CENTRES FOR EXCELLENCE IN MATHS

Online: On Point or Off-kilter?

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OUR PARTNERS

FUNDED BY

Department for Education

Working in partnership with the Education and Training Foundation to deliver this programme.

Acknowledgements

Thanks go to our network partners – Carlisle College, Furness College, Kendal College and Lancaster and Morecambe College whose contributions and support were invaluable. Our thanks also go to our wider network partners - Hugh Baird College and the Energy Coast University Technical College for their contribution to our final piece of research.

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.

Abstract

This small-scale research explores how technology can support learners to experience maths in new ways, supporting mastery skills and learner independence. The COVID pandemic drove schools and colleges to move their teaching online, and this afforded the perfect opportunity to investigate what exactly is required - for both learner and teacher – to design and effectively use digital pedagogical approaches in mathematics teaching. It explores the digital and pedagogical barriers faced by both teachers and learners and suggests ways to address these barriers.

The research involved fourteen teachers from six colleges and one secondary school. Over a period of five months, they undertook three interventions exploring: collaboration supporting learner interaction; independent work and formative feedback; using evidence-based strategies in an online setting.

Data was collected via tutor reports, tutor reflective journals and questionnaires and charts. The learner voice was captured via questionnaires and Socrative.

The research indicates that the role of the teacher is vital in building online relationships, but also reveals that the 'teacher' role in a digital environment is often misunderstood or displaced in favour of facilitating technological applications and software. There is a tendency to 'replace' classroom teaching rather than 'remodel'. Teachers lack both the time and confidence in their own digital skills to create their own content, relying on more traditional classroom-based methods or 'off the shelf' mathematics software packages.

The report makes a number of recommendations to address these issues which includes: a whole college approach to a dedicated CPD policy that affords both time and regularity, and one that takes into account tutor constraints, thus allowing teachers access to technology that can enhance and expand the learner experience in maths; improving the awareness of digital pedagogy as a threshold concept, avoiding 'like for like' classroom modelling; using digitally-focused reflective models to improve maths TLA.

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Introduction

In undertaking this piece of action research, our aim was to:

Find out how we use technology to support learners to experience mathematics in new ways, which give new insights into concepts and structures, whilst supporting the independent learner at its heart.

Our research objectives were as follows:

1. How can learners be supported to study **independently** online in order to maximise their outcomes?
2. How can **collaborative** learning be delivered online to improve learners' self-efficacy and make them into independent learners?
3. What is the **role of the teacher** in online learning and how can this be structured in order to make the best possible use of teaching, learning and assessment?
4. What **support/CPD** does the teacher need to confidently deliver a package of online learning resources?
5. What strategies can the teacher use to both increase initial **learner engagement** and sustain it?
6. How can **collaborative** learning techniques promote **peer support** and reduce feelings of isolation experienced with online learning?

Research Environment

The Lakes College Partnership consists of five colleges, with Lakes College as the lead, supported by Carlisle, Furness, Kendal, and Lancaster and Morecambe Colleges. All five colleges in the partnership are small to medium-sized community FE and HE colleges, serving relatively distinct geographical catchment areas across the whole of Cumbria and the Lancaster area.

Each college has an inclusive, non-selective recruitment philosophy and practices, and takes great care to ensure the mix and balance of provision offered meets local needs. These needs and the subsequent offer vary from college to college to some extent, noting the large geographical area covered. For example, three of the colleges have A-Level provision, whilst two do not. All are active in apprenticeships, and work directly with employers in their sub-regions, committing to a wide and deep offer of FE and HE wherever economic and possible. Apart from the Barrow area and Furness College, all colleges compete with local schools, to a greater or lesser extent, to recruit 16-18-year-old students. Furness College merged with the local Sixth Form College 4 years ago.

With the exception of Kendal, all colleges work with communities that exhibit varying degrees of social deprivation, unemployment, and associated challenges. This includes ‘cold spots’ of HE

participation. Whilst NEET levels and unemployment are relatively low, there are pockets of deep and long-standing deprivation throughout the areas covered by the colleges.

11–16 education performance throughout the area has been at or below national averages for several years; however, this has recently shown slight improvement. Relatively large numbers of 16-18-year-olds leave school and enrol at the partner colleges with poor attainment generally at GCSE level and notably low attainment in mathematics. Invariably, they have a negative disposition towards GSCE mathematics and resit starting points, which presents a considerable challenge to each college.

Response to Covid 19

September 2020

Each college responded to the challenges of the Covid pandemic in slightly different ways in terms of teaching and learning:

- *Lakes College* taught all mathematics remotely, online through the College's VLE: Canvas.
- *Carlisle College* adopted a combined approach with learners operating in bubbles. Learners attended face-to-face for two days a week and worked remotely online for the remaining three days. Their remote, online learning was through Century, MyMaths and Microsoft Teams platforms.
- *Furness College* taught mathematics 100% face-to-face. Learners were using MathsWatch in the classroom, together with several software applications, e.g. Padlet.
- *Kendal College* and *Lancaster and Morecambe College* taught 100% face-to-face supported by online learning approaches using Microsoft Teams, One Note, MathsWatch, Padlet and PowerPoint.

January 2021

In response to the Government's directive for all face-to-face teaching in schools and colleges to cease until February half term, all partner colleges moved to online learning.

At this point in our research, we decided to invite some wider network partners to participate in the final action research activity. We approached three colleges and one secondary school from the Lancashire and Cumbria area. The school (Energy Coast UTC) and one college (Hugh Baird) replied with a positive response. These wider network partners agreed to collect data on which online strategies work when delivering maths, and what digital CPD did they need as teachers in order to facilitate effective online learning.

Reviewing the Literature

This action research sought to explore how technology was being utilised to support learners to experience maths in new ways. The research focus was the use of technology both in the classroom and remotely, to promote independence and learner collaboration, whilst also tracking progress. The project sought to provide an important opportunity to advance the understanding of teachers' Continual Professional Development (CPD) needs in relation to the use of technology in face-to-face, synchronous and asynchronous delivery, by empowering teachers with the confidence and skills to experiment with diverse online teaching approaches to enhance their learners' experience of mathematics.

Use of Technology in education

A potential barrier to online learning for learners, and possibly teachers, is the availability of appropriate hardware and a reliable internet connection. The pandemic highlighted this problem, with the Government investing money into the purchase of laptops and local organisations donating laptops to schools. Coupled with some teachers' reluctance to explore different online learning strategies through a lack of confidence/skill, the move to 100% online learning presented a number of significant challenges.

