Engaging with mathematics during Covid-19: students aged 16+ responding to a mathematics 'Box Set' of enrichment video materials

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This paper reports on a mathematics outreach programme, 'Bridging KS5 to University', that offered video materials to students aged 16+ during the school closures in spring/summer 2020 in Wales. The 13 videos, provided by the Further Mathematics Support Programme in Wales (FMSPW), ranging from 20 to 50 minutes long, included activities and exercises addressing mathematical topics outside the school curriculum, and engaging with them can thus be seen as enrichment activities. The study is primarily concerned with the ways in which students engaged with the materials and what motivated them to begin watching them and then continue to watch them. Interviews with students found that the students' behavioural and emotional engagement with the materials was much as might have been expected, but that their cognitive engagement was perhaps higher than expected. Considerations for developing further similar enrichment programmes for use in times of crisis, including equity issues, as well as for up-cycling the bridging programme for 'normal' times are also discussed.

Keywords: enrichment; video; pandemic; transition to university; box set.

1. Introduction

In March 2020, all schools and colleges in the UK, including Wales, were closed in order to limit the spread of the Coronavirus. Teachers were required to adopt emergency remote teaching: "a temporary shift of instructional delivery to an alternate delivery mode due to crisis circumstances. It involves the use of fully remote teaching solutions for instruction or education that would otherwise be delivered face-to-face or as blended or hybrid courses and that will return to that format once the crisis or emergency has abated" (Hodges *et al*., 2020, p.7). This placed considerable pressure on teachers (and students) and many schools provided a reduced educational offer characterised by diminished or slower paced curricula, reduced scaffolding and/or limited access to adult support (Hodgen *et al*., 2020).

Further, the external end-of-year examinations, which had been due to take place in May and June, were cancelled. Students were to be awarded Centre Assessed Grades. Given the pressure under which teachers were operating, and the fact that students were no longer required to take examinations, teaching of many 'exam classes' (with students who had been due to take an external examination) was cancelled. Consequently, the Wales Minister for Education called on Higher Education Institutions and other education providers in Wales to

create resources to help learners, especially those aged 16 or 18, to continue learning during the pandemic.

In response to the call and recognising that some students in their final year of school might disengage with mathematics for considerable time, the Further Mathematics Support Programme in Wales (FMSPW) launched a programme consisting of 13 video enrichment mathematics lectures, designed to help students transition from school to STEM university degrees: Bridging to University. The topics were wide-ranging, covering pure mathematics, statistics and mechanics areas and generally motivated by, or including, applications of mathematics and assumed the knowledge of A-level Mathematics but not Further Mathematics. See Appendices 1 and 2 for session examples and session topics.

The programme was launched in May and continued until mid-July which would be the end of a 'normal' school year in Wales. The take up could be considered as good with 7 further education colleges and 23 state-funded schools subscribing 98 students, all apparently intending to study at university. While no socio-demographic data is available on the participants, we note that the majority of participating schools were in two lower quartiles with respect to the proportion of students receiving free school meals, see Appendix 3. Female participants made 34% of the population. For comparison, around 40% and 30% of students studying A-level Mathematics and A-level further Mathematics are girls in Wales.

The programme ran from April to August and the videos received on average 75 views, with the first few videos receiving above 100 views and the videos at the end receiving circa 20 views each. Additionally, there were more than 500 downloads of additional materials. Feedback from those students who responded to the survey indicated that the programme was well received. Out of 18 students (9 girls and 9 boys including 6 students with disability) who completed the electronic feedback form that was emailed to all the students at the end of the course, 100% agreed that the programme helped them to continue learning mathematics while the schools were closed, and 92% perceived that the materials were good or excellent. Furthermore, a clear majority (94%) said that the sessions would have been helpful in 'normal' times.

The above motivated us to look at how students responded to the programme, that is how students engaged with the material, what strategies they employed and what characteristics of the programme design appeared to help them to remain engaged. To date, research about school closures has been mostly based on examining teacher, school or whole education system approaches to remote teaching, such as drawing on teacher surveys (see, e.g., Lucas *et al*., 2020; Hodgen *et al*., 2020). The present study, of a programme that has typical characteristics of the lockdown period, focuses on the perspective of students themselves.

2. Teacher and Student Engagement during Covid-19 school closures

According to the report by the Brooking Institution (2020), 85% of Pisa-participating countries offered online educational opportunities during the pandemic school closures with some 33% distributing video online. However, many studies expressed concerns about student engagement being low and unequal (see, e.g., Vegas, 2020; Montacute, 2020; Redmond *et al*., 2020). The reasons cited included students' limited access to technology, low level of support available at home, personal or family challenges but also shortfalls in the school approaches to

education, including low expectations of sustaining teaching instruction, tracking and monitoring students' progress (Gross and Opalka, 2020; Lake and Dussealut, 2020). Teachers teaching remotely, in particular, were worried about not being able to provide timely scaffolding to more disadvantaged learners or simply not knowing when students get stuck (Hodgen *et al.*, 2020). Digital equipment deficit, lack of clarity in school policy and guidance and its suitability for effective remote teaching, low or unrealistically high expectations of rapid teacher innovation but also time constraints were reported as obstacles to achieving effective remote teaching during the pandemic (Hodges *et al*., 2020; Lyakhova, 2020; Golding and Grima, 2020).

Several factors were found to promote better engagement, including students' prior attainment and resourcefulness (Hodgen et al., 2020). Better engagement was reported for higher achieving students but also whenever synchronous forms of interactions were employed (Lucas *et al*., 2020; Yao, 2020). The latter was problematic during the pandemic as preferences sometimes were expressed for asynchronous forms of engagement (see, e.g., Hodgen *et al*., 2020, Hodges *et al*., 2020; Welsh Government, 2020). These, it was argued, could ease pressure on families in terms of simultaneous use of broadband and electronic devices (Lyakhova, 2020); however, a lack of teacher presence could also increase pressure on parents to engage with their children around the content of asynchronous materials provided by the school. Further, if parental involvement is not possible, it may simply result in students disengaging with the materials.

In addition to understanding students' and their families' practical resources and problems and understanding how to develop teaching approaches in this environment (Engelbrecht *et al*. 2020a), learner resilience could be an important factor for engaging with learning. The challenges of the pandemic were expected to lead to many students making learning losses, but a small proportion of learners was expected to make gains (Iqbal *et al*., 2020; Kuhfeld *et al*., 2020). According to Hattie (2020a; 2020b), this depended on students' ability to self-regulate, which he defined as one's ability to know what to do when not knowing what to do.

The content of activities that students should have engaged in during the pandemic was debated. Some educators argued for non-routine, interesting tasks and those that could engage the whole family to increase participation (Hattie, 2020b). But teacher preferences for basic routine tasks to help students to engage were also reported, with one study highlighting that lockdown provided limited opportunities for mathematics talk, metacognitive activities and problem solving and led to a reduced level of challenge for high attaining students (Hodgen *et al*., 2020). The latter, perhaps signifies a reason for providing enrichment in mathematics in times of crisis.

