designed for and delivered via Desmos leaned more towards supporting variation activities and developing learners' conceptual knowledge, including exploring mathematical relationships. In terms of addressing misconceptions and providing feedback, key supporters of a mastery-based pedagogy, both platforms fared equally as well. When reflecting on themes outside of fluency and variation, learner engagement and progress was reported as being higher with Desmos, and teachers also reported that it helped support group work and class discussion. This was not positive of the tool that was highlighted in earlier data collection sets and reflections, which meant it was a discovered bonus from the action research.

In terms of negative comments, like in the earlier reflection logs, Whiteboard.fi continued to pose technical issues, with 50% of lessons delivered via the platform being negatively impacted. At the extreme end, this did lead to the usage of the platform being abandoned in one lesson, but more often let to the activity overrunning. This is in contrast to Desmos where the earlier reported access issues seem to have been resolved. Comments such as needing more time for the activity and learners preferring to work in their books now were largely related to the use of Whiteboard.fi, whereas these had reduced with Desmos.

When asked what adaptations teachers would make for using the next activity, or using the tools again, there were comments that the activities on both Whiteboard.fi and Desmos would need to be allowed more time. One stand-out quote from a teacher:

"Don't underestimate the amount of time an online synchronous learning activity takes!"

Aside from discussing time allowances, for Whiteboard.fi, teachers stated that they still needed more development with using the technology before improving the lesson. For the teachers using Desmos, these comments related more to how they would develop the activity to promote greater fluency and variation, or challenge in the lesson. In conclusion, for the intervention activities, Desmos was able to become a “transformative tool” whereas Whiteboard.fi was comparatively still being held back by technology limitations.

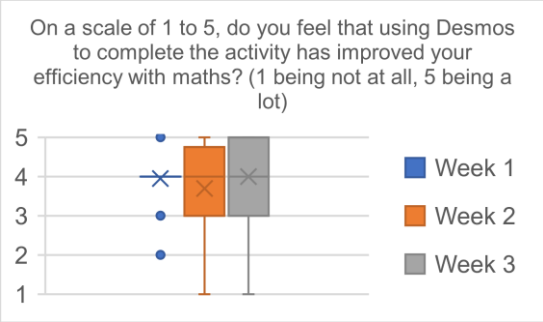
Post-intervention Learner Review forms

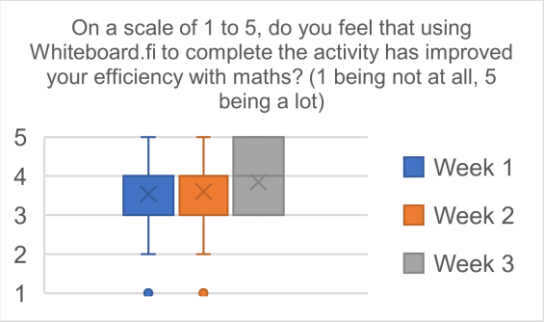
Learner Response count per week and technology type for the interventions

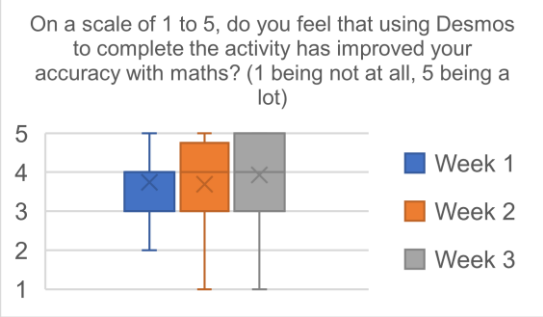
Activity	Week 1	Week 2	Week 3
Desmos Tricky Questions 1 & 2	19	36	27
Whiteboard.fi SSDD	24	35	13