Burns (2010) examined the limited use of technology in education and potential causes more than 10 years ago - a lifetime in technology terms! His research focused on the relationship between the professional development required to confidently use technology, and the benefits it brought to the learning experience. One hundred and fifty teachers were questioned regarding their professional development needs. Feedback identified that all CPD should meet the "5Js": it must be 'job related, just enough, just in time, just in case and just try it' (ibid). The 5Js continue to be pertinent today with 'just try it' of particular relevance to this action research project.

As already described, during this research, the COVID pandemic drove schools and colleges to move their teaching online. Crawford-Thomas & Thomson (2020) state that 'The pandemic has triggered a re-think about the role of technology in education and has led to accelerated plans for incorporating digital learning into teaching and learning.' Regardless of the mode of delivery – one hundred percent online, face-to-face or a hybrid model - their research identifies a requirement for intensive CPD to ensure that teachers feel confident in adopting and using online learning approaches effectively.

For teachers who were reluctant to embrace the use of technology in their practice, the pandemic enforced engagement. Prior to this, in 2019 a JISC survey revealed that forty three percent of staff in Further Education considered themselves 'early adopters' of digital technology when they could see the clear benefit. The remaining 57% were still to be persuaded of the benefits of digital learning (Thomson, 2019). This demonstrates the importance of using appropriate online learning strategies, rather than the use of technology as a "gimmick" with little educational value. Importantly, Thomson (ibid) proposes that engagement requires teachers to change their practice, rather than organisations investing heavily in different technologies. Used appropriately, technology can 'maximise differentiation, independent progress and peer support.' (ibid).

Jesso & Kondratieva (2015) found that a gap exists between teachers' use of technology and its implementation in the classroom. Their research showed that although teachers of mathematics engaged with technology to support administrative and communication tasks, they rarely used math-specific technology. They attributed this to several factors, including concerns about low student engagement with technology, their own digital competency, and limited awareness of rapidly changing technological developments. Interviews revealed that if students found content difficult, teachers might be tempted to explore technology to support delivery, and if a tool was familiar, they might also consider using it. The research concluded that maths teachers require subject specific CPD, preferably led by a subject expert.

Dr R. Puentedura cited in Crawford-Thomas & Thomson (2020) introduced the SAMR model, a valuable digital tool that analyses the use of digital technology to transform classroom approaches. Reece & Walker (2007) liken this model, with its levels of increasing difficulty, to Bloom's Taxonomy of learning (1956). The SAMR model enables teachers to assess how they are using technology to shape teaching and learning practice. The levels increase from substitution to complete redefinition of a task, providing teachers with valuable insights into their use of different digital approaches and allowing them to identify essential CPD in order to reach the redefinition phase of the model. Throughout the action research interventions, some teachers employed this model, reflecting on their use of technology using OneNote reflective journals.

Planning the use of technology

Kline (2020) emphasises the importance of planning and organisation to optimise online learning and determine the best approaches to meet the growing need for information, ideas, reassurance, and real human connection. Kline highlights the importance of a safe environment where learners feel that their contributions will be listened to, respected, and equally valued. Geng et al (2019) agree, discussing the importance of emotionally and socially engaging learners in the learning process. This is further supported by Brindley et al (2009), who explored the importance of an enhanced sense of community in the online environment, resulting in increased skill acquisition and improved learning outcomes.

To better understand the use of technology in mathematical reasoning, Lassak (2015) used a variety of technologies to engage students. As well as careful choice, they highlighted the importance of planning. A key finding was that the use of technology allowed the teacher an improved awareness of students' understanding and, for the students, the opportunity to "…communicate and share mathematical thinking in ways that may not have been previously possible for them."

Thomson (2019) asserts that online learning requires three stages: blended learning through tutor input, self-paced practice with teacher and peer support, and mastery-based learning, with an exit ticket issued on completion of an assessment activity to enable progression. The exit ticket establishes an individual's progress, enabling the tutor to target the next steps through an online progress tracking system. This objectivist/constructivist stance promotes an individualised approach to learning, enabling learners to progress at a level appropriate to their understanding (Vygotsky, 1978).

Continuing Professional Development for digital competency

There is significant evidence supporting the need for robust training to support teachers in their use of technology. During the pandemic lockdown of 2020, Joyce (2020) undertook research into what works in online learning across the Further Education sector. Findings identified 'The varying competence and confidence of staff with information technology has affected providers' success in making the transition to online learning. Staff training has been crucial.'

Following the Further Education Technology Action Group (FETAG) report (2013), Swindon College launched an initiative that required learners to complete one hour per week of online study (York, 2017). Learners were required to independently complete work allocated by their course tutor. Delivery methods were determined by the tutors, who were given flexibility as to the mode of delivery. Evidence collected identified several themes, including practicality, purpose, accountability and workload. Tutors found creating an hour's online study more time consuming than planning the equivalent face-to-face lesson, highlighting a requirement to learn how to use and implement the technology. To overcome this barrier, Lakes College provided partners with a Padlet of resources and suggestions for use during each intervention phase, together with an additional short video of instruction where necessary.

A positive finding from York's research (ibid) was improved learner independence and a decline in incomplete work. Initial research with learners across several different curriculum areas, prior to the start of this action research, highlighted the importance of learners and teachers being technology-ready, with limited and inadequate equipment posing a major barrier to the effectiveness of online learning.

Rycroft-Smith et al's (2020) report on the design principles of digital maths learning resources provides several important insights. Although "off the shelf" online maths resources are available for teachers and learners, they are often considered to be of poor quality. This implies that there is a need for teachers to have the skill set to produce their own appropriate digital resources, as the selection of learning materials is crucial for remote learning. They concur with Thomson's (2019) view that objectivist and constructivist methods may be effective in remote teaching. Furthermore, learner feedback revealed learners were more comfortable participating in online learning than face-to-face, and that learning remotely gave more flexibility in terms of scheduling.

According to Mayer and Land (2003, 2005, 2006) cited in Cousin (2015), threshold concepts are key ideas essential for mastery of a subject. Once these concepts are understood, the experience is transformational and may be likened to that of 'passing through a threshold', causing a significant change in understanding. Threshold concepts are identified through five main characteristics: they are transformational, resulting in a change in ontological perspective and a conceptual shift; they are frequently irreversible; they are integrative, revealing hidden connections; they are bounded, in that they can only illuminate until the next threshold concept is encountered; they are likely to involve "troublesome knowledge" (ibid). Since all these characteristics can be applied to the concepts of online teaching and digital pedagogy, it is reasonable to identify them as threshold concepts for teachers of mathematics (and other disciplines). This presents a significant challenge for those planning and delivering CPD.