3. Enrichment and mathematics learning

The definition of mathematics enrichment has been long debated in literature and there is no recognised framework for studying enrichment (Barbe, 1960; Piggott, 2007). When the term enrichment was introduced it was mostly set in the context of provision for the most able (see, e.g., Martinson, 1968; Worcester, 1979). However, with growing concerns about students' attitudes to mathematics together with low engagement beyond the age of 16 and poor

preparation for later studies, an argument in favour of mathematics enrichment for all students became increasingly popular (Smith, 2004; Royal Society, 2008). It was hoped that mathematical enrichment could compensate for the deficiency of traditional mathematics classrooms seen in outcomes such as poor attitudes towards mathematics and poor mathematical skills. Additionally, a belief that school mathematics affords mostly procedural teaching and has little space (or time) for creativity and problem solving (Jones and Simons, 2000; Richardson and Mishra, 2018; Wright 2021), which are intrinsic to mathematics learning (Schoenfeld, 1992), although difficult to test, explains the need for a complementary enriching experience of mathematics.

The above may explain why, as observed by Santos and Barmby (2010), research on mathematical enrichment mostly concern the hoped-for outcomes of enrichment activities rather than how learners interact with enrichment materials. We singled out two studies that complement each other in terms of their contexts: students engaging in a traditional classroom teacher-led synchronous mode of study (i.e., learning with others and at the same time) and student engagement with a free online library of learning enrichment resources (puzzles and problems) that could be used asynchronously (i.e., on their own and in their own time). The latter study, since it came relatively early in the adoption of widespread online learning and thus the materials were somewhat less sophisticated than what is available today is perhaps particularly pertinent, and its argument that materials were interesting enough to attract students in their own time is relevant to our interest in student engagement.

Feng (2005) studied some four mathematics enrichment programmes widespread in the UK and observed perceived benefits predominantly in terms of learners' mathematical development, personal and social development, support for mathematics learning at school and exposure to higher education. He also noted that these depend on the design of the programmes. Shorter regular classes were associated with gains in mathematical knowledge while benefits to personal and social development were more pronounced in a residential summer school that allowed a more immersive experience. Taking part in mathematical challenges was thought to benefit mathematics learning at school most through the experience of working under pressure in preparation for exams. At the same time, the activity made no difference to students' interest or perception of the subject. Generally, participating in enrichment is thought to help in consolidating mathematics studied at school, sometimes being seen as extra tuition and as helping to remedy shortfalls in school mathematics provision (especially if students were from low attaining schools or disadvantaged backgrounds). It was also noted that a sense of prestige associated with studying in university premises could influence students adopting a more mature mode of studying, such as learning for oneself rather than for a teacher. In terms of the actual engagement, students were found to interpret their experience according to their experiences of learning mathematics in school. For example, investing time and effort to identify and apply strategies, or exploring the answer and evaluating their method to solve problems was valued as opposed to just getting to the answer quickly using known techniques in class. The enrichment tasks were found to be interesting, more challenging and more difficult than tasks in school and more varied than those from a textbook, which students found exciting. Collaboration was seen as a key part of the experience with students learning from adult specialists and peers. Working with like-minded people was seen as enrichment in itself and

competition between students of the same age and similar level of attainment served as motivation to succeed and to understand.

Simon and Jones (2000) considered learner engagement with NRICH materials that were launched in the UK in 1996 with the aim to, "promote an interest in mathematics and to assist the mathematical development of children who have the potential to go on to study mathematical subjects at university" (2000, p. 104). This was planned to be achieved through the provision of regular online puzzles, problems and games, enhanced by an electronic answering facility for students to get in touch and ask questions. The study found that the materials were interesting enough to attract students in their own time. Engaging with the materials made students more interested in mathematics and more likely to continue studying mathematics. The problems were perceived to be better than at school: more interesting; offering novel contexts; more challenging; affording, "not just the simple types of mathematics", but problem solving. One student was quoted saying that the problems showed them, "how it feels to be stuck on a mathematics problem and not know how to do it". The majority accessed materials about once a month, with half of respondents doing it from home and another half from school. The latter allowed students to enliven their school day as they could spend time thinking and doing interesting maths during breaks or lunchtimes. No collaborative working was discussed in the study and one student was quoted as saying that she tried encouraging her friends to try NRICH although they did not like maths. Only a small proportion used NRICH answering service although those who did appreciated receiving replies and, especially, seeing their solutions published. Interestingly, for the majority of students there were no in person extra curriculum mathematics activities in school and half of the students were recommended NRICH by their teachers who were reported to feel, sometimes strongly, that NRICH was particularly good for mathematically able students.

In summary, mathematics enrichment could be defined "as simply activities that bring about engagement in mathematics" (Santos and Barmby, 2010, p.204), that enrich the student experience, and that offer benefits beyond the 'ordinary' classroom experience. These benefits, or outcomes, although not unsimilar to those one may expect from learning mathematics in school (or, indeed, in any context), may be difficult to realise for all students in mainstream education, leading to an assumption of mathematical enrichment taking place outside, and in addition to, the mainstream mathematics classroom.

4. Learning from and with video

We approach the theme of learning from video in the context of enrichment with caution. The use of technology in the mathematics classroom is a popular research subject (Clark-Wilson et al., 2020). Similarly, the use of technology outside the classroom, such as for flipped classroom activities or blended learning, contributing to the learning of the main school or university curricula, is well-studied (Borba *et al*., 2016). This is, however, not so much the case with enrichment, which is often perceived as involving more "hands-on", or even kinaesthetic tasks that are done in class (Santos & Barnby, 2010). Nevertheless, with a view that learning and doing mathematics is an important outcome of mathematics enrichment, we survey the studies on learning from video set within contexts other than enrichment.

Early studies on how students respond to video found that learners like the flexibility and control granted of when and how they access the video (Beyth-Marom *et al*., 2004), while some other elements of studying from a video were perceived as more onerous in comparison with more traditional study methods (Caspi *et al*., 2005). Pausing, rewinding and forwarding as well as summarising, note taking and navigating to were found to be beneficial to some learners when learning from video. However, it was also noted that navigating with video is not the same as with printed material and can be disruptive and that note-taking with video can cause cognitive overload.

However, according to research in educational psychology, the very fact that learning from video may require learners to adopt such learning strategies could be beneficial. The strategies listed above are known to generate deep learning in students which focuses on comprehension, generating explanations, and building concept maps as opposed to surface learning oriented toward reproducing subject matter by memorisation (Saljo, 1997; Magliano *et al*., 1999; Novak, 1990). Note taking and summarising is known to result in higher achievements than copying or reading pre-generated material (Lahtinen *et al*., 1997), and self-generated texts are associated with better memorisation when compared to materials prepared by others (Slamecka & Graf, 1978). Additionally, the novelty of studying through a different media could stimulate students to generate new spontaneous strategies which could be at least as effective as more familiar strategies imposed by training (Thornton *et al*., 1990).