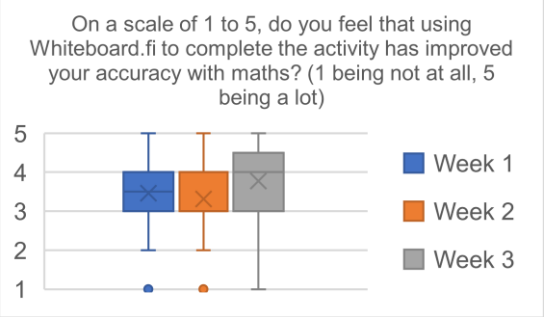
A loss of data at one of the colleges impacted the response rate significantly. Intervention occurrences were also impacted due to assessments weeks at some colleges, and the numbers of learners was impacted in week 3 due to poor attendance F2F. The above figures do not represent the entire cohort that was exposed to the interventions, just those who completed the review forms.

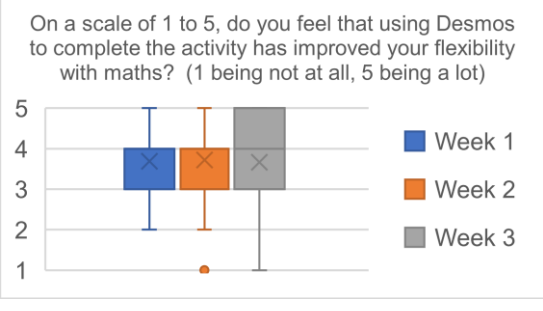
For the Learner Review forms completed by learners after each intervention, the questionnaire asked learners to rate whether the activity improved their efficiency, accuracy and flexibility. Learners were also asked about the ease of completion of the activity, the impact from Century Tech and whether they preferred using the technology or their books.

