How Covid-19 has modified STEM outreach in South Wales; a case study.

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Abstract
The Covid-19 pandemic has thrown education into disarray, with particular concerns arising from school closures, with all the many implications that this will have for education. Swansea University Science for School Scheme (S4) is a science outreach project based in Wales that has had to radically change its delivery model in order to continue engaging with their current pupil cohort. This model has shifted from an exclusively face-to-face model to one that incorporates blended learning, including online content, outdoor workshops and livestreaming sessions.
The feedback gained from the teachers from participating schools has been extremely positive and encourages our continued development of other avenues of delivery.

Introduction
The SARS-CoV-2 (COVID-19) pandemic has thrown the world into chaos. In the UK alone the implications have been severe with, for example, unprecedented economic losses ((Keogh-Brown et al., 2020) and grave societal issues. For example, self-isolation and 'shielding' have become commonplace, with knock-on consequences for mental health that, in the very worst cases, can lead to death (John et al., 2020; Nicola et al., 2020).
As part of measures to contain the virus, schools were instructed to close in March 2020 (Senedd Research, 2020). The ramifications of this are thought to be major (Schleicher, 2020), with physical health and general protection of pupils being the primary causes for concern. At the height of the first wave, almost 1.5 billion people across 172 countries were out of education (Archer, 2020; UNESCO, 2020b).

Many other concerns have also been raised since the beginning of the school closures though, including how to supply children with adequate nutrition (GOV.UK, n.d.; Hoffman & Miller, 2020; UNESCO, 2020a), how to mitigate disrupted education (Schleicher, 2020; UNESCO, 2020a; van Lancker & Parolin, 2020), as well as how to react to general safeguarding (Social Care Institute for Excellence, 2020) and mental health concerns (YoungMinds, 2020). Additionally, the disparity between socioeconomic classes has only been exacerbated during school closures due to fewer learning opportunities for the under-privileged (Armitage & Nellums, 2020; Marchant et al., 2020; UNESCO, 2020a).

During the initial 14 weeks of school closure, teachers resorted to 'emergency remote learning' (Marchant et al., 2020) and many schools shifted their teaching onto online platforms. At this time, feedback from teachers maintained that the return of the work by pupils was minimal (Howe, 2020); indeed it was not always clear whether pupils had access to the work (Spencer, 2020). As part of this, and recognising that technology poverty is an ongoing issue in lower socioeconomic

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demographics (Children in Wales, 2020) with its associated implications about overall accessibility to online classes, school advisory bodies tended to prioritise mental health over school work (S4, 2020).

Science, technology, engineering and maths (STEM) outreach has become of focal interest over the last few decades, not least because STEM appears key to healthy economic growth (National Audit Office, 2018). As part of this, between 2007 and 2017 over £990m was spent on STEM enrichment funding in the UK alone (National Audit Office, 2018). Research into the lack of STEM subject uptake post compulsory education, or lack of interest in STEM in general, has focussed on trying to understand how this issue can be resolved (DeWitt et al., 2014; Smith, 2011).

The promotion of STEM outreach has galvanised many universities to embrace outreach. In fact, many research funding bodies for research insist on outcomes such as 'societal benefit' from their projects (NERC, 2020). It is now key to ask how such outreach activities can effectively continue when much of the country is in lockdown.

Swansea University Science for Schools Scheme

Swansea University Science for Schools Scheme (S4) is a science outreach programme focused on widening access to science education, particularly in low participation demographics in South Wales. Led by research scientists, S4 uses curriculum embedded workshops to get young people engaged in science. S4 normalises STEM gender and equality perceptions, and disrupts social inequalities around higher education expectations by using a bespoke classroom on the university campus, in workshops taught by gender-diverse staff.

S4 is currently funded as part of the Trio Sci Cymru (TSC) consortium to support a Key Stage 3 (KS3) research-led STEM intervention project with schools from low socioeconomic demographics in the region. S4 is part of TSC's longitudinal cohort analysis of STEM outreach outcomes in our participants.

In March 2020, schools across Wales closed in the hope of stopping the spread of Covid-19 (Welsh Government, 2020), also putting a halt on school visits to S4. In this paper, we discuss how S4 has adapted and made changes to their delivery model so as to continue operating effectively during the COVID-19 pandemic.

Delivery model before COVID-19

Key aspects in S4's delivery model pre-covid-19

Since 2018 S4 has been working with the same pupil cohort as they move through KS 3. Classes from partner schools were able to visit the College of Science Margam Outreach Space (CoSMOS) in Swansea University once a term for a day. For this, pupils were engaged in hands-on, research-led, curriculum-embedded and curiosity driven activities, split into three workshops focusing on biology, chemistry and physics (with overlap between these disciplines).