Although certain elements of video design could stimulate learning, such as through incorporating audio or visual signalling to highlight important information, using audio and visual channels to convey complimentary information, keeping videos brief etc. (see, e.g., Brame, 2016), technology on its own does not influence learning. Clear evidence has been found that the teacher is the most important factor in influencing student activity (Hattie, 2003; Kieran *et al*., 2013). Consequently, more recent studies turned to the question of how teachers can use different types of technology to orchestrate or to enhance learning (Clark-Wilson *et al*., 2014). Incorporating clear and easy to use channels of communication (teacher to learner and peer to peer), e.g., forum boards, tools for assessment (peer-, self- and teacher-) and to provide prompt feedback alongside videos is considered good practice. Situating video within a learning management system and making video part of a larger homework assessment could stimulate learner engagement; while adding teacher explanatory texts, recording narrations, explaining links to preceding materials and expressions of teacher excitement about aspects of the content could increase a sense of social partnership between learner and teacher (Brame, 2016). The latter is particularly important in remote teaching, where physical presence is not possible.

In the title of this paper, we have referred to the programme under consideration as a ‘Box Set’. In this, we are referring to two box set attributes, one, most associated with serials, is the attempt to leave viewers with the desire to watch the next episode, the other, most associated with series, is to afford viewers agency in deciding in what order to watch the episodes. Lowe (2021) posed a question about whether asynchronous mode of learning enables students to ‘box set’ their degrees, that is to binge or skip as students see fit. He discussed the dichotomy between the (perceived) ability of young people to binge watch serials, and thus cover large amounts of content in a short time, with the advantages of slow considered study as well as the danger of students only accessing material which they perceive to be interesting

and skipping the less attractive material. Another study (Erickson *et al*., 2019) considered narrative engagement and asked whether binge watching engendered deeper connection between audiences and media content. The results of their experiment suggested that it did.

Recent studies (e.g. Borba *et al*, 2017) point out that digital content and on-demand learning is attractive to *mathematics-learners-with-mobiles*. However, there are some questions and concerns about how the access to online resources generally disrupts the traditional learning and teaching of mathematics when learners turn to online materials before, or even instead of, turning to teachers and how that could impact on the quality of mathematics learning.

5. FMSPW Covid-19 Programme Design

FMSPW produced 13 videos as that was approximately equivalent to the number of weeks in the summer term. The video lectures were between 30 and 45 minutes in length. This allowed for a mixture of instruction and activity for the student. The programme was intended to be an active learning experience rather than a passive one, hence pausing the videos to tackle questions was part of each session.

The full programme of talks was advertised to all state-funded schools and colleges in Wales and teachers were invited to subscribe their students directly with the programme with some schools opting to forward every release of the programme to their own students instead. To minimise a possible binge effect and to encourage students to adopt a routine, it was decided that talks would be released gradually, every week. In line with this, it was further decided to make each talk available for a limited period of time. The latter decision had to be abandoned as soon as the programme started, as FMSPW received late subscriptions and repeatedly was asked for the video to be displayed for longer. In the end, all the videos were displayed until the start of the next academic year. For easy access, all the videos were displayed on a dedicated YouTube channel.

For the content, academics in Welsh universities with previous experience in delivering enrichment lectures face-to-face, and hence with a good understanding of students of this age, were approached and recorded sessions on topics of their choice relevant to further study of mathematics at university. They were asked to choose something they were interested or passionate about, that the students could relate to, while also leading to mathematics studied at university. The content of the video was required to incorporate opportunities to do rather than merely to watch mathematics. The academics were asked to provide a short description in advance of the programme (see Appendix 1 for an example). In some cases, extra links to pre-requisite materials were added on advice of the FMSPW, if it was envisaged that not all students would have enough knowledge. Typical university modules where the topics would be useful were also listed. Three of the sessions were made by female academics and another three were offered bilingually in English and Welsh. Examples of session coverage are in Appendix 1 and a list of sessions is in Appendix 2.

Although the programme did not assume any synchronous engagement between the lecturers and the students, it felt that some ‘teacher’ presence needed to be established. One of the contributing academics was appointed a programme coordinator. Each weekly release of a new video was accompanied by an introduction from the programme coordinator. Participants

were encouraged to ask questions by emailing the presenter via the programme coordinator. Several questions were received and answered either by email or by follow-up videos. Questions and answers were shared with all participants.

6. Methodology

The emphasis of the study is on why and how students engaged with the material, what they preferred to do and what helped them to learn mathematics rather than on what they learnt. In our approach to investigating these, we return to the work of Santos and Barmby (2010). They distinguished between the inputs to, and outputs from, enrichment activities, proposing that the key output from an enrichment activity is student engagement. It is generally agreed that engagement has three components: behavioural, emotional and cognitive. Santos and Barmby (2010) explain that the behavioural dimension (students actively taking part in the activities) and the emotional dimension (students developing interest, motivation and appreciation of mathematics) are highly intertwined and are often seen as good evidence of engagement. The cognitive dimension, which relates to students' use of metacognitive strategies and self-regulation strategies (Mecce *et al*., 1988), approaches to learning (Kong *et al*., 2003) and could also include motivational goals (Fredericks *et al*., 2004), can sometimes be overlooked. In their analysis of student engagement in mathematics, Santos and Barmby mapped their findings related to engagement onto all three dimensions. Using this approach, they highlighted the cognitive dimension of enrichment, pointing out that it is important to make sure that this is present in addition to the behavioural and emotional dimensions.

With the above in mind, we explored how students engaged with the material and what strategies they employed. We were further interested in what characteristics of the programme design appeared to help them to remain engaged. As part of investigating the cognitive component of engagement and what strategies were adopted by the students, we looked at what mathematics students did, and how, such as efforts on their part to understand mathematics, especially if they met something they found difficult. In relation to this, self-regulatory behaviours (such as self-initiated strategies to set goals and plan work, evaluate progress, seek additional information, seek help, keep and organise records and review records) are known to be a resource that students call upon in a difficult situation (Zimmerman and Pons, 1986).

All participants were invited for interview via email sent at the end of the programme: four agreed to take part. The four were boys from different state-funded institutions with one student from a minority ethnic background: one school in FSM band A (see Appendix 3 for FSM bands), 2 schools in FSM band B, and one college. Three students studied Further Mathematics and two were studying through FMSPW. One student studied through the medium of Welsh. Lockdown may have played a role in our difficulty in recruiting more participants– difficulties with communication during the pandemic were mentioned to us by their teachers. The selection of interviewees was, essentially, those who were willing and able to give time to it.

Participation in the study was voluntary and, the participants were free to withdraw at any time during the study. Informed consent was sought from, and given by, the participants. The research was conducted in accordance with BERA ethical guidelines (BERA, 2018).