Flipping Learning

Previous research (e.g., Straw et al, 2016; DeSantis et. al, 2015) has established clear benefits where a flipped learning approach is successful. For Straw et al (2016), these include providing additional class time for active learning approaches (where learners can practice and apply mathematical understanding), coaching on a one-to-one basis by the teacher, and collaborative and whole-class discussion. A flipped learning approach facilitates independent learning by requiring learners to take ownership of their learning, resulting in deeper knowledge and quicker progress, which in turn improves confidence. However, challenges included whether teachers were receptive to this type of delivery, their ability to deliver in this way, the availability of technology and the suitability of resources used.

Joyce (2020) discussed critical factors that can impact engagement and are generally associated with disengagement in online learning settings. A key finding of this research is that online learners are at greater risk of feeling isolated. Online chat functions did not replace classroom experience. They recommend engaging with learners to make personal connections as a teacher and encouraging them to connect with peers. They draw attention to the value of differentiating the curriculum using a variety of digital tools in order to maximize participation.

DeSantis et. al (2015) cited in Araujo et al. (2017) carried out a comparison of one occurrence of flipped geometry instruction with non-flipped teaching and in terms of learners' mathematical progress found no noteworthy distinctions. However, their research stated that there was a minimal preference for a non-flipped approach. Research in a university setting conducted by Love, et. al (2014) and Sahin, Cavlazoglu and Zeytuncu (2015) was more positive about a flipped learning approach. However, there was no detail regarding variability of flipped methods that might affect learners' views.

Keeping on track

The necessity to track and demonstrate student progress is an essential requirement for any teacher. Beere (2010) states that in order for a lesson to be judged outstanding, it is essential that all learners make progress, while Coe et al (2014) state that if students are not making progress, then teaching is ineffective. This is linked to the concept of "effective teaching", which is defined as "...that which leads to improved student achievement" (ibid). Whilst admitting it is not easy to define what 'effective teaching' is, they conclude that it can be measured through the progress made by students. The research identified strong evidence to indicate that teachers with good content knowledge are better able to understand how students think about a subject and are more likely to identify common misconceptions leading to good progress. In contrast to this, Fenstermacher & Richardson (2005) assert that that a direct link cannot be made between teaching and student performance without addressing a range of complexities.

Day (2019) carried out research into the effects of teachers' autonomy and students' academic progress, examining the tensions between those teachers who welcomed collegially agreed change and those who did not. The research, in the form of a three-year case study, examined the impact of 'collegial autonomy' and its effects on academic progress. Those who embraced

this form of change in their practice saw an improvement in students' academic progress and performance, while those who resisted and challenged the collegial approach saw a decline in progress and attainment over the research period.

In essence, an online learning environment has benefits and limitations for both the teacher and the learner. Successful online learning requires careful planning and the inclusion of activities that promote peer engagement to prevent disengagement. Supporting a teacher to gain digital competence and increased confidence through focused CPD is essential to improve the learners' online learning experience through engaging and thought-provoking interactive activities.

Research Interventions

The Lakes College partnership consists of five colleges of Further Education. Twelve teachers were involved in the action research intervention, covering both GCSE mathematics and level two Functional Skills mathematics. The number of learners participating varied as delivery patterns were adapted to the constraints of the pandemic lockdown and learners adjusted to 100% online learning. An approximate number of learners who participated in the research across the five colleges was four hundred and fifty. In addition, we invited four wider network partners to undertake the final piece of research. One college of Further Education in Lancashire and one University Technical College worked with us, providing data on our final piece of action research based on a cohort of forty-four additional learners.

Through a series of online meetings with network partners, an action research plan was agreed. The initial intention had been to undertake three different activities for partner colleges and four activities for Lakes College. Our intended project start date was 9 November 2020, with an activity completion date of 28 February 2021. All the colleges faced unforeseen challenges with regard to the impact of the pandemic, and as a result, the plan was adjusted to start on 30 November 2020 and end on 12 March 2021, with a review after February half term. In addition, the fourth activity, based on using breakout rooms, was included within the third activity as an additional option for those colleges who had the capacity to offer them.

A lockdown in January made further adjustments necessary. With significant support and powerful sharing of ideas across our college partners, we adjusted our final activity and revisited our objectives to take account of new delivery patterns. Each online intervention was undertaken for approximately four weeks.

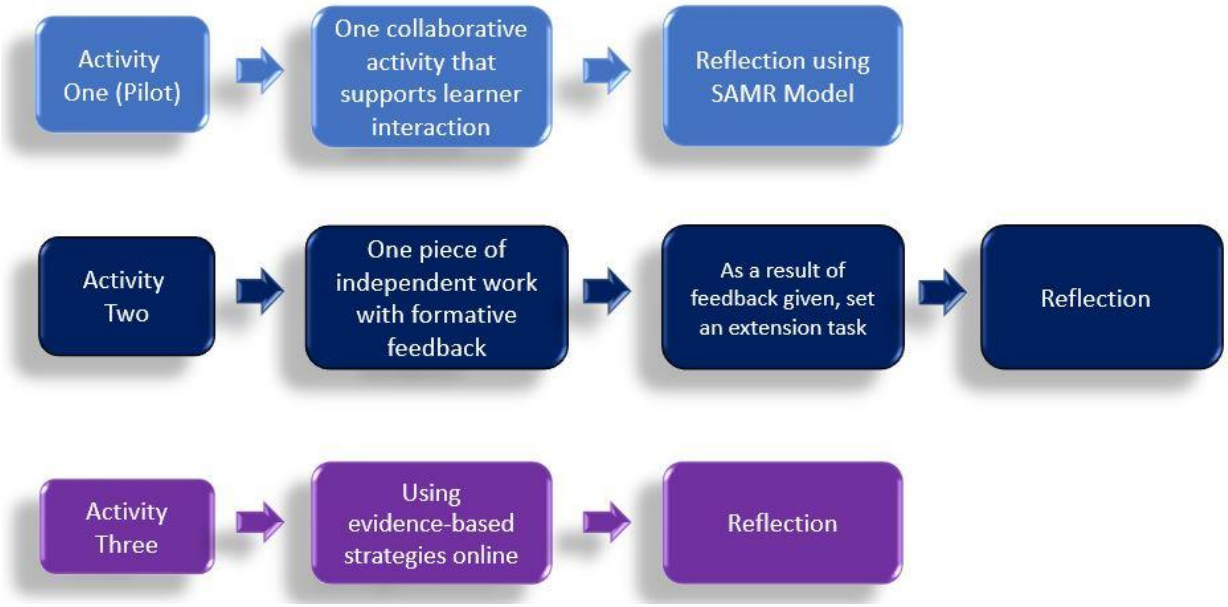

Figure 1 - Interventions

Throughout the data collection phase, Action Research Teachers had access to support from the lead college. A Zoom meeting introduced each new phase, and suggestions and support given with online pedagogy and applications. The first intervention was run as a pilot to identify possible problems that might be encountered.