In CoSMOS, S4 has its own bespoke classroom, giving participants their own space on campus, disrupting social inequalities and creating a space for participants to experience science in a higher education environment. This also allows pupils to become accustomed to the 'faces and places' of science, breaking down the barriers to STEM learning and the belief that science is for the 'elite'.

S4 interventions take place over several years with the same pupils recognising that the longer the programme, the greater the perceived learning and change in 'science confidence'.

As part of an independent, within school feedback session, one school supplied a particular amount of information regarding negative impacts on the following;

- Lack of pupil interaction and feedback
- Virtual relationships
- Deprivation gap
- Impact on wellbeing
- Impact on skills development

This has been included and referenced throughout this paper to enhance our perspectives.

Adapted delivery model

As a response to Covid-19, S4 changed its delivery model to continue providing STEM content to participants. S4 now provides blended learning, including online content, face-to-face teaching and outdoor sessions to provide maximum support to all learners. For this, although the target groups for S4 is KS4, some additional material supporting other key stages were released for partner schools (ranging from Key Stages 1-5). The main focus during the content production, however, remained with KS3.

Wherever possible, S4 has aimed to minimise the impact of the five key issues highlighted by partner schools and the primary changes and additions undertaken are highlighted below.

Online content

As the schools in Wales closed, the S4 initial response was to create content online allowing pupils to maintain access to learning materials. This began with videos reviewing content previously covered in the on-campus workshops, and then expanded to include new content. Video length of S4 generated content varied between 3 and 9 minutes and included diverse topics that varied between, for example, "the chemistry of making water disappear" and "phase transitions".

S4 also collaborated with wildlife presenter Lizzie Daly, to share "Lizzie Daly's Earth LIVE" lesson videos, and Mark Thomson, astronomer and TV presenter, for a live summer show, "A Guided Tour of the Universe with Mark Thompson", which also included a Q&A session.

All online content was sent to S4's partner schools' teachers so that they could share it *via* their own online class sessions.

Feedback from teachers on the online content included "the current work set up you have is fab." and "Great am using the links every week on teams."
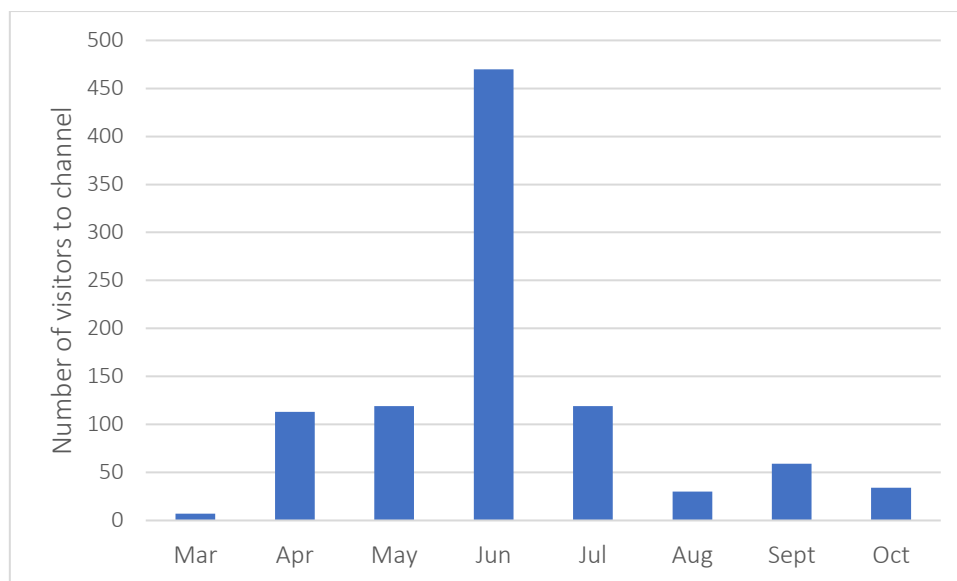
Figure 1. The monthly number of visitors to the S4 channel on YouTube since the beginning of school closures in March 2020 through to October.

S4 saw an increase of visitors to their YouTube channel, which coincided with S4's launch of online lessons in April 2020 (Figure 1). Online videos were then continuously released onto this channel from this point up until, and through, September, when schools reopened and S4 began delivering content in new innovative ways (see below).

Other forms of online engagement included *via* social media such as Twitter and Facebook, on which material release was reiterated, local scientific events shared, and additional activities released, such as leaf gathering for the Wales climate change week.