The students were interviewed in a meeting over the phone or via an online platform. A list of open-ended questions (see Appendix 1) was prepared in advance about why they chose to participate, how did they feel when they received the first set of resources, how they worked with the materials, what did they do when stuck and why, their opinion about the style of learning, what other mathematics they did during the lockdown and their advice to students who may be considering joining the a similar programme in future. Analysis involved classifying data in accordance with the three dimensions of engagement for the purposes of identifying patterns but also for understanding whether some elements of the design of the programme contributed to learner engagement.

7. Findings

Since our emphasis is on student engagement, we have organised the findings into sections reflecting the three components of engagement: emotional, behavioural and cognitive. We then complete the findings with a section on student perceptions of what they gained from the programme.

However, we start this section with a remark that the interviewed participants perceived the format as good and welcomed the course, with one student, for example, signifying the importance of the programme during the pandemic:

> I am impressed with how FMSP has been during the coronavirus time in the way they have been distributing all these materials and resources, I haven't had that from another of my subjects. To have it in further Maths has been especially [useful] as it's advanced materials and it will be useful and I will definitely utilize the resources in the future. (JB)

7.1 Motivation (emotional dimension)

Students mentioned a number of practical reasons for taking part, referring to time to be filled, wanting to focus on more advanced topics and preparation for future mathematics studies. There was a fear of being unprepared due to missing out on the exams that were cancelled, as well as a willingness to engage with technology in a university-like way:

> 'Simply because I didn't have anything better to do and I was also a bit afraid of going to university being a little unprepared so it gave me something to do and also it did really prepare me a bit of how university was going to be like in terms of the work.' (IB)

A perception of the program as easy entry (no test, no cost, no commitment) as well as being convenient and beneficial led to a feeling that participants were likely to enjoy it and, most importantly, the programme interested students. The description of the topics released in advance appeared to interest students because it promised extending mathematical concepts already familiar to students to something they had heard of, but "never really managed to try". These generated a number of emotional responses in anticipation of the course, including the words 'excited', 'enticing', 'enjoyable', 'intrigued'.

> 'I must say I was excited because I'd heard of eigenvalues and things like that and there is something enticing about the stuff you've heard of but don't understand.' (DH)

Once the programme started the participants felt that they were not disappointed ("I gave them [new topics] a go and they were good."). Topics that built on pre-existing knowledge (matrices, complex numbers) but also those that were perceived as entirely novel that needed to be researched or learned independently (modular arithmetic) were noted as memorable and enjoyable. More applied topics in physics or engineering were enjoyed because of their

perceived utility in a STEM field. While not studied at school, learning about these topics, it seemed, could help to decide on a university course. Students appeared to enjoy those sessions where they struggled and had to go through the material several times, but at the end understood it. The words challenging, difficult and enjoyable were often used together to describe a topic. The aspects that they could not fully comprehend were less enjoyable but nonetheless interesting as they offered an insight into new mathematics. In one instance, a particular aspect of mathematics was referred to as amazing but also as "really scary" and "intimidating".

In addition to finding the mathematical content interesting, the students talked about being motivated to do the work because the program created "a nice routine" but also its utility in preparing for university:

> 'The feeling that this will prepare you for university. I felt that I kind of had to do it. It was a motivation for me. It definitely motivated me to do more maths and to do some thinking!' (IB)

Feeling motivated seemed to be important as there were several aspects that the participants found challenging ("hard", "difficult", "overwhelming"). There was a feeling that one needed to adapt to the video format of the programme first, "just because it was a different medium" and, more specifically, because more information was transferred in a video format and because one could not ask questions. In this respect watching a video was compared to "a lesson when no one else was there".

> 'I found [the video format hard] as I am a person who likes to ask a lot of questions to make sure I understand the work. I'd much rather do work in the classroom with people to talk to but I didn't mind the video layout.' (TC)

Discussing materials with peers and asking "a lot of questions to make sure I understand the work" was not possible because of the video format but also because of the pandemic. All the participants strongly felt they would be discussing the materials with their teachers or peers had they been in school. None of the students were in touch with their teachers, but some had an opportunity to engage with friends.

> 'I didn't get in touch with my teachers and unfortunately didn't know anyone else who were watching the videos. I tried to persuade my friends but I think they'd had enough of maths and were pleased to have a break.' (DH)

The lack of a social component seemed to be important to the students as they spoke about introducing live or online sessions to make the programme more interactive, with one participant offering his view on the two formats:

> 'The only upgrade would be online lectures but maybe some people wouldn't like that as you can't watch it in your own time…but thinking about it, if there's 20 people watching there's not much opportunity for interaction. It would have to be in small groups and then we're talking about tutoring. I think video is a very good format.' (DH).

Two further features related to the content of the programme were perceived to make learning less enjoyable or more challenging for the students. Firstly, the programme went up and down in terms of challenge and the topics did not follow on from each other. One respondent suggested making clear which aspects of mathematics already known to students were referenced in each video and another suggested splitting the series into topic areas, e.g., to indicate 'some which focused on theories, some on calculus and some on algebra'. There was another suggestion about improving the way the materials could be utilized to prepare for school exams:

> 'Make it clear which sessions were using which skills that would make it easier for someone to focus their learning on those topics they need for the exam.' (JB)

Secondly, students reflected on too much prior knowledge being assumed in some videos. One student noted how some presenters would go over simpler aspects first and wished that more videos would do that:

> 'There's no harm in covering basic concepts and ideas at the very beginning of the video so that the watcher feels comfortable and confident and is prepared and then at the end of the video. I mean, all the videos were pushing and doing very wacky things at the end but there's always room for more wackiness and that's good because people can then start very comfortable then they can go as far as they can handle and then don't feel bad if they drop out near the end, that's as far as I can get.' (DH)

So far, we have seen that while students enjoyed the programme and felt motivated to engage, they found some aspects of the format novel, different or difficult and the materials mathematically advanced. Students' remarks on what they found difficult and how to make the programme more engaging, reveal critical awareness of themselves as learners. Importantly for our research question, we observe that some of the strategies that students would normally employ when learning mathematics, were not available to them because of the format but also because of the pandemic. We now turn to investigating what strategies they employed instead.