The first phase focused on learner interaction and collaboration. All colleges were asked to undertake a collaborative activity online that supported and promoted learner interaction. The second phase considered how learners engaged with formative feedback online through audio, video or written feedback. The final intervention was the main focus, where we experimented with different evidence-based activities online.

Our intention was to understand two things:

1. When delivering online maths, what strategies work in terms of learner engagement and achievement? Additional themes might be increased independence and confidence.

2. What digital skills/CPD do teachers need to effectively and efficiently create and facilitate these activities?

Each college was given a revised plan in the light of teachers' responses in the context of Covid (Appendix 1 Intervention 3). We selected five of the top evidence-based teaching strategies and each college was asked a set of questions to inform their understanding.

1. How successful is the activity online in terms of learner engagement and achievement?

2. Are learners demonstrating increased confidence when participating in this activity?

3. What adjustments (if any) are needed to develop this activity?

4. Do you need any training to support the transition from face-to-face to online learning strategies?

5. As a final reflection, use the SAMR model to ascertain the effectiveness of this classroom-to-online activity.

A Padlet was shared with examples of resources that could be used. See QR Code.

Data Collection Methods

Data collection was undertaken throughout the project and adjustments were made following a short pilot of different methods. In principle, the cycle followed was:

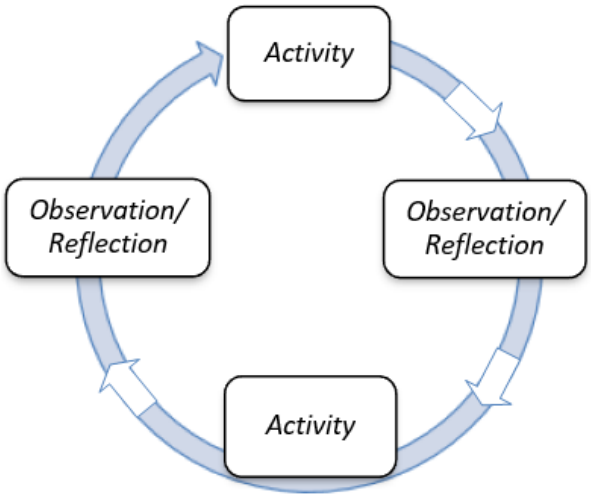

Figure 2 - Data Collection cycle

A mix of approaches was used with predominantly a qualitative focus. It was felt that the potential challenges of analysing qualitative data would be outweighed by the rich data collected. Quantitative data gave an indication of the percentage of learners' responses to set questions. The table below outlines data collection methods for each intervention.

Data Collection Method	Intervention 1 All colleges 9th Nov to 27th Nov 2020	Intervention 2 All colleges 30th Nov to 18th Dec 2020	Intervention 3 All colleges 4th Jan to 29th Jan 2021	Intervention 4 Lakes only 1st Feb to 26th Feb 2021
OneNote Reflective Journal	Yes	Yes	Yes	Yes
Questionnaires	No	Yes	No	No
Tutor reports	Yes	Yes	Yes	Yes

Table 1- Data Collection Methods

As a starting point, we asked all action research teachers to keep a reflective journal, using OneNote, which could be shared easily with the Lead. An online tutorial on how to use OneNote

was provided, together with a refresher on reflective practice and a suggestion as to a choice of reflective models.

Teachers were asked to complete their reflective journal after each session. In practice, it quickly became clear that teachers could only share their One Note journals within their own organisation, which led to an extra step of copying and pasting the content into a Word document and sending via email.

The next step was to gather data on the learner voice, complicated by a lack of face-to-face interaction, forcing any data collection of their views via an online platform. A Socrative quiz was created, which used a traffic light system for learners to identify, in real time, their level of understanding during the activity. This was piloted by the lead college and shared with partner colleges. After discussion, some colleges felt that they already had other methods of collecting the learner voice and it was agreed that partners could use a method of their own choice. Appendix 2 Socrative. As a result, a number of colleges adopted Microsoft forms as a tool to collect learner feedback.

Tutors submitted short reports after the final intervention, outlining their findings and feedback. These also provided us with a rich insight into those teachers' lived experience of online mathematics teaching during a global pandemic. Pseudonyms are used for colleges in the results section to support participants rights to anonymity (BERA, 2018).

Ethics

Action research teachers made all learners aware of the research being undertaken through a discussion at the start of the project, and permission was gained to use anonymised data. Participants were also informed that they had the right to withdraw their data at any point (Bera, 2018). Interventions were designed to be easily embedded into lessons and not onerous for teachers or detrimental to learners. In addition, regular reviews were implemented to ensure that interventions maximised opportunities for learning. As reflective practitioners, adjustments could be made quickly to respond to any ethical dilemmas, limiting risk and ensuring interventions were beneficial to learning and well-being. Data was anonymised and stored securely in line with GDPR guidelines (2018).

The action research teachers who took part in the research all had high workloads and additional responsibilities within their own organisations. To support their well-being, project funding was available in order to enable each college to release time, allowing them to focus on the research and ensure their workload was manageable. Sadly, this was somewhat negated by the onset of COVID and the requirement to move teaching online at short notice.

Results and Discussion

Four key themes emerged from the data:

- The importance of building online relationships**.**
- The role of the teacher.
- CPD and teacher confidence.
- Learner confidence and independence.