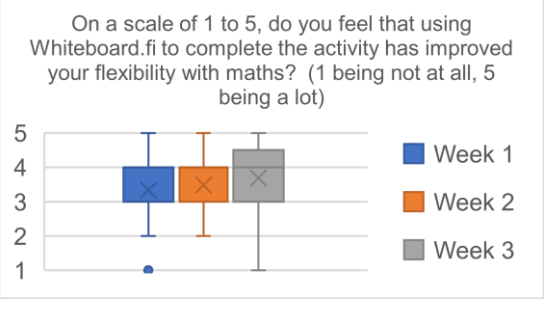




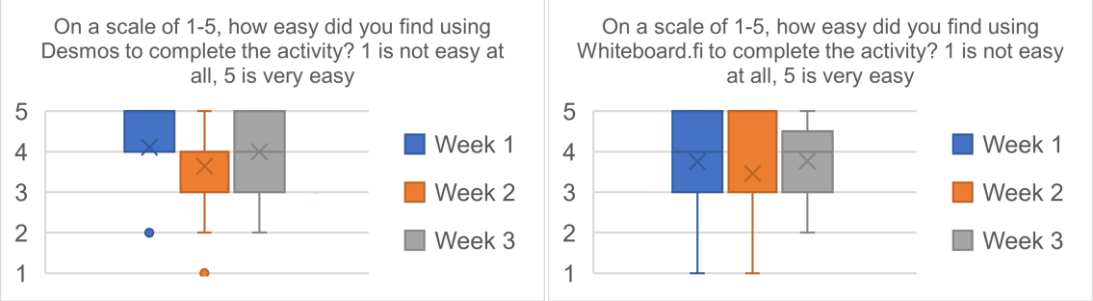






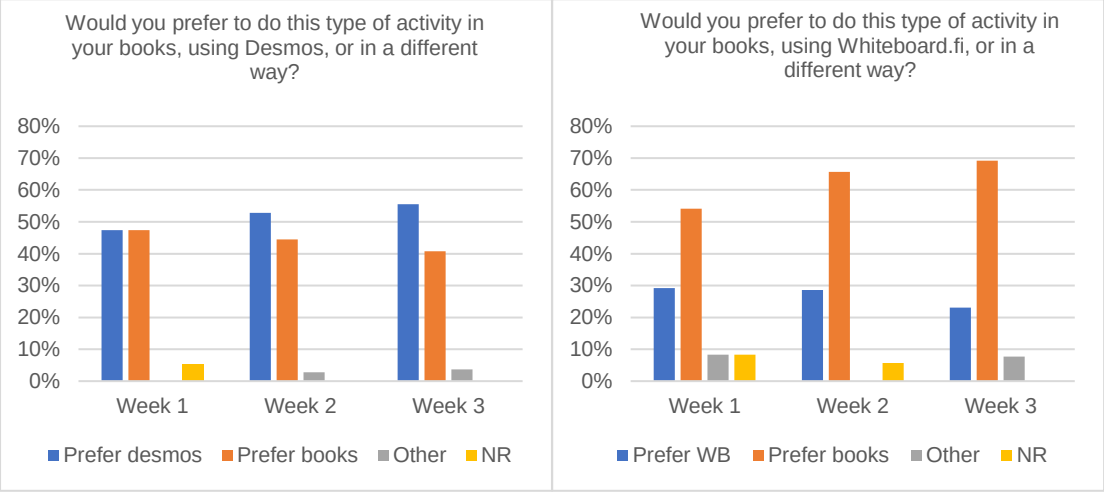


The box plots shown above show how over the 3-week period of interventions, for learner efficiency, accuracy and flexibility, learners for Whiteboard.fi had a marginally increased rating. However, for Desmos, the picture was more variable, with only the medians for accuracy improving. This tallies with the teacher reflections that Whiteboard.fi had a larger impact on learner fluency, despite the tech issues. Reflecting teacher opinion again, the learner ratings in terms of ease of completion (see the box plots below) showed that for the interventions, Desmos was easier to complete the activity week on week, though the variance in the types of activities used/how the teachers delivered, as well as the baseline of learner skills would have impacted this. In these interventions, learners cited issues with using Whiteboard.fi on their phones, but they did also comment that the activities were helpful and improved their mathematical understanding.



In terms of whether Century Tech helped learners complete the activity on Desmos vs Whiteboard.fi, there was a more marked improvement week on week and slightly higher ratings for Desmos than for Whiteboard.fi. However, the number of learners who completed the Century Tech nuggets that also completed the intervention activities was too low to draw any significant conclusions.

In terms of whether they would prefer to have completed the variation and fluency activities using the tech platform or their books, this is perhaps our strongest finding from the learner activity reviews.



It is clear to see that for Desmos, as the weeks went on, learners increasingly preferred to complete the activity using Desmos – showing a change in perception on using the tool. However, for Whiteboard.fi, the opposite was the case – 15% more learners would prefer to do the activity in their books rather than using the tech platform in Week 3 compared to Week 1. Whilst this could have been affected by the change in delivery settings i.e. Week 1 was mostly remote, whilst Week 3 was mostly F2F, this does tally with the feedback from teachers given. Additionally, one learner actively commented on the questionnaire in the

additional feedback section to say that they preferred using Desmos to doing work in their book for their maths learning – which supports the proposal from the teacher activity review discussion that Desmos could be used as a transformative tool for a learners maths learning – as per Hoyles, the online tool is now affecting the way in which a learner views their learning and how they learn maths.

Final reflections

Final Teacher Questionnaire

For the final teacher questionnaire, we asked the action research teachers to reflect on the impact the different cycles of the action research had on their practice, their confidence and skills and their learners. After coding the qualitative responses and analysing the responses from the 8 action research teachers, we split the key findings into: impact on teacher confidence, technology, the impact on learners and the impact on teacher practice.

Impact on teacher confidence

All the action research teachers reported improve levels of confidence as a result of the sharing sessions and the bespoke CPD sessions where they had been attended, whilst a majority felt that sharing practice with other teachers had a positive impact on their confidence levels. The sharing sessions enabled the sharing of knowledge, experience and pedagogy and created a supportive community in an FE specific environment. Teachers said that the sharing sessions and the CPD sessions developed their technology skills and helped with planning for mastery and within different settings. The sharing aspect also helped teachers save time and one teacher noted that the sharing sessions provided a safe space to explore the use of the tools for fluency and variation, which also boosted their confidence.