7.2 Engagement strategies (behavioural dimension)

We analysed the students' descriptions of the way they learned (that is when they were trying to make sense of mathematics in the video). The strategies related to video itself we found were: taking written notes, pausing and working out (also writing), breaking up each video and watching it step by step, and re-watching. We note that all the students wrote but for some their intention towards getting pen and paper out changed over time while one student remained systematic (the emphasis is ours):

> '*To begin with* I just watched the video and thought that it was interesting but [later on] I decided to start making notes and uploaded my notes and kind of looked at as revision notes.' (JB)
>
> '*At the beginning* I had a notepad and pen to work through all the problems and each time I'd pause them and work through them. *As I went on* I got a bit more lazy and would just kind of watch. If there was something that really interested me I was like "can I actually do that?" and I'd get a pad out and write it but I guess my work ethic suffered as it went on.' (DH)
>
> 'I tried to write down everything, *that's just what I like to do*, I like to write down all the notes although it takes time and I think it's the best way if you want to remember it and memorize it or try to understand it a bit more. For me I try to write all the questions, all the notes on a piece of paper.' (IB)

The very need or want to understand mathematics, and especially when being stuck, prompted employing some of the strategies above, most notably re-watching and working out but also revisiting the bits they found difficult in a few hours or days, seeking further information that could help or seeking the help of family, friends or FMSPW. Generally, the preference was to try and understand it for oneself first, then search for other sources to read or watch and then to ask someone else. Carrying out research on the Internet (for example in online forums) was a popular source of help with one student explaining why it was his preferred method:

> 'There are tons of forums online where you can find out help, chances are someone has had the same problem… It was easier on the forums because [there are more chances to find] the people who are at the same level as I am.' (JB)

When having difficulties, none of the students communicated with their own teachers, commenting that they didn't receive much (if anything) from their schools as their courses had largely or completely been declared as finished. However, students appeared not to be worried

about this and two mentioned that the teachers would have helped if they asked. This was not the case with the peer support, as we showed earlier. It was not just about getting help but also about the joy of sharing their thinking and being competitive. For example, the participant who had an opportunity to work with a friend who was similarly interested in mathematics said:

> 'We were always checking with each other "have you watched the third one, the fourth one", checking who's behind, we did discuss the content and we were like wow and that was amazing. I remember one which we discussed, the weird graph, I can't remember the name, a graph which repeats itself in itself. When they gad a link to the graph it was like 'have you seen this video, how good is that', we were both very interested in maths.' (IB)

The respondent who emailed FMSPW and got his questions answered, thought that he should have done it more often and re-emphasized this in his advice to future participants.

Some other strategies seem to be influenced by the way information was presented in the video or by the structure of the programme. For example, releasing each video weekly led to students finding time in the week to watch or re-watch it, knowing another one was coming. This helped students getting into "a routine" with one participant feeling prompted to create a timetable. All students tackled the videos in the order that they were released avoiding, it seems, the binge syndrome:

> 'If they were released all in one bunch there's nowhere near the same incentive to watch them over and over again because there's too much. I think a week was very good spacing because you find some time in your week to watch it and you know there's another one coming.' (DH)

Questions embedded in the videos and the lecturers saying 'pause the video and have a go' led to tackling most of these and wanting more. Similarly, having descriptions of the topics in advance encouraged students to research the topics prior to watching the video. Finding a 'lower level introductory video' and adapting it for help was one example.

7.3 Effort and commitment (cognitive dimension)

With regards to expending effort, participants appeared to identify aspects they did not understand and demonstrated perseverance when they could have just left it.

> 'There was one which was part of differential operators, which is pretty advanced stuff, I understood a little bit but I had to go back to make sure I understood it. I did enjoy the session, it was insightful.' (JB)

On the other hand, the students were not too worried about not being able to understand all the mathematics in the videos and demonstrated perseverance with specific topics. Some were more selective based on whether they had time and what topics interested them or what topics they needed for university. As one participant put it, "I studied the stuff I liked the most and the stuff I didn't understand as best as I could." We also observe that "the productivity dropped somewhat overall" towards the end of the programme with some skipping of the last few videos reported.

The aspects that the students decided to persevere with demanded more time (such as when watching a video multiple times in order the understand the work), which was cited as one reason for none of the interviewees engaging with the additional worksheet. The other reason was that they did not feel motivated, e.g., there was no one to check their work nor an extrinsic outcome. Another reason, it seemed, was that all the participants felt happy about the way they were able to challenge themselves without committing to the worksheet. Making an

effort to understand the video was onerous enough for some but others felt free to pick and persevere with more challenging content:

> 'Mechanics was really intimidating even though it's something that I need to study because I want to go on to do engineering. So, I generally got stuck into those subjects first. The variety of videos that are on offer make it easier to challenge myself as well.' (JB)

The above quote reinforces how participants enjoyed being selective about which content to engage with. While no participant in our sample watched every video, they nevertheless felt happy about this approach.

We also note here that participants talked about not engaging with worksheets in other FMSPW programmes nor with those sent by the school.

7.4 Outcomes

The perceived actual benefits of completing the programme echoed the reasons for joining the programme cited earlier and the participants recommended engaging with the programme to other students ("do it!"/ "try it and you are more likely to enjoy"). As one outcome, engaging with the programme helped students feeling more confident in their ability 'to adapt to new and different maths' and their problem-solving skills, essentially feeling themselves becoming better mathematicians. Additionally, adapting to a new style of learning, although requiring effort/focus on their part, was seen as a new skill or practice that was essential for university study or, more generally, for a 'new' normal ("for a world where we rely more on technology").

The other outcome was the new mathematical knowledge that they gained including being exposed to some advanced, "weird" or even "wacky" mathematics. Participants also made clear that they enjoyed the programme. One student saw the course as a way of widening one's mathematical perspective:

> 'I think a lot of people see maths as boring or more boring than science has the potential to be. But these videos highlighting unusual stuff that professional mathematicians find interesting and therefore are likely to be the most interesting parts in maths so I think it's a very good eye-opener to some of the cooler and more abstract applications of mathematics.' (DH)

The above quote signifies that students put some trust in what they were presented with. One participant further explained how whilst some topics initially seemed "arbitrary and abstract", he could see how these will be used later.

One additional outcome was participants noting that they wanted to re-visit the original materials (video and/or worksheet), their own notes or to watch similar other videos on the FMSPW YouTube channel in future, such as, during a gap year, in their spare time over the summer, or once at university.

8. Discussion

The study aimed to understand how students responded to an asynchronous mathematics enrichment opportunity during the lockdown. The students in the sample appeared to be well engaged in all three dimensions, that is cognitively, emotionally and behaviourally. They were motivated, active in learning, eager to participate, and willing and able to put in effort.

We observe that the students were all resourceful and well resourced. They appeared to have access to technology, to be able to reach for help, and to know how they learn best. All the students displayed maturity in their approaches, and it is evident that they possessed good learning habits. They persevered with the aspects of mathematics they found difficult even though they did not need to do well in a test and without encouragement from teachers or (in some cases) peers. Clearly, engaging in the programme required self-regulation strategies and the students in our sample all seemed to display self-regulatory behaviours. This perhaps contrasts with students' views. While they perceived the programme as easy entry, we view the skill set one needs to engage in it as sophisticated and perhaps quite unusual for students of this age.

The format of the programme was suitable for such students, who engaged in the programme in flexible ways in terms both of when and how to watch pre-recorded sessions and also which elements and what content of the programme to engage with. They tackled questions included in the video and researched new concepts presented in the video. However, the students did not engage with worksheets for the bridging programme, other FMSPW programmes or, indeed, those sent by the school, which may need to be investigated further. This may reflect warnings in other Covid-19 studies that the levels of engagement could be lower or higher than those that schools and teachers were able to detect (Lucas *et al.*, 2020).