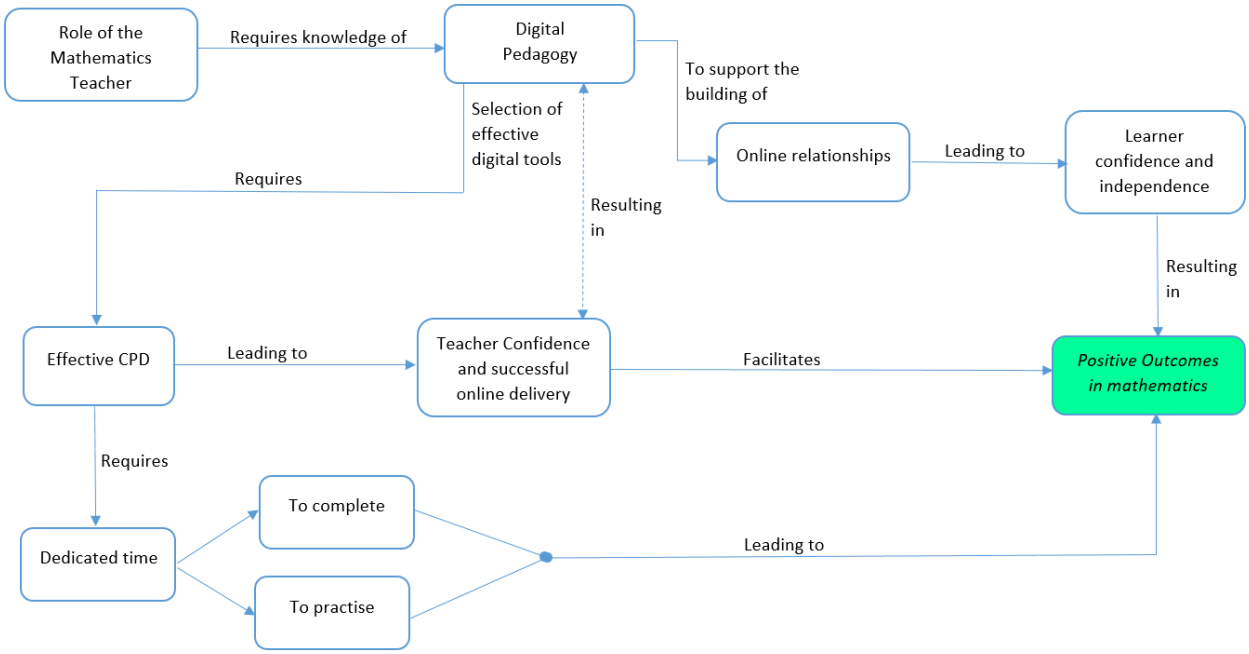

Figure 3 - Concept Diagram of Findings

The importance of building online relationships

Findings highlighted the importance of building positive online relationships between the teacher and learners. The main barrier to building relationships online was a lack of learner engagement.

> *"It was difficult to judge if a learner was there.... and listening" (Teacher, Daisy College)*
>
> *"I hadn't realised how much I relied on facial expression which was missing online" (Teacher, Rose College)*

There was evidence of frustration with the challenges of applying effective, targeted questioning online (Lavender, Tulip and Daisy colleges). Tutors acknowledged that this was a strategy they relied heavily on in a face-to-face situation, but online -

> *"...some learners have problems with their microphones or do not like to talk in a lesson that is being recorded." (Teacher, Rose College)*

The quality of sound also affected a tutor's ability to hear a learner's response. This was an ongoing theme with most of the colleges.

> *"…targeted questions being difficult due to lack of microphones" (Teacher, Rose College)*

A lack of two-way communication *"speaking into the void" (Teacher, Bluebell College and Lavender College).*

This was overcome using the private chat function for learners, giving them direct access to the tutor for advice in a private capacity (teacher, Tulip College, Violet College, Lavender College, Carnation College). Some tutors also overcame this by showing PowerPoints with questions and asking learners to put answers in the chat box. However, this strategy did not help to build online relationships, although there were some examples of peers answering their peers' questions with the public chat option, promoting a surface level of communication. This evidence is supported by Scull et al. (2020) who identified that online chat functions did not replace classroom experience. Evidence highlighted that interactive, fun activities increased collaboration and engagement.

Online learning is more than a learner just turning up to the session, it is about a learner's contribution to and engagement in the learning, which proved to be more challenging online than face-to-face. Lavender college introduced a strategy whereby learners only received an attendance mark if they had actively participated in the lesson. This quickly improved online contributions and participation.

Role of the Teacher

Digital Pedagogy

Data collection methods produced some rich data through tutor reports, tutor reflective journals and questionnaires and charts, capturing tutor reflections and feedback from learners.

A survey by Carnation College found that sixty percent of learners felt that support from their tutor was very important/important in online learning, suggesting the role of the teacher online is key to a rewarding learning experience. As discussed in the literature review, a JISC survey reported by Thomson, 2019, revealed that only forty three percent of staff in further education considered themselves to be 'early adopters' of digital technology, demonstrating that there is still some way to go.

Some tutors felt their role was divided between being a maths tutor and an IT facilitator. Typical responses included:

"It is interesting to see how the role of the teacher in an online setting slightly shifted to become an IT facilitator in addition to a maths teacher." (Marigold College);

"It took me a while to get to grips with and to understand how I could adapt them into my lesson delivery." (Lavender College);

"The teacher's role is as a facilitator, to locate or direct to the most efficacious resources, to be ready to respond to queries and encourage questions in a timely manner."

"There were assumptions about digital skills and devices."
(Tulip College).

For some colleges (Rose and Lavender), lesson focus was on modelling examples using an I do/We do/You do approach. There was an emphasis on "show and tell" with some tutors "sticking" to the format they would use in class.

"Teachers found that the pace of the lesson needed to be slower, with a requirement for extra help and simpler explanations". (Tulip College).

The teacher's role involved more encouragement and praise than they would normally give in a classroom situation, with learners missing the support from the teacher they experienced in a face-to-face situation where they could put up their hand and get immediate help. However, three colleges felt online learning gave opportunities to provide more support out of class time (Daisy, Rose and Carnation colleges), illustrating the benefits of an online setting for feedback and guidance between lessons.

In some cases, there was evidence of the learning cycle fracturing after the "doing" phase, with tutors reporting on a lack of in-class feedback about how a learner had understood a topic and the limitations of being able to quickly assess a learner's work online. Kline (2020) identified the importance of planning and organising to enhance online learning, thus ensuring teachers had a clear understanding of an individual learner's progress.

Typical responses identified that interactive approaches engaged the majority of learners. A multi-user whiteboard promoted peer support and interaction, although its success was plagued by technical problems if used on a phone.

Quizzes with a competitive element engaged many learners, but there was a need to be aware of the potentially negative impact on the confidence of others (Violet College). Polls were an effective tool to develop skills and timing for multiple choice question skills (Carnation College). Learners experienced feelings of isolation suggesting a lack of interaction, lots of PowerPoints and not much writing. Videos with tutor explanations and support proved popular at Violet College.

There was a limited choice of, or potentially a lack of time, to research "off the shelf" online resources. All tutors felt they had limited time, and sometimes skill, to create their own resources from scratch, with attempts to research "off the shelf" online resources proving frustrating. This

finding is supported by Rycroft-Smith et al (2020) research on the need for teachers to have the skill set to produce their own appropriate digital resources.

There was a significant difference in approach between those who adopted a face-to-face approach online, and those who had a greater understanding of, and confidence in, digital pedagogy. This was supported by Thomson (2019), who suggested that technology can 'maximise differentiation, independent progress and peer collaboration.

Where available, break out rooms gave learners time to think and share ideas. They enabled tutors to differentiate activities in each breakout room (Marigold, Carnation and Tulip Colleges). However, there was an acknowledgement that facilitating break out rooms was challenging, and greatly helped if there was a support assistant in the lesson (Carnation College). One college noted that collaboration in public chat dispelled feelings of isolation and encouraged peer support, but that this was only evident with higher ability groups (Carnation College). Evidence showed that all tutors made use of private and public chat to gather learner feedback, which was most effective when learner responses only went to the tutor.