Most teachers experienced a positive change to their confidence levels with using technology as a result of completing the lesson visits, and cited that practice using the tools, reviewing usage with support and observing how other teachers used tools boosted their confidence.

The impact of technology usage

In terms of access issues with technology which could have affected the interventions, the final questionnaire echoed the findings of the teacher review forms: Wi-fi issues; login details (Desmos); digital poverty; and issues with phone users for both platforms. However, teachers were then asked how learners with different working levels responded to using technology tools for fluency and variation activities – the key finding being that half of the teachers said that the working level of learners did not affect their usage of the tools, particularly when using features such as independent pacing on Desmos. However, 3 out of 8 teachers did feel that the working level of learners affected their response to the intervention activities: higher ability learners were more engaged and used the technology better, whereas lower ability learners struggled to complete the tasks within the agreed time and were less able to articulate their mathematical ideas – so were less fluent (Q14).

Key features of the tools discussed by teachers in the AR group which were key for enabling teaching and learning with fluency and variation activities in different settings were:

- the ability to have live learner response/teaching
- live engagement tracking and individual and immediate feedback
- the ability on Desmos to have the independent pacing

- the teacher's whiteboard, as well as the shapes functions, for teacher and learner modelling on Whiteboard.fi
- the snapshot feature on Desmos.

In terms of whether the tools would need to be changed, Whiteboard.fi had the most comments for features to be added, such as integration of 3D/virtual manipulatives, being able to move the slides around whilst planning or delivering a session, and having a learner login for learners to save and track their own work. Another comment was that Desmos did not have virtual maths equipment (such as a protractor) integrated (Q15).

Over half of the teachers felt that using the different technology tools helped with the transition between learning environments (Q21) – the most common reason for answering yes was that the tools helped with the monitoring of learner progress throughout the year. For teachers that felt that the tools did not help, the most common reason was that online teaching and learning is too different to face-to-face to have a smooth transition (Q22).

When asked about the differences that teachers have experienced between using the tools in different settings, 3 out of 8 teachers either did not answer or said there was no difference. For the 5 teachers who commented, 2 teachers stated that when face to face, learners preferred using their books instead of Whiteboard.fi for the activity, and one commented about the difference between 16-19 year olds and 19+ learners, saying that 16-19 year olds did not see the reason for using online tools in class, and were less engaged than 19+ learners in class. Other differences included saying that whilst Desmos works better in a remote setting, class discussion is delayed in a remote/mixed setting compared to face-to-face(Q23).

Overall advantages of using the technology tools in a blended learning environment are (Q24):

- Half of the AR teachers commented that you are able to share ideas with learners and teachers instantly
- A quarter of teachers said the tech tools enabled stimulating class activities
- Improved work life balance
- Enable personalised learning

Overall disadvantages of using the technology tools in a blended learning environment are (Q25):

- 7 of 8 teachers stated that relying on technology is a disadvantage as Wi-Fi/tech issues can cause negative impacts.
- A quarter of teachers discussed that it can be difficult to find an appropriate space to work in
- Other disadvantages stated were that some vocational area learners are less engaged than others (IT learners), that using technology can cause negative distractions in lesson, and that you lose interaction time with learners when you are using online tools.

When asked whether their opinions had changed about how the tools can be used for different purposes over the course of the project (Q28), all teachers either said their views had evolved or that they had a partial shift in attitude. Half of the teachers said they had developed new ways of working, and a quarter discussed real applications of using the tools in their practice.

Impact on learners

All teachers felt that the tools were either somewhat effective, effective or highly effective with enabling learners to develop their fluency and variation in their maths learning (1 – somewhat, 5 - effective, 2 – highly effective) (Q13). When asked how the activities impacted learners' flexibility, accuracy and efficacy, the most common response was that the activities helped learners to develop their use of appropriate strategies to solve problems. 2 out of the 3 teachers commented that the SSDD activity on Whiteboard.fi impacted learner accuracy and flexibility. Immediate feedback and skills identification were also mentioned as factors. Other comments were that there was increased flexibility using Desmos, and that motivation was increased by the Tricky Question activity (Q12).