Being selective could well be suitable or even desired for mature students and appropriate for an enrichment programme. There is, however, an argument in the literature that such a style of learning may be a preferred option by the children of today. For example, Engelbrecht *et al*. (2020b) argued that digital technologies are forcing us to think in different ways about the classroom and the education process is moving from a teacher-centred 'push' approach to a student-centred 'pull' approach. However, making choices about what to study is difficult for young people, as one needs to know the consequences of such choices. This is especially true for advanced mathematics where effort to understand mathematics is required before an understanding of the wider picture can be reached. Therefore, the role of the teacher remains important in selecting valid resources and content which was reflected in the design of the bridging programme and also confirmed in students' comments.

Covid-19 studies stress the need to engage students who are disadvantaged and the lack of participation from schools with higher proportions of students in receipt of free school meal, see Appendix 3, confirms this. But our findings also highlight that even students who have an advantage in terms of their skills, support networks or other resources, could feel anxious, abandoned or bored because of the pandemic and need to be cared for. As such, an enrichment programme, such as the one researched in this study may be appropriate for such students, leaving more teacher time for less advantaged students during the times when teacher resource is limited. Hattie (2020a) proposed that some groups of students need carefully thought through teacher differentiation including students with low self-regulation, high level of stress, emotional concerns and/or behavioural issues, or no access to educational resources, while others may thrive with less supervision and more flexibility. Our study, which focused on the latter group of students, confirms Hattie's proposals.

We observe that despite the mode of engaging in our outreach programmes being different from a traditional enrichment programme (master-apprentice, collaboration, hands-on), the perceived benefits of the programme considered in the study were what one may expect. One extra outcome that

was not previously noted in mathematics enrichment literature and may be unique to the format of the bridging programme, was a feeling in participants that they acquired a sort of a 'box set' with which they could re-engage in future. The participants perceived that such an engagement may be useful, among other things, for the transition to university. Transition to university was associated with the motivation to join the programme, to further persevere with it but also with the perceived outcomes. First year undergraduate students are known to struggle with the structure and the style of university-like learning (McPhail, 2015). This may further deepen in the cohorts of students affected by the pandemic (Pownall *et al*., 2021). Appropriate enrichment programmes may help to close the gap.

The limitations of the sample and the sampling method do not allow us to evaluate fully how typical the interview participants were, although the sample of their home institutions appeared to be similar to the whole sample, see Appendix 3. Additionally, the one student not studying Further Mathematics could not be seen as an exception, as schools and colleges offering and not offering Further Mathematics subscribed to the programme. While the entry to the programme was deliberately made easy to encourage a greater take up during a somewhat chaotic time of the pandemic, more data may need to be collected to evaluate how representative our interview sample may have been of all the participants. For example, all of the interviewed participants intended to study for an applied STEM degree, but it is unclear if that was typical of the whole sample. The level of the usage of the resources in the whole sample in combination with the interviewed students' answers suggests that our interviewees were in the group of more 'enthusiastic' participants. While the sample of the interviewed students may or may not be representative of the whole sample, it nevertheless highlights the level of skill needed to cope with the course.

There are further warnings and suggestions for improving the programme. While online materials could be accessed anytime and anywhere, thus potentially widening access to mathematics, there might be underpinning equity issues when accessing enrichment materials asynchronously. Indeed, in the NRICH study (Simon and Jones, 2000) only one third of respondents were girls, only 5% were from state-funded schools, and only a handful accessed materials from a public place as opposed to school or home. Similarly, in our study the majority of subscribing participants were boys and no girls gave an interview. The lack of collaborative opportunities as noted in the interviews, may be one factor to consider in order to improve engagement. As such, creating a forum where students could collaborate asynchronously could be useful, while a blended approach of live sessions and asynchronous sessions could also be considered.

In conclusion, we propose that there is a case for developing further similar enrichment programmes for use in times of in crisis, but also for up-cycling the bridging programme for 'normal' times. Consideration should be given to the skill set required of participants but we are also highly aware of the barriers to engagement, from lack of appropriate technology or motivation to issues of mental health and in future iterations we will aim to address at least some of these barriers. Given the potential of asynchronous mathematics enrichment materials, on which education systems might draw in a crisis, we conclude by proposing that such materials should have a firm place on the mathematics education research agenda.

Appendix 1: Example of a Bridging Session Abstract and Information

20 May 2020: "Mountaineering Monks, Pancakes and Continuous Functions: The Intermediate Value Theorem and Some Existence Proofs" by Professor Elaine Crooks, Swansea University.

This talk will centre on the famous Intermediate Value Theorem one of the key results that students encounter in introductory analysis courses at university, and will introduce concepts such as continuous functions, existence theorems, and completeness of the real numbers, alongside applications ranging from monks meeting on mountain paths to equitable division of pancakes.

New concepts: Continuous function, Intermediate Value Theorem, Bisection of shapes, antipodal points, Bursak-Ulam Theorem, completeness of the real line.
Useful for undergraduate modules: Foundations of Mathematics, Real Analysis.

Cliciwch yma am fersiwn Gymraeg.
20 May 2020

A-level to University Bridging Sessions

Session 3: The Intermediate Value Theorem

Welcome to the third session in the **Bridging Mathematics** series. We hope you are still keeping well at this unusual time. If you need a refresher on what the series is all about, or why you shouldn't worry if you don't fully understand these new ideas, and what to do if you're stuck, then have a look at the first (bilingual) introductory note *01 Y13 Fectorau eigen - Eigenvectors*, at

https://tinyurl.com/FMSPW-bridging-to-uni-intros

In this third session, **Professor Elaine Crooks** from Swansea University tells you about an important theorem called the **The Intermediate Value Theorem**. It comes from an area of maths called Analysis that you would typically encounter in the first year of a maths degree. Analysis is concerned with checking that the logical foundations of Calculus are secure. After the invention of Calculus at the end of the 17th century, people were slightly spooked by its use of infinite and infinitesimals, and wanted reassurance that their proofs were valid — Analysis provides this. But it provides more. Elaine uses the Intermediate Value Theorem to neatly deduce some non-obvious (but true!) conclusions. In doing so, she also showcases the style of sustained and precise mathematical argumentation needed.

There are no prerequisites to Elaine's talk, so please get yourself a pen and paper, and enjoy watching the talk by clicking the link:

https://tinyurl.com/FMSPW-bridging-to-uni

and then choosing the video 3. Pause the video and use your pen and paper whenever you need to think something through, and don't hesitate to replay parts to get things clear in your head. If you sign up to our YouTube channel, you will be easily able to find all our available videos. The video will now be available for *four* weeks, since we've just been asked to extend the viewing window.