Teachers have informed us that there were multiple ways in which they shared S4's online content:

- Sharing teacher's guidance and resourced to the science department.
- Sharing relevant links weekly with GCSE and A-level classes through Microsoft Teams
- Sending links to the Home Learning Team so that they may, in turn, set up whole year group tasks on Microsoft Teams.
- Placing the links on the shared OneDrive for home learning, sorted by year group.
- Printing hard copies for those pupils who requested them due to limited access to the internet at home.

Worksheets
Worksheets were specifically created to run alongside the videos, although the video content was not necessary in order to complete these worksheets. It was deemed essential that pupils without access to the necessary technology could still access the learning material.

Worksheets and Q&A sheets were also created to run alongside other resources, which included a variety of online videos and podcasts.

A typical worksheet contained background information on the topic, further study information and exercises. Answer sheets to the worksheets were also provided so that pupils could check their understanding.

An example of this is the worksheet that covered "What happens to our bodies in space?". This worksheet has a short description of the accompanying video of a bell jar experiment where a marshmallow full of air is subjected to a vacuum, followed by an introduction of what would happen to our bodies in space as well as facts about space suits. The final section of this worksheet includes questions and an activity to be completed, in this case, designing your own mission patch.

The school teachers were often grateful to be able to forward these worksheets to their pupils *via* Microsoft teams. They commonly said things like; "Thank you for letting me pass on the wonderful resources.".

Bumper Workbooks

Bumper workbooks were created as stand-alone content to be used in conjunction with, or without the online videos. Each bumper workbook contained information and exercises on a variety of subjects ranging from "creepy crawlies" to "the chemistry of bath bombs".

Some of the content covered in the bumper workbooks had already been covered in previous workshops run by S4 that the relevant cohort had attended. This was deliberate and intended to reinforce previous learning.

These workbooks will also be made available as editable online content through the S4 portal (see below), giving pupils the options to complete these workbooks on this site. This will be in addition to the current hard copies that are made available to the schools. Some of the partner schools are currently not allowing paper copies of materials, to avoid unnecessary inter-person contact.

Teacher feedback on the bumper workbooks included "you have really helped to enthuse and cheer up a difficult period." and "It supports the Key Stage 3 curriculum; whilst also introducing new science and stimulating interest. Our pupils do not have a textbook that they can take home, so this provides a great home/school link to promote their learning.". Other feedback included;

"The school will be supplying this year group with these fantastic resources upon their return in order to support their learning loss and their future learning loss. […] we are extremely appreciative of these workbooks which are highly engaging and match our curriculum." and "the workbook supplies great ideas for pupils to examine their environment and experience Science through action."

Additional feedback from teachers stated that workbooks were a useful resource for pupils who did not have internet access, but also as material that comes in addition to the work that the teachers would normally set.

Science Boxes

At home science boxes were created containing all the materials needed for at home experiments and curriculum relevant activities. Additional information and worksheets to complement these science boxes were made available on the participant portal (see below), but printed copies were also made available upon request. An example experiment from the science box was "Build your own electromagnet", this activity was specifically designed so that pupils could explore electromagnetism at a level suitable for the KS3 physics curriculum.
All activities used in the science boxes underwent risk assessment and were given approval by partner schools' teachers.

S4 participant portal

S4 has created a portal through which all content can be accessed by pupils enrolled onto the S4 programme, as well as their teachers. Content made available on the portal includes anything specifically developed for this cohort of pupils (after S4 became a closed project in 2018).

Individual pupils receive their own user id and password, giving them access to all learning materials. This also allows S4 to run analytics across individuals, and follow which schools or pupils use the online content and how it is used.

Examples of materials available on the portal include:

- Video content
- Worksheets
- Q&A sheets
- Bumper workbooks
- Annual enrolment forms for pupils and parents/guardians

The participant portal now also includes the annual enrolment forms to be completed by pupils and their parents/guardians. This was brought into effect as some of the partner schools do not allow paper copies due to the risk of cross contamination of covid-19. Paper copies are however still available for those schools which prefer it, and a risk assessment is completed for when these are dropped off to schools by S4 staff.

Live streaming lessons

Tailored to the schools' individual needs, S4 is now able to live-stream workshops sessions into schools using Microsoft teams. These sessions are each an hour long and fit in with school lessons. Any necessary equipment is provided to the schools so that they may join in with the workshop activities. A thorough risk assessment is carried out, adhering to both Swansea University's and the individual school's guidelines before any equipment necessary for the workshop is delivered to the schools.

The basic structure of a live streamed workshop includes an introduction, the demonstration of the activity, time for the pupils to complete the activity themselves, followed by additional information and time for questions and goodbyes.