When asked about what impact the project has had on learners overall (Q16), most teachers felt that the tools had improved learners' learning and mathematical skills (D, P, WB & CT)[1] – factors mentioned included enabling learner ownership (D & P), enabling reflection on learning (D, WB), improving the connectivity of learning (D & WB), increasing fluency and flexibility (D & WB), increased confidence (D), improved feedback to learners (D & WB) and improved use of technology. Half the teachers felt the tools enabled reflection on learning (WB & D) and increased engagement (D & P) and attendance – teachers mentioned that the learners enjoyed the activities. However, half of the teachers also said that whilst there was some impact, the impact was limited due to the following factors:

- Time pressures
- Changes to learning environments
- Low number of trials with the interventions
- Learner confidence

When asked to describe the overall learner response (Q17) to using the technology tools for their maths learning, 6 out of 8 teachers described positive responses, citing increased engagement, impact from feedback and increased collaboration with a "community feeling", whilst 2 out of 8 described negative responses, citing that weaker learners were less engaged and struggled with some of the Desmos tasks, and that Padlet could sometimes lead to pressure due to less possibilities for anonymisation. Teachers also commented that some learners preferred bookwork, and that initial access and continuing tech problems impacted progression. For Century Tech, it was a mixed picture, with mixed engagement, though a positive impact on learning when learners did engage.

Impact on teacher practice

In terms of impact of the project on teachers' own teaching practice (Q18), all teacher responses were positive – the most notable reasons given below:

- Increased confidence and skills with technology
- Increased knowledge of how to use the technology tools for the specific purposes
- Improved and more efficient teaching practice (including for problem-solving)
- Increased reflection on their teaching practice and usage of technology tools

Other reasons given relate to easier in class feedback, increased awareness of fluency and variation activities and the impact they can have on learners, being re-inspired, and increases in action research related skills.

[1] Key for abbreviations: D – Desmos, P – Padlet, WB – Whiteboard.fi, CT – Century Tech

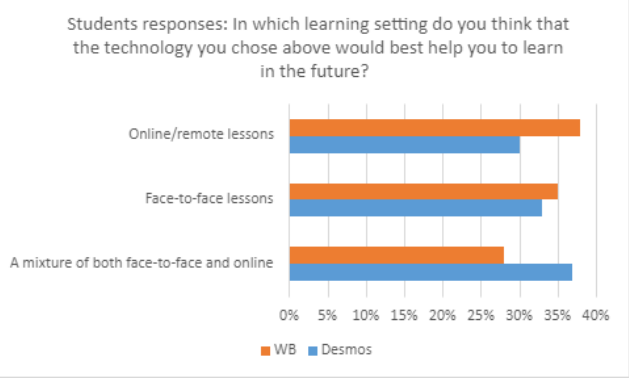
All teachers felt that being part of the action research project helped them to deliver lessons in different learning environments (Q19). When asked to explain how the AR project helped (Q20), a wide variety of answers were given which included the following: it helped them to consider how best to use the technology for these learning environments, and with the learners; sharing this knowledge impacted their colleagues; knowledge of new tools was gained; and learner engagement increased.

Almost all teachers can see themselves using the tools in face-to-face classrooms in the future (Q26); half of the teachers' comments related to seeing pedagogical advances when using the tools and a quarter said they saw positive engagement with the technology. Some teachers said that they would only use the tools remotely, or with the right technology, and other reasons for not continuing the technology in face-to-face classes included engagement issues and distractions with technology (Q27).

