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Let's get virtual! Reinventing a science festival during a pandemic: limitations and insights

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ABSTRACT

Non-formal, yet educative, activities such as science festivals can positively influence the public regarding their attitude towards Science, Technology, Engineering and Math (STEM) subjects and students' willingness to pursue STEM-related careers. We evaluate the changes made to adapt the Oxford Brookes Science Bazaar, a science festival that has been delivered face-to-face since 2008, to a virtual format in 2021 due to the COVID-19 pandemic. The online festival included 28 pre-recorded and 12 live activities of different types (hands-on, demonstration, games, lectures, podcasts, virtual tours). Hands-on activities and virtual tours had the highest number of unique viewers, while lectures and podcasts were the least watched. The videos were watched also after the advertised date of the festival and reached a broader audience than the physical events. The number of participants, the holding time, and the proportion of people who filled the feedback forms, however, were lower in the online than the physical events. STEM organisations should consider hybrid events, with both virtual and in-person contents, to reach a broader audience and to create more inclusive events. We provide recommendations on how to maximise the benefit of virtual formats, including expanding blended virtual activities to reach a wider variety of age groups.

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Introduction

Modern informal and non-formal science activities, including various extra-curricular activities, often take place in different environments and contexts ranging from museums, exhibitions, planned events, and universities (Tisza et al., 2020). Fan and Williams (2010) showed that extra-curricular activities, when compared to formal activities, lead to an increase of motivation and engagement amongst young students. Science, Technology, Engineering and Math (STEM) disciplines are increasingly important as the need for STEM professionals is growing exponentially (OECD, 2008; Vennix et al., 2018). It has been shown that informal activities can positively influence students regarding their attitude towards STEM subjects and willingness to pursue a STEM-related career (Bell et al., 2009; Miller et al., 2018). For instance, students who attended STEM camps show an increased interest in the STEM disciplines and are more likely to pursue a STEM-related career compared to students who did not (Binns et al., 2016; Kong et al., 2014).

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Similar findings have been found regarding students who attended science programmes, camps, or competitions (Dabney et al., 2012; Miller et al., 2018). Furthermore, adult scientists reflected that their participation in science fairs had positively influenced their career paths.

Still, several countries report a concerning decrease in students' interest in STEM disciplines and thus in embracing science-related careers (Martins Gomes & McCauley, 2021; Regan & DeWitt, 2015; Stocklmayer et al., 2010). Students shape their interest in disciplines such as mathematics and science long before they join college or university (Sadler et al., 2012). Furthermore, a vast majority of students chose a major in STEM disciplines mainly due to their interests over personal achievements (Maltese et al., 2014). A decline in interest for STEM disciplines is often related to parental attitudes towards science (Staus et al., 2020). It is thus pivotal to understand the key elements, such as school curriculum, family, and teachers' influence, and out of school activities that promote students' engagement with STEM disciplines, and their relation to a broader participation in STEM careers (Christensen et al., 2015; reviewed in Peterman et al., 2020; Tillinghast et al., 2020).

Science festivals offer an example of non-formal science communication events, attracting a wide range of publics, with different ethnicity, educational levels, and interests (Wharton & Rutherford, 2011). Science festivals offer a unique opportunity for the attendees to engage with scientists and experience STEM disciplines' application in the real world (Bultitude et al., 2011). Science festivals have been also shown to enhance parents' positive attitudes towards STEM disciplines and STEM careers (Canovan, 2019a). They are usually a one-day event, although their length can vary significantly from a day to a month (Wiehe, 2014). Due to these valuable aspects, science festivals have recently grown in popularity and attendance, where most of the public consists of new visitors each year (Nielsen et al., 2019).

Measuring the impact and success of science festivals is key for practitioners. Since the main aim of science festivals is to attract a wide range of the public and let them engage in diverse activities, their impact and success are usually estimated based on number of participants, breadth of the audience reached, and attendee satisfaction (Canovan, 2020; Jeske et al., 2021). Kersting et al. (2021) also explored in depth the participant engagement of virtual reality experiences at a science festival. The engagement in activities comprises not only observable behaviours but also internal cognition and emotions. For example, Van Beynen and Burress (2018) considered several indicators of child engagement in a free-choice learning environment, such as the ability to interact with peers and adults during their engagement. Canovan (2019b) investigated the affective (i.e., excitement, inspiration) and cognitive (i.e., factual) learning in pupils, teachers, and festival organisers. Grimberg et al. (2019) assessed the knowledge gain and the emotional reactions towards a STEAM (i.e., STEM + Arts) event. Previous experience and former engagement are also important when assessing the engagement with exhibits (Shaby et al., 2019). Finally, inclusivity, accessibility, and the reach of a large audience should be considered when evaluating the impact and success of science festivals (Idema & Patrick, 2019; Kennedy et al., 2018).