As ever, if you have any questions or points to make, we at the FMSPW would love to hear from you, and Elaine would also be delighted to answer any questions about her talk. Just email fmspwales@swansea.ac.uk. N.B. In maths there is no such thing as a stupid question. If you've got any helpful feedback: things you like, things we could improve, please let us know too and we'll do our best. We'd also be grateful if you have time to complete the feedback form on Google. This will allow us to feedback to the Welsh Government on the success of the programme.

https://tinyurl.com/FMSPW-bridging-to-uni-eval

Enjoy!

Francis Hunt

FMSP Wales Tutor, on behalf of all the FMSP Wales team.

Fig. 1. Session Information.

Appendix 2: List of session topics

1. Eigenvectors, Eigenvalues and the Cayley-Hamilton theorem
2. The Complex Plane (delivered bilingually in English and Welsh)
3. Mountaineering Monks (delivered by a female presenter)
4. Cool Mathematical Software
5. Mathematics of Vibrating plates: Chladni figures and Tacoma Bridge
6. The Geometry of Curved Spaces
7. Modelling the Zombie Apocalypse (delivered by a female presenter)
8. Maths & Art (delivered by a female presenter)
9. Number Theory and Cryptography
10. Mathematics with Bubbles (delivered bilingually in English and Welsh)
11. A Mathematician's Holiday
12. The Central Limit Theorem
13. Six degrees of separation (delivered bilingually in English and Welsh)

Appendix 3: Participation data split by the type of institution and gender where schools are categorised according to the number of students in receipt of free school meals (FSM)

Participation and national data	Colleges	Schools by FSM category						Total
		A	B	C	D	E	Total	
Male participants	10	22	24	8	0	0	54	64
Female participants	6	10	16	2	0	0	28	34
Institutions participated	7	10	12	1	0	0	23	30
proportion of schools by FSM category		*43%*	*52%*	*4%*	*0%*	*0%*	*100%*	
Institutions offering A-level in Wales	18	21	66	29	22	2	158	176
proportion of schools by FSM category		*13%*	*42%*	*18%*	*14%*	*1%*	*100%*	

Category A indicates schools with less than 8% of students in receipt of FSM, category B indicates schools not included in A and with less than 16% of students in receipt of FSM, category C indicates schools not included in A or B and with less than 24% of students in receipt of FSM, category D indicates schools not included in the above categories and with less than 32% of students in receipt of FSM and category D indicates schools with at least 32% of students in receipt of FSM. FSM data is not available for colleges.

References

Barbe, W. B. (1960) What is Enrichment? In J. F. Magary and J. R. Eichorn (Eds.) *The Exceptional Child: A Book of Readings*, Holt, Rinehart and Winston Inc., New York.

Beyth-Marom, R., Saporta, K., & Caspi, A. (2005) Synchronous vs. asynchronous tutorials:

Factors affecting students' preferences and choices. *Journal of Research on Technology in Education*, **37(3)**, 245-262.

Borba, M. C., Askar, P., Engelbrecht, J., Gadanidis, G., Llinares, S., & Aguilar, M. S. (2016) Blended learning, e-learning and mobile learning in mathematics education. *ZDM Mathematics Education*, **48(5)**, 589-610.

Brame, C. J. (2016) Effective educational videos: Principles and guidelines for maximizing student learning from video content. *CBE—Life Sciences Education*, **15(4)**, 6.

British Education Research Association, BERA. (2018) Ethical Guidelines for Educational Research. London: British Educational Research Association.

Caspi, A., Gorsky, P., & Privman, M. (2005) Viewing comprehension: Students' learning preferences and strategies when studying from video. *Instructional Science*, **33(1)**, 31-47.

Clark-Wilson, A., Robutti, O., & Sinclair, N. (2014). Introduction. In: The mathematics teacher in the digital era. *AMC*, **10**, 12.

Clark-Wilson, A., Robutti, O., & Thomas, M. O. J. (2020) Teaching with digital technology. *ZDM Mathematics Education*, **52(7)**, 1223-1242.

Engelbrecht, J., Borba, M. C., Llinares, S., & Kaiser, G. (2020) Will 2020 be remembered as the year in which education was changed?. *ZDM Mathematics Education*, **52**, 821–824 (2020).

Engelbrecht, J., Llinares, S. & Borba, M.C. (2020) Transformation of the mathematics classroom with the internet. *ZDM Mathematics Education* **52**, 825–841 (2020).

Erickson, S. E., Dal Cin, S., & Byl, H. (2019) An experimental examination of binge watching and narrative engagement. *Social Sciences*, **8(1)**, 19.

Feng, W. Y. (2010). Students' experience of mathematics enrichment. In M. Joubert, & P. Andrews. *Proceedings of the British Congress for Mathematics Education*, pp. 81-88.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004) School engagement: Potential of the concept, state of the evidence. *Review of Educational Eesearch*, **74(1)**, 59-109.

Golding, J. & Grima, G. (2020) A pandemic summer: Impact on teaching and learning for mastery in Power Maths primary schools. In *Proceedings of the British Society for Research into Learning Mathematics*, **40(3)**.

Gross, B. & Opalka, A. (2020) Too many schools Leave Learning to chance during the pandemic. Center on Reinventing Public Education (CRPE). https://www.crpe.org/publications/too-many-schools-leave-learning-chance-during-pandemic (accessed 28 February 2021).

Hattie, J. (2003) Teachers make a diference: What is the research evidence? Paper presented at the Australian Council for Educational Research Annual Conference on Building Teacher Quality. Melbourne, Australia.

Hattie, J. (2020a) 'The New Normal of Learning: Build Back Better.' *Corwin Connect*. Available at https://corwin-connect.com/2020/05/the-new-normal-of-learning-build-back-better / (accessed 28 February 2020).

Hattie, J. (2020b) Visible Learning Effect Sizes When Schools Are Closed: What Matters and What Does Not. *Corwin Connect*. Available at https://corwin-connect.com/2020/04/visible-learning-effect-sizes-when-schools-are-closed-what-matters-and-what-does-not/ (accessed 28 February, 2020).

Hodgen, J., Taylor, B., Jacques, L., Tereshchenko, A., Kwok, R., & Cockerill, M. (2020). Remote mathematics teaching during COVID-19: intentions, practices and equity. London: UCL Institute of Education.

Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020) The difference between emergency remote teaching and online learning. *Educause Review*, **27**.

Iqbal, S. A., Azevedo, J.P., Geven, K., Hasan, A. & Patrinos, H.A. (2020) We should avoid

flattening the curve in education – Possible scenarios for learning loss during the school lockdowns. World Bank Blogs. Available at https://blogs.worldbank.org/education/we-should-avoid-flattening-curve-education-possible-scenarios-learning-loss-during-school (accessed 28 February 2021).

Jones, K., & Simons, H. (2000) The student experience of online mathematics enrichment. In T. Nakahara & M. Koyama (Eds.), *Proceedings of the 24th Conference of the International Group for the Psychology of Mathematics Education* (Vol. **3**, pp. 103–110). Hiroshima, Japan: International Group for the Psychology of Mathematics Education (PME).