Final Learner Questionnaire

For the final learner reflective questionnaire, like the final teacher questionnaire, we were able to code qualitative answers, and the analysis led to categorisation of our key findings: impact on engagement, fluency and problem solving, how using the tool changed dependent on the learning environment and comparisons between the tools of Desmos and Whiteboard.fi. Whilst most learners answered that as a result of the interventions they became more engaged with their maths learning (over 60% for Whiteboard.fi and almost 70% for Desmos), almost 40% of learners answered that they felt they became a better problem solver (for both Whiteboard.fi and Desmos) and some answered that using technology they became more fluent – a higher proportion for Desmos. This is in contrast to the immediate responses given to the learner forms but may give a more indicative result of the impact of the interventions – this questionnaire included learners who had not completed all of the interventions and included responses from all learners across all 4 colleges. Despite this, the majority (just under 80%) of learners want to do the activities using Whiteboard.fi and Desmos again (same figures for both), including in a face-to-face setting.

For the different settings, most learners answered that their experience of using Desmos changed when they were accessing the class remotely vs F2F, whereas, the opposite was true for Whiteboard.fi, with most learners answering that their experience remained the same. In a mixed delivery learning environment, whilst nearly all learners said their experience was not changed using Desmos, this was only half of learners for Whiteboard.fi. In terms of which learning setting learners thought the technology helped them learn best, this can be seen in the graph below:



Whilst both technology tools showed around a third of learners thought it helped them learn best in F2F lessons, Whiteboard.fi had the edge when it came to online/remote lessons, but Desmos was more popular for a mixture of both F2F and online lessons. In terms of how the activities impacted on their maths learning for Desmos, of the learners who gave a response, comments included enjoyment, motivation, engagement, confidence, helping their maths learning and understanding, and improvement in problem solving skills. For Whiteboard.fi, there were similar responses, but the numbers answering were lower than for Desmos.

Conclusions and Recommendations

Key Conclusions

Our main conclusions from our action research can be split into how the technology tools were used, the impact of our different cycles on confidence, learner and teacher response to the different cycles and the overall impact on learners and teachers.

From the results from the different cycles, both learner and teacher opinion of using the online tools for maths teaching evolved either partially or fully – particularly with regards to whether they would like to use the tools for F2F teaching. By the final reflections, the majority of learners wanted to use the tools to do the activities again for their maths learning, and for teachers, the same could be said for Desmos. There was reluctance with regards to Whiteboard.fi from teachers, due to the impact of technical issues, but the evidence from the learner results indicate that whilst they struggled with using Whiteboard.fi, they could still see the tool as being useful for their maths learning in class. Both teachers and learners placed a high value on the feedback that could be given with both Desmos and Whiteboard.fi, which teachers felt had a positive impact on learner efficiency, flexibility and accuracy – our key breakdown of learner fluency. Another impact on learner fluency from the use of the online tools was the enabling of learner reflection and student ownership – this was felt to be a key driver that improved students' learning and mathematical skills.

We also found as a group that learner engagement affected learner progress, and teachers felt that the tools and interventions did increase learner engagement and attendance to varying degrees. Certainly, a majority of learners felt that the interventions increased their engagement with their maths learning. However, we as an ARG felt that a longer trial section would have afforded more reliable results.

From a teacher perspective, and to support our reading and recommendations from our literature review, all teachers reported improved levels of confidence as a result of our sharing sessions and bespoke CPD, as well as improved skills. Not only this, but the sharing sessions, time for reflection and CPD allowed for teachers to increase their knowledge of how to use the technology tools for specific pedagogical purposes and in turn, they felt this improved and made their teaching practice more efficient.

One of the teachers described the CPD, tools and being part of the action research as a "game changer" for their practice! The tools allowed us to see what students were doing when we weren't with them, but they also showed us that it is possible to digitise a mastery classroom.

Even though some teachers felt, and still feel, that in different delivery environments you lose a certain atmosphere and buzz that can be created in a mastery classroom, the benefits of being able to identify learner misconceptions and give instant feedback individually and as a whole class with both tools, surpassed for some teachers the feedback possibilities in a traditional F2F mastery classroom.

Finally, one recurrent theme which ran through teacher reflections was the need for more time. Whether in the initial stages of time to explore tools as teachers and learners, time to develop the activities further to use more specifically for fluency, or simply time in lesson affected by technology limitations or login issues with tools, teachers felt that the impact of the project was affected by time allowed. It is important to recognise that the time needed also depended very much on an individual and class basis and varied from teacher to teacher as well as learner to learner.