For safeguarding reasons, these workshops are live streamed instead of delivered as a video conference to maintain pupil anonymity, since the school classes now include a mix of pupils both enrolled and not enrolled onto the S4 programme. The chat function on Microsoft teams allows the pupils to ask questions and to make the sessions more interactive.

Feedback from the pupils on our live lessons showed that they really enjoyed doing the hands-on activities with an average of 93% of pupils giving positive feedback on their sessions. This is further highlighted by quotes such as "I liked looking at tardigrades under the microscope", and many pupils claiming that their favourite parts of the sessions were "drawing the onion and the cheek cells" and the "blocked nose taste test".
The most popular part of the live lessons was when pupils were able to try the activities for themselves such as using the microscopes.

Face-to-face workshops

Differing regulations across the partner schools mean that some allow face-to-face workshops while others do not. For schools that allow face-to-face teaching we provide workshops, either indoors or outdoors on the school grounds. An example of such a face-to-face workshop is mackerel dissections. Again, thorough risk assessments are undertaken before each of these workshops, following both Swansea University's and each individual school's guidelines.

Pupil feedback on the fish dissection workshop showed that the most popular parts of the workshop was the dissection itself but also specific moments such as "dissecting the eye". The least favourite part of this workshop was "the smell of fish", although this did not seem to deter most of the pupils.

Outdoor workshops

S4 has collaborated with both the Birds of Prey Centre and the National Botanic Garden of Wales to set up safe, outdoor activities and workshops.
Although S4 facilitates these events, the external organisations deliver the content and run the workshops. This process has included collaboration on content for Bird of Prey Centre specific bumper workbooks, filled with scientific content that complements the show.

Each visit to an outdoor workshop has a risk assessment that adheres to that of each specific school, that of the university and the visited organisation's guidelines. This is in addition to standard safeguarding practices.

Additional Covid-19 regulations are also put in place, keeping the visitors socially distanced and split into groups upon arrival at the locations.

In the future S4 intends to carry out more of these outdoor style workshops.

Discussion

S4 has changed its operating model substantially to be able to continue the projected delivery during the Covid-19 pandemic, recognising the disproportionate effect that Covid-19 is likely to have on socioeconomically deprived areas (UNESCO, 2020a) and the potential loss of science and society that this engenders. The attempt to maintain the greatest outreach and catalysis of interest in STEM subjects during the pandemic has necessitated that interaction with pupils operate predominantly online. While challenging in itself, this has mean that S4 has been stimulated to produce an exceptionally diverse array of materials and methodological approaches using blended learning materials. Indeed, this is something that will continue to be developed as future workshops are created. It has long been recognised that pupil attention in schools is enhanced by the variability of the way subjects are presented (e.g. Blonder & Sakhnini, 2012) so, although the online response was deemed a necessity as part of restricting covid-19 transmission, it gave rise to an opportunity that enhanced information diversity in delivery.

The mixed methods approach has found great resonance in teachers and pupils alike, maximising the range of learners reached and helping negate some of the effects of digital poverty while prioritising engagement. However, this requires substantive investment of time and resources since maximising effect needs S4 to be in constant contact with partner schools to be able to appreciate school-specific (and thereby area-specific) challenges and difficulties. We note that the particular

conditions in socio economically deprived areas of South Wales may differ from those of other areas in the UK, with technological paucity being an ongoing challenge, the consequence of which should not be underestimated. As such, thought needs to be put into the way the specifics of bended learning approaches are adopted, in our case on a school-to-school basis. The variation in school pupil capacity to engage in various methods we used (e.g. workbooks, worksheets, live-streaming lessons, portals etc.) was carefully considered before execution of planned methods. Within this context, lockdown, rather than partial school attendance (such as by children of key workers), for example, is particularly pertinent because this condition maximised educational inequality which are especially difficult to overcome.

Covid-19 has been stark in the way it has exposed socioeconomic differences across the UK, particularly as regards education. This has, at once, acted as a clarion call for more engagement by government to catalyse interest in STEM subjects (and many others) but it has also catalysed teaching innovation that has, to some extent, helped bridge inequality divides. So much so, in fact, that S4 will use many of the blended teaching methods developed for the future without covid-19. We believe that this will also help schools change their teaching style which goes beyond digital platforms to options such as outdoor workshops that can demonstrate diversity and breadth of science across multiple situations. If such interventions and approaches can be maintained over appreciable periods, we see potential for STEM and higher education support to be delivered more effectively, making science more accessible to pupils from more diverse backgrounds.

As awful as this covid-19 pandemic has been, it has made us more acutely aware of the inequalities and perhaps inefficiencies in our educational system. We hope that the road to addressing these may provide future school children with an experience which makes them realise science is exciting, relevant, and truly for all.

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