For many teachers, a barrier to engagement was the lack of response from learners and limited digital skills.

> *"I was speaking into the void, and it was hard to check for understanding." (Teacher, Lavender College).*

This had a direct impact on the pace of the lesson, for example, as teachers were forced to wait while learners typed answers into the chat.

CPD and teacher confidence

Traditional mathematics teaching tended to be 'non-digital' with a teacher-centred approach involving a whiteboard, class discussion and practical exercises. Although there have been advancements towards the inclusion of technology in the mathematics classroom, this has largely depended on the teacher, their digital confidence and attitude to technology used as a tool to support teaching and learning. The COVID pandemic forced teachers and learners, regardless of digital competence, to engage with technology. Despite all teachers in this study receiving some digital training, there was evidence that the shift to online learning was, for some, confusing and stressful. The majority had received training in Microsoft Teams; however, there was often a requirement to interact with multiple platforms and software with little or no training, leading to a sense of frustration and stress. One teacher commented:

> *"Much of the in-house training received is too short and does not allow time to practice the skills. It also does not prepare you for when things do not function as they should." (Teacher, Tulip College)*

They went on to emphasize the importance of providing ongoing support and the need to invest time and money into regular digital training for staff. This echoes Crawford-Thomas & Thomson (2020), who identified the need for rigorous CPD to support online teaching. Then again, providing CPD is no guarantee of application.

> *“I have received CPD training on Microsoft Teams and Forms, along with other applications that I have not yet incorporated into my lessons.” (Teacher, Rose College).*

The majority of teachers who took part in the research used technology as a delivery mechanism rather than an innovative tool with the potential to shape practice. This is similar to the findings of Jesso & Kondratieva (2015) who found a gap between mathematics teachers use of technology and its implementation. This has implications for teachers of mathematics as there is the potential for mathematics to be left behind in a digital world where other subjects are embracing the use of technology.

Findings indicate that a mathematics teacher’s personal self-confidence in their digital skills and mindset has a direct impact on their attitudes towards digital tools and pedagogical delivery.

> *“I have to say I'm not a fan of online teaching and would much rather be in the classroom.” (Teacher, Daisy College).*

Feedback from teachers indicated it was common practice to attempt to duplicate what would happen in a physical classroom online, as a method of reassuring learners by providing a familiar structure to lessons.

> *“I have not used PADLET or breakout room options as I have tried to stick to the format that I would use in class to keep the teaching consistent.” (Teacher, Rose College).*

The indication is that a teacher's self-confidence, and how this might influence approaches to engagement with technology, is an important consideration for future Continued Professional Development.

Even teachers who developed confidence in their digital skills tended to use a more traditional approach to teaching mathematics, using digital tools as an appendage to support this. From the data collected, there was limited evidence of developing materials to support and move mathematics delivery forward. Mathematics as a subject seems to have been eclipsed in the hasty transition to online delivery. Instead, the focus appears to have firmly shifted towards developing the digital skills necessary for lesson delivery. Learners also appeared to be following this trajectory.

> *“Students often ask how to do …? Instead of what to do…? How to attach their work, how to share a screen, how to access Socrative ….” (Teacher, Marigold College).*

Since mathematics was only part of their study programme delivered online, it is interesting to note that some learners reported that they struggled to use technology effectively. This raises the question as to whether they encountered similar issues with their digital skills in other subjects. The ability to provide digital support for learners appears to have been hampered by teachers' rudimentary technical skills. Most teachers acknowledged that they lacked the basic digital competencies to enable them to provide advice about technical issues, or to know whether the technical difficulties a learner encountered were real.

Our findings indicate that the use of technology in teaching mathematics is a threshold concept with the potential to transform teaching and learning (Meyer and Land, 2006). This also holds true for the many learners who, despite being 'digital natives' (Prensky, 2001), struggled to use technology to access and engage in learning. Those teachers (and learners) could be considered to be in a state of liminality. This is a dynamic phase on the journey to competency where it is necessary to grapple with problematical ideas. The state of liminality is a space that must be negotiated in order to move across the threshold from lack of competence to full competency. Once this is navigated, there is a new intellectual capacity that transforms understanding. Many of the teachers and learners who struggled with technology were unable to enter a liminal state, which presented a further barrier to the teaching of mathematics and poses added challenge to the delivery of CPD.

Personal confidence plays an important part in the successful traversing of threshold concepts. Felton (2014) confirms this notion stating that to permanently cross a threshold you have to believe that you "belong on the other side".

Learner confidence and independence

There is potential conflict when a learner is taught a subject that they do not feel confident in, on a medium or platform that they do not also feel confident in, or which does not always work or is fit for purpose.

Figure 4 - Learner Feedback

As shown in Figure 4, when online maths teaching goes well, the responses are 'casually' positive – "great" "good" "enjoyable" "useful" "helpful" (learners, Tulip College). Compare this with the much more emotive feedback from those learners for whom online maths learning does not work: "mentally draining" "horrible" "traumatic" "stressful" (learners, Tulip College). Maths anxiety is well

documented and there has been much research on it in the past. Combine this with *online anxiety*, when learners lack the digital confidence to participate in the lesson effectively and then the outcome is doubly difficult. Teacher responses indicate that students more often ask "how to" in the context of finding and using digital information rather than "how to" apply the maths they are learning (teacher, Marigold College) Learners' responses showed that they have a lack of understanding of how they can be supported in their studies online:

> *"I am supposed to get support – how can that happen when we are on Teams?" (Learner, Daisy College); "I find it easier to work in a classroom so I can speak to the teacher face-to-face and that way she can see my work and I can get help easier" (Learner, Daisy College);*
>
> *"It can be complicated because we aren't in the classroom and we don't have our books to write in and the teacher isn't there to help in person" (Learner, Tulip College)*

Many learners need considerable support in mathematics, particularly those for whom mathematics still feels like a huge barrier they cannot cross. Therefore, a lack of understanding as to how they should be supported in an online class will further impact on their learning.

In addition, learners often use phones, adding another layer of problems if the work set does not suit being completed via this medium. Many learners gave feedback about the annoyance of using phones with signal interruptions, and certain activities being unsuccessful when tried on a phone. Other barriers to learning online included:

- Having to share devices with siblings.
- Lack of equipment.
- Microsoft Teams did not work on a phone.

If this is combined with a lack of tutor confidence, then a **third layer** of difficulty is added to the mix.

> *"The students were very helpful in teaching me technology" (Marigold College)*

– although this is positive comment/interaction, does the fact that the learners are having to 'teach the teacher' the technology detract from the importance/urgency of the subject/method they may be studying in that session/term?