For our next steps, all teachers have said they want to continue to use Desmos in F2F lessons in some way (and 75% of learners want this too), but teachers also want to explore the flip learning possibilities for Desmos.

For Whiteboard.fi, next steps would need to involve either changes or adaptations to the technology itself, in order to then be able to continue to develop the activities with variation for fluency.

We also want to explore using different mediums for the activities we developed, as well as looking at how we can adapt the activities and tool usage for lower level GCSE and Functional Skills learners.

Recommendations

From this action research of exploring the use of technology and teacher confidence to develop supporting teaching and learning with variation for fluency in 16-19 year old GCSE re-sit learners, within different learning environments, with particular reference to Desmos and Whiteboard.fi, recommendations are for FE teachers, managers but could be relevant in secondary or other settings. We feel that:

- Managers and leaders should ensure that teachers are given adequate time and support to develop their technology skills and confidence with specific tools with individual practice, sharing sessions, sharing practice amongst teachers and bespoke CPD with a chance for individual, specific questions which are technically related and pedagogically related
- Likewise, teachers should build in time for learners to become familiar with the technology tool you are using for their maths learning if it is either a tool new to them, using it in a different learning environment or using it on a new piece of hardware, whilst recognising that some learners will need longer to become familiar with a tool than others
- Teachers and managers alike should recognise and accept the limitations of each technology tool, such as the loss of a community feeling, the ability to write maths, or manipulatives, and ensure you plan appropriately – identifying other tools which could fill those gaps (such as MathsBot for manipulatives or other virtual maths tools systems) – whilst we are working towards a perfect all-encompassing maths online tool, the variety of using different tools can drive engagement
- Teachers and managers should share and discuss your tool usage at a wider forum where possible – this year we were able to discuss with other teachers both at our colleges and across the CfEM network, this had a positive impact on both the project and our practice
- Teachers should allow for extra time when using online tools in FE maths classes, particularly when you are in remote or mixed delivery settings – the nature of lower attendance/continuing enrolment meant that in most sessions we used tools, time needed to be built in to ensure that all learners were able to use the tool effectively and login. In addition to this, Wi-Fi connections or equipment access issues also affect the time taken to do activities, and learner ability.
- Desmos as a platform can be particularly useful for impacting learner efficiency, fluency and accuracy, with its uses for identifying and addressing misconceptions, instant feedback possibilities, and wide variety of activity styles that can be created on the platform. Desmos is also particularly useful when you want to create a specifically sequenced activity using variation. Desmos can be used for both flip learning, in lesson activities, and has strengths in allowing for stretch and challenge and differentiation.

- Whilst being cautious of technical difficulties, teachers can use Whiteboard.fi particularly for in lesson activities, identifying and addressing whole class misconceptions, looking at structure, and using multiple representations.

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Appendices

All Appendices can be found at this Padlet:
https://padlet.com/elizabeth_hopker/20_21_NewhamCfEMAR1

Appendix 1: Padlet to compare different available technologies

https://padlet.com/elizabeth_hopker/ARG1Tech

Appendix 2: Initial learner questionnaire

See Cycle 2 column of Padlet here:
https://padlet.com/elizabeth_hopker/20_21_NewhamCfEMAR1

Appendix 3: Initial Teacher questionnaire

See Cycle 2 column of Padlet here:
https://padlet.com/elizabeth_hopker/20_21_NewhamCfEMAR1

Appendix 4: Teacher reflection log proforma

Action Research Project 1 Newham CfEM Teacher reflection proforma	
Lesson time and date:	
Key info about the class (attendance, delivery mode, age range etc):	
Technology used:	
How the technology was used:	
Access issues:	
In lesson adaptations made for any access issues:	
Any changes to be made when using the tools in future lessons:	
Overall reflections:	

Appendix 5: Teacher visit reflection log

Action Research Project 1 Newham CfEM Teacher visit reflection questions			
Teacher delivering:		Teacher visiting:	
Key info about the group:			
Which technology tools are used in the session?			
How confident does the delivering teacher appear with using the technology? /How confident did you feel using the technology?			
How confident do the students appear with using the technology?			
Describe any issues with moving from one technology tool to another			
How engaged do the students seem? Out of all the students on the call, how many respond and use the technology?			
How do students respond to different platforms or tools? How easy is it for students to use different platforms in one lesson?			