Kieran, C., Krainer, K., & Shaughnessy, J. M. (2013). Linking research to practice: Teachers as key stakeholders in mathematics education research. In M. A. Clements, A. J. Bishop, C. Keitel, J. Kilpatrick, & F. K. S. Leung (Eds.), *Third international handbook of mathematics education* (pp. 361–392). London: Springer.

Kong, Q. P., Wong, N. Y., & Lam, C. C. (2003) Student engagement in mathematics: Development of instrument and validation of construct. *Mathematics Education Research Journal*, **15(1)**, 4-21.

Kuhfeld, M., Soland, J., Tarasawa, B., Johnson, A., Ruzek, E., & Liu, J. (2020) Projecting the potential impacts of COVID-19 school closures on academic achievement. EdWorkingPaper: 20-226. Available at https://doi.org/10.26300/cdrv-yw05 (accessed 28 February 2020).

Lahtinen, V., Lonka, K. & Lindblom-Ylanne, S.(1997) Spontaneous study strategies and the quality of knowledge construction. *British Journal of Educational Psychology*, **67**, pp. 13–24.

Lake, R. & Dusseault, B. (2020) Districts and CMos are making progress on instruction and monitoring, but lag in grading and attendance. *Center on Reinventing Public Education*

(CRPE). Available at https://www.crpe.org/thelens/districts-and-cmos-are-making-progress-instruction-and-monitoring-lag-grading-and-attendance (accessed 28 February 2021).

Lowe, T. (2021) When modules become box sets. https://wonkhe.com/blogs/when-modules-become-box-sets/ (accessed 28 February 2021).

Lucas, M., Nelson, J., & Sims, D. (2020) Schools' Responses to Covid-19: Pupil Engagement in Remote Learning. Slough, UK: NFER.

Lyakhova, S. (2020) Remote Teaching and Covid-19 Approaches to School Education. Commissioned at the request of the Children, Young People and Education Committee to inform its inquiry into the impact of the Covid-19 outbreak on children and young people in Wales, Senedd Cymru, https://business.senedd.wales/documents/s105162/ (accessed 28 February 2021).

Magliano, J.P., Trabasso, T. & Graesser, A.C. (1999) Strategic processing during comprehension. *Journal of Educational Psychology*, **91(4)**, pp. 615–629.

Martinson, R. (1968) *Curriculum Enrichment for the Gifted in the Primary Grade*. New Jersey: Prentice-Hall Inc.

McPhail, R. (2015) Pre-university prepared students: a programme for facilitating the transition from secondary to tertiary education. *Teaching in Higher Education*, **20(6)**, 652-665.

Meece, J. L., Blumenfeld, P. C., & Hoyle, R. H. (1988) Students' goal orientations and cognitive engagement in classroom activities. *Journal of educational psychology*, **80(4)**, 514.

Montacute, R. (2020) Social Mobility and Covid-19: implications of the Covid-19 crisis for educational inequality. The Sutton Trust.

Novak, J.D. (1990) Concept mapping: A useful tool for science education. Journal of

Research in Science Teaching, **27(10)**, pp. 937–949.

Piggott, J. S. (2007) The nature of mathematical enrichment: a case study of implementation. *Educate~*, **7(2)**, 30-45.

Pownall, M., Harris, R., & Blundell-Birtill, P. (2021) 'Supporting students during the transition to university in COVID-19: 5 key considerations and recommendations.' PsyArXiv Preprints | Supporting students during the transition to university in COVID-19: 5 key considerations and recommendations (accessed 28 February 2018).

Redmond, B., Golding, J. & Grima, G. (2020) Covid19 summer: Impacts on mathematics A Levels teaching, learning and progression. In *Proceedings of the British Society for Research into Learning Mathematics*, **40(3)**.

Saljo , R. (1997) Reading and everyday conceptions of knowledge. In F. Marton, D. Hounsell and N. Entwistle eds, *The Experience of Learning*, 2nd edition, (pp. 89–105). Edinburgh: Scottish Academic Press.

Santos, S., & Barmby, P. (2010) Enrichment and engagement in mathematics. *In Proceedings of the British Congress for Mathematics Education*. Vol. **30**, No. **1**, pp. 199-206.

Schoenfeld, A. H. (1992) Learning to Think Mathematically. In D. A. Grouws (Ed), *Handbook of Research on Mathematics Teaching and Learning*. New York: Macmillan.

Slamecka N.J. & Graf, P. (1978) Generation effect – delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning and Memory*, **4(6)**, pp. 592–604.

Smith, A. (2004) Making mathematics count: the report of Professor Adrian Smith's inquiry into post-14 mathematics education. London: The Stationary Office Ltd.

Richardson, C., & Mishra, P. (2018). Learning environments that support student creativity: Developing the SCALE. Thinking Skills and Creativity, 27, 45–54. https://doi.org/https://doi.org/10.1016/j.tsc.2017.11.004

The Royal Society. (2008) Science and mathematics education, 14-19: a 'State of the Nation'

report on the participation and attainment of 14-19 year olds in science and mathematics in the UK, 1996-2007. London: The Royal Society.

Thornton, N.E., Bohlmeyer, E.M., Dickson, L.A. & Kulhavy, R.W. (1990) Spontaneous and imposed study tactics in learning prose. *The Journal of Experimental Education*, **58(2)**, pp. 111–124.

Vegas, E. (2020) 'School closures, government responses, and learning inequality around the world during COVID-19.' Brookings Institution. Available at https://www.brookings.edu/research/school-closures-government-responses-and-learning-inequality-around-the-world-during-covid-19/ (accessed 28 February 2021).

Welsh Government (2020) 'Stay Safe, Stay Learning: Supporting the Education System' https://gov.wales/stay-safe-stay-learning-continuity-learning#StaySafe.StayLearning:supportingtheeducationsystem (accessed 30 April 2020)

Worcester, D. A. (1979) Enrichment in Educating the Gifted: Acceleration and Enrichment. In George, W. C. Cohn, S. J. and Stanley, J. C. *Revised and Expanded Proceedings of the Ninth Annual Hyman Blumberg Symposium on Research in Early Childhood Education*. Baltimore and London: The Johns Hopkins University Press: 98-106.

Wright, P. (2021). Transforming mathematics classroom practice through participatory action research. *Journal of Mathematics Teacher Education*, *24*(2), 155–177. https://doi.org/10.1007/s10857-019-09452-1

Yao, J., Rao, J., Jiang, T., & Xiong, C. (2020) What Role Should Teachers Play in Online Teaching during the COVID-19 Pandemic? Evidence from China. *Sci Insight Edu Front*, **5(2)**, 517-524.

Zimmerman, B. J. & Pons, M. M. (1986) Development of a structured interview for assessing student use of self-regulated learning strategies. *American Educational Research Journal*, 23(4), 614–628.

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