The layers of difficulty mathematics teachers encountered when using technology, highlights the requirement for teachers (and learners) to have a minimum level of digital skills to be able to work confidently and minimise disruptions to learning. It is also important that teachers develop a firm understanding of "technological know-how" in terms of the suitability of devices chosen and the selected applications/software to enable learners to successfully engage with and achieve a task.

Conclusions and Recommendations

Our recommendations identified the importance of a whole college approach to support teachers and learners in an online learning environment.

Figure 5 - Recommended Ground Rules

A series of simple ground rules would benefit both teachers and learners, leading to enhanced confidence in a digital world.

Key outcomes from our research identify the following recommendations:

1. Engage in relevant CPD and allow time to practice and trial new applications in order to gain confidence.
2. Embed and measure using the college observation process.
3. Identify what online facilities learners have access to.
4. Insist that all learners have cameras turned on when requested.
5. Spend time building (online) relationships between tutor and learner, and between learners themselves (icebreakers).
6. Use interactive approaches, sometimes with a competitive element.
7. Avoid modelling practice on classroom/face-to-face lessons.

8. Chunk learning, providing different pathways for faster progression.
9. Be confident to use breakout rooms to promote collaboration.
10. Use public and private chat to give and receive feedback.

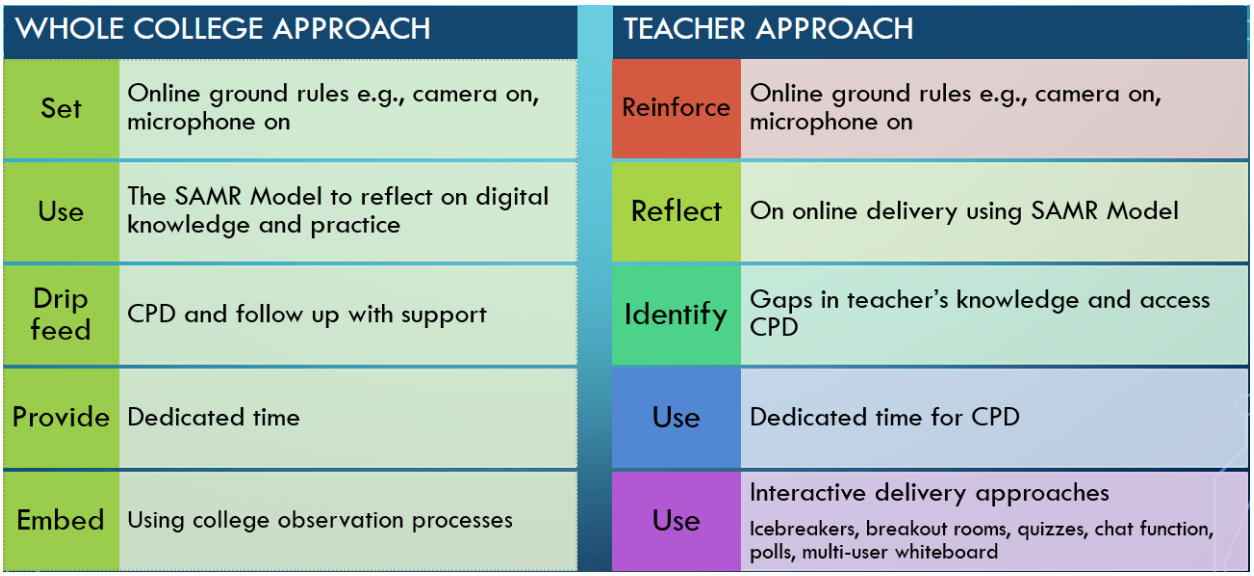

Figure 6 - Whole College and Teacher Approach

So what did we learn?

A whole college approach is required to provide an effective and cohesive online learning environment. Tutors need to be supported through targeted CPD, which is timely, accessible and appropriate for teaching mathematics, evidenced in practice, and could be part of the observation process. Tutors should be given time and support to explore and implement online strategies to promote an understanding of digital pedagogy and a consequent increase in confidence.

Whilst it is not necessary to invest large sums of money in hardware and software, it is important to ensure that all learners have access to the right equipment in order to maximise learning opportunities.

A whole college approach to ground rules regarding learner presence online – cameras and microphones on, will support the building of relationships and provide better opportunities for participation. It is important that teachers are provided with safeguarding training to support a 'cameras on' approach.

Procedures should be in place to ensure that the learner takes responsibility for their own digital issues such as using a 'student helpdesk' so that problems accessing and taking part in lessons may be addressed swiftly and without disruption to the lesson and to other learners.

Finally, an interactive approach to online learning maximised opportunities for collaboration and engagement.

References

Araujo, Zandra de; Otten, Samuel; Birisci, Salih (2017) Conceptualizing "Homework" in Flipped Mathematics Classes, [online] Available at: https://j-ets.net/ets/journals/20_1/22.pdf

Beere, J. (2010) *The Perfect OFSTED Lesson*, Carmarthen: Crown House Publishing Ltd

Brindley, J E.; Walti, C.; Blaschke, L. M. (2009) Creating Effective Collaborative Learning Groups in an Online Environment, [online] Available at: http://irrodl.org/index.php/irrodl/article/view/675/1271

British Educational Research Association [BERA] (2018) *Ethical Guidelines for Educational Research*, fourth edition, London. Accessed 6/10/20, [online] Available at: https://www.bera.ac.uk/researchers-resources/publications/ethicalguidelines-for-educational-research-2018

Burns, M. (2010), How to Help Teachers Use Technology in the Classroom - The 5Js Approach., *eLearn Magazine*, 9, Article 4, Sept. 2010, [online] Available at: https://dl.acm.org/doi/10.1145/1858579.1865476 Accessed on 14.10.20

Cousin, G. (2015) An introduction to threshold concepts, *Planet*, (17), pp. 4-5 Available at: https://www.tandfonline.com/doi/full/10.11120/plan.2006.00170004

Crawford Thomas, A., Thomson, C., (2020), Applying the SAMR model to aid your digital transformation, *Jisc*, 12 August 2020, [online] Accessed on 5.11.20 Available at: www.jisc.ac.uk/guides/applying-the-samr-model,

Coe, R., Aloisi, C., Higgins, S. & Major, L.E. (2014) *What makes great teaching? Review of the underpinning research*. [online] Accessed: 6.01.21 Available at: http://www.suttontrust.com/wp-content/uploads/2014/10/What-Makes-Great-Teaching-REPORT.pdf

Curtis F, (2019), Developing curiosity in the classroom: The case of the four triangles, *Proceedings of the British Society for Research into Learning Mathematics,* 39 (2) June 2019, Available at: https://bsrlm.org.uk/wp-content/uploads/2019/09/BSRLM-CP-39-2-8.pdf

Day, C. (2020), How teachers' individual autonomy may hinder students' academic progress and attainment: Professionalism in practice, *British Education Research Journal*, (46) pp. 247-264 Available at: https://doi.org/10.1002/berj.3577