If you were the delivering teacher, the question to answer is highlighted in yellow.

Appendix 6: Intervention Activity Plan proforma

Action Research Newham CfEM Project 1 – To explore the use of technology and develop ways to use it to support the teaching of variation and fluency to 16 – 19 GCSE Maths resit learners in a blended learning environment.

Include timings for each activity

<table>
<tr><td colspan="3">ARG intervention Activity</td></tr>
<tr><td colspan="3">Teacher:
College:</td></tr>
<tr><td colspan="3">Notes about the class</td></tr>
<tr><td>Relevant ARG objectives</td><td>2. To identify possible barriers to access and delivery using IT - specifically for fluency and variation

4. To research and plan interventions, that focus on variation and fluency, collaboratively as a maths team and trial with learners.

What technology will work for fluency and variation, what elements of a teaching lesson - in order to incorporate fluency and variation - does the technology need to support.

3. To develop staff confidence and knowledge of using technology for teaching maths - what interventions will work for which teachers

5. To investigate how learners respond differently to different teaching interventions and strategies - what interventions work for which learners

7. To collect and use teacher reflections on ease/usefulness of each intervention</td><td></td></tr>
<tr><td>Big picture</td><td>Using technology to develop…
- Deeper understanding
- Efficiency: learners choose efficient strategies and don’t get bogged down in too many steps
- Accuracy: learners are accurate in their workings, have great recall of facts and double check their answers
- Flexibility: learners understand that there are many ways to solve a problem</td><td></td></tr>
</table>

	Building maths fluency in your classroom | MNP Blog : Maths — No Problem!	
Outline of intervention	1. Students attempt a question, they would do a confidence checker 2. … 3. Students attempt a question again, they would do a confidence checker	
Digital platform		
Link to platform		
Pre-assessment	• Question & Confidence checker	Question in here
Intervention Plan		
Post assessment	Students have another go at the tricky exam question 1. Students attempt the tricky exam question without support. 2. Students review their confidence of attempting tricky exam questions	
Evaluation of lesson (Student)	On MS forms Questions – see link	
Reflection form (Teacher)	Questions – see MS forms link 1. How well was the tech suited to the activity? 2. How learners responded 3. How confident you as a teacher felt with doing this style of activity compared to similar in class/non-tech using activities.	

Appendix 7: Link to completed intervention plans

See “Intervention Activity Plans” column on this Padlet here:
https://padlet.com/elizabeth_hopker/20_21_NewhamCfEMAR1

Appendix 8: Link to Desmos activities

https://teacher.desmos.com/collection/604611c2ee94110b711a0fde

Appendix 9: Whiteboard.fi Activities

Please scroll down in “Cycle 3” at this Padlet board to see PDF versions and sharing codes of the Whiteboard.fi activities:
https://padlet.com/elizabeth_hopker/20_21_NewhamCfEMAR1

SSDD boards from: https://ssddproblems.com/

Appendix 10: Teacher activity review form

See Cycle 3 column of Padlet here:
https://padlet.com/elizabeth_hopker/20_21_NewhamCfEMAR1

Appendix 11: Learner activity review form

See Cycle 3 column of Padlet here:
https://padlet.com/elizabeth_hopker/20_21_NewhamCfEMAR1

Appendix 12: Final Teacher Questionnaire

See Cycle 3 column of Padlet here:
https://padlet.com/elizabeth_hopker/20_21_NewhamCfEMAR1

Appendix 13: Final Learner Questionnaire:

See Cycle 3 column of Padlet here:
https://padlet.com/elizabeth_hopker/20_21_NewhamCfEMAR1