DeSantis, J., Van Curen, R., Putsch, J., & Metzger, J. (2015) Do students learn more from a flip? An Exploration of the efficacy of flipped and traditional lessons, *Journal of Interactive Learning Research*, 26(1), pp. 39–63

Felton, P. (2014) *On the threshold with students*, July 2014, Durham University

Fenstermacher G.D., & Richardson, V., (2005) On Making Determinations of Quality Teaching, *Teacher College Record*, (107), pp. 186-213 Available at: http://dx.doi.org/10.1111/j.1467-9620.2005.00462.x

Geng, S., Law, K.M.Y., Niu, B., (2019), Investigating self-directed learning and technology readiness in a blended learning environment, *International Journal of Educational Technology in HE*, (16), 17 Available at: https://educationaltechnologyjournal.springeropen.com/articles/10.1186/s41239-019-0147-0#citeas

Jesso, A. T. & Kondratieva, M. F. (2016) Instructors' use of technology in post-secondary undergraduate mathematics teaching: a local study, *International Journal of Mathematical Education in Science and Technology*, (47) 2, pp. 216-232, Available from: https://doi.org/10.1080/0020739X.2015.1066896

Joyce P. (2020) Ofsted blog: schools, early years, further education and skills, 15 July, *Online education in further education and skills: learning about what works* [online] Accessed:15.03.21 Available at: *https://educationinspection.blog.gov.uk/2020/07/15/online-education-in-further-education-and-skills-learning-about-what-works/*

Kline, N. (2020), *The ten behaviours that generate effective thinking*, [online] Accessed 19.11.20, Available at www.timetothink.com/thinking-environment/the-ten-components/

Kline, N (2020), *Virtual meeting: A thinking environment guide to getting the best thinking* [online] Accessed 19.11.20, Available at www.timetothink.com/thinking-environment

Lassak, M. (2015) Effectively using multiple technologies, *International Journal of Mathematical Education in Science and Technology*, (46) 5, pp. 783-790

Love, B., Hodge, A., Grandgenett, N., & Swift, A. W. (2014) Student learning and perceptions in a flipped linear algebra course, *International Journal of Mathematical Education in Science and Technology*, 45(3), pp. 317–324

Meyer J.H.F., Land R. and Davies P. (2006), Implications of threshold concepts for course design and evaluation, in Meyer J.H.F. and Land R. (eds.), *Overcoming Barriers to Student Understanding: threshold concepts and troublesome knowledge*, London: Routledge

Reece, I. & Walker, S. (2007) *Teaching, Training and Learning*, 6th Edition, Sunderland: Business Education Publishers

Rycroft-Smith, L., Macey D., Horsman R. & McClure L., (2020), Cambridge Mathematics, *How would you classify the design principles of your digital maths learning resources?* [online] Accessed 25/11/20, Available at: https://www.cambridgemaths.org/Images/espresso_30_remote_mathematics_learning.pdf

Sahin, A., Cavlazoglu, B., & Zeytuncu, Y.E., (2015) Flipping a college calculus course: A Case study, *Educational Technology and Society*, 18(3), pp. 142–152

Straw, S., Quinlan, O., Harland, J., Walker, M. (2016) *Flipped learning: research report, National Foundation for Educational Research (NFER) and Nesta* [online] Accessed 09.11.20 Available at: https://apo.org.au/node/60747

Scull, J., Phillips, M., Sharma, U., Garnier, K., (2020) Innovations In Teacher Education At The Time Of COVID19, An Australian Perspective, *Journal of Education for Teaching*, (1) 10 pp. 497 - 506

Thomson, C. (2020), *None of this is really about technology...,* JISC 21 January 2020, [online] Accessed 19.11.20, Available at: www.jisc.ac.uk/new/none-of-this-is-really-about-technology-digital-transformation-and-culture-change

Thomson, C. (2019), *Innovation is all about keeping up with the technology, right?*, Jisc, 2 July 2019, [online] Accessed on 19.11.20, Available at http://inspiringlearning.jiscinvolve.org/wp/2019/07/innovation-is-all-about-keeping-up-with-the-tech-right/,

Vygotsky, L. S. (1978), *Mind in society: The development of higher psychological processes*, Cambridge, MA: Harvard University Press

York, N. (2017) Journal for Professional Teachers & Trainers in FE and Training Sector, issue No 2, Spring 2017, [online] Available at: https://set.et-foundation.co.uk. Accessed 24.11.20.

Appendices

Appendix 1 - Intervention 3

Start Date – week beginning Monday 18 January 2021

Review Date – week beginning Monday 22 February 2021

This piece of research involves experimenting with different activities online.

There are 2 main things we need to find out: what works and what you need to help make it work

We want to find out:

1. When delivering online maths, what strategies **work** in terms of learner engagement and achievement? Additional themes might be increased independence and confidence.
2. What digital skills/CPD do **you** need to effectively and efficiently create and facilitate these activities?

During this period, **use one or more evidence-based strategies** from the list below.

We would like EVERYONE to use number 1 – a graphical organizer for at least two sessions. For the remainder of the intervention, please select a different strategy from the list. A more detailed explanation is available in the link below – **The Core List.**

1. Summarise new learning in a graphical way. (this works well with Show and tell)
2. Show and tell, I do – We do – You do, model.
3. Questioning to check understanding – use a variety of questioning techniques and use some form of student response system.
4. Provide your learners with feedback - "dollops" and "dollops" of it to ensure they understand what they did well, where they are at and what they need to do next.
5. Productive group work – where this is possible for you to use break out rooms or work in Teams. Make sure that each member of the group is responsible for a specific task and allocate one person to bring all the different elements together.

Evidence Based Teaching Strategies - The Core List

You may wish to use an activity that you have previously used face to face. If you choose to do this, please ensure that you are adjusting it to be a fully interactive activity.

Using your OneNote reflective journal, you will reflect on the following:

- How successful is the activity online in terms learner engagement and achievement?
- Are learners demonstrating increased confidence when participating in this activity?
- What adjustments, if any, are needed to develop this activity?
- Do YOU need any training to support the transition from face to face to online learning strategies?
- As a final reflection, use the SAMR model to ascertain the effectiveness of this classroom-to-online activity.
- Use the Socrative tool or a method of your choice to find out what learners think about the strategy you have used.

Appendix 2 – Socrative

socrative

Name _____
Date _____

Your Voice Matters ('Copy')

Score _____

1. How well did you understand the starter?

2. What previous skills would have supported in the starter?

3. How does the format/structure of the lesson support your online learning?

4. What ideas do you have to make the lesson more interactive?

5. Do you get enough time to answer the questions in the online lesson?