The main engagement methods that can be found in science festivals are scientific lectures, hands-on activities, exhibits, debates and dialogues, science shows and demonstrations (Bultitude et al., 2011). With the spread of online teaching, other engagement methods have emerged. Exhibits are now more frequently presented in the form of virtual tours (Bennett & Saunders, 2019), and debates are often presented as podcasts (Trujillo Torres, 2011). Also, games and apps are considered as a good way to engage students with educational topics (Morris et al., 2019).

The advent of the COVID-19 pandemic unexpectedly forced educational institutions to find rapid solutions to ensure continuity in learning, mostly by switching from face-to-face to remote education (Bozkurt & Sharma, 2020; Hodges et al., 2020). As with formal education, non-formal and informal education face the same challenges. Recent studies explored the impact of the pandemic on different aspects of education, e.g. on vulnerable learners (Drane et al., 2021) on adolescent mental health (Nearchou et al., 2020), and on school closure and management practices (Viner et al., 2020). Due to the aforementioned positive impact that non-formal learning provides to

students, there is an urgent need to maintain STEM outreach available to students and keep a high level of engagement and to understand the impact moving to remote learning has on such events.

'Oxford Brookes Science Bazaar' is a science festival that has been running annually as a one-day event since 2008 at Oxford Brookes University in Oxford, UK. Due to COVID-19 and the consequent National lockdown, the Science Bazaar moved completely online in 2021. In this study, we investigate the changes that have been made to adapt this normally face-to-face event to a virtual format for the first time. Our research questions were: (1) which engagement methods at the science festival worked better in an online format than in the traditional format? (2) which activities were less or more engaging in the online format compared to the physical editions of the Science Bazaar? We define engagement as the number of unique views, duration of the visit, and possibility to reach a larger audience. We evaluate the effectiveness of the first online edition held in 2021 in comparison with the previous physical editions. In particular, we evaluate the possibility to replicate face-to-face activities by providing several types of online resources and we investigate which resources were preferred by the audience.

Methods

Context

The 'Science Bazaar' is a science festival that has been running at Oxford Brookes University since 2008. The festival offers STEM-related activities divided into five main zones: Discovery, Mind Your Brain, Tech, Happy and Healthy, and Life Factory. In the recent years, we also offered activities from Arts and Humanities, thus the Science Bazaar became a STEAM festival (Tillinghast et al., 2020). The zones changed between years, with some zones growing in representation, and other new zones adopted. Each zone is related to a different scientific area, with activities varying from hands-on, demonstration, lectures, debates, and games. The target audience is children aged five to twelve years, with some additional activities and information available for their responsible adults. Each activity is led by a team of researchers and volunteer students. Some of the activities are also externally led due to collaborations with other organisations (e.g. local hospitals, Oxford University, and other local companies). In 2021, the Science Bazaar moved completely online, and the new format was entitled 'Beyond the Science Bazaar', with more activity types implemented (virtual tours, podcasts, online games) (Table 1).

Data collection

The pre-recorded videos and live events for the online Science Bazaar were uploaded onto the Brookes Panopto platform, which allowed for automated statistics on the number of unique viewers per pre-recorded video or live event. We monitored the access to online resources and compared the number of interactions with online resources the day after the event and two months later. The activities and resources for the online Science Bazaar are open access and can be found at the following link: https://www.brookes.ac.uk/science-bazaar

For the physical events, feedback forms were collected systematically since 2018. The feedback forms include the following questions: (1) How many people are in your group? How many children and of what age? (2) Have you visited the Science Bazaar before? (3) From where did you travel today? (4) How did you hear about the Science Bazaar? (5) How long did you stay today? (6) What was your favourite activity? We additionally asked for suggestions and rating of specific parts of the Science Bazaar (activities, signage, refreshments, restrooms). The feedback forms for the online Science Bazaar were similar, with modifications relative to the online adaptation (e.g. how many people logged on from your home today?). The country from which visitors joined the event was also obtained.

Table 1. Main activities in the online Science Bazaar 2021 and how they were adapted from physical to live Science Bazaar.

Activity name	Description	Activity type	Adaptation
Electric racing cars	One live event describing the history of electric cars.	Lecture	Moved from a virtual reality use of a racing car to a lecture by a young charismatic speaker.
Rocket cars	Demonstration of how to build own rocket car from straws, cardboard wheels and a balloon	Hands-on	Packs sent to schools and homes rather than face to face. It was also accessible to those who did not receive the packs as alternative materials were suggested.
Crocodiles of the World Ltd	Talks on the behaviour and ecology of crocodiles with live animals. Virtual tour of crocodiles of the world with a focus on conservation.	Virtual tour	Video of the presenter in the zoo rather than live interaction with animals.
Jungle explorer	Scientist reveals the lives of Borneo's animals through camera traps.	Virtual tour	Moved from presenter at a table to online showing of films with integrated questions.
Augmented reality (AR)	Looking through an AR vision tool to learn about AR.	Lecture	Moved from hands-on to a pure lecture.
Bright Sparks Science CIC	Interactive science show with experiments that can be performed at home	Hands-on	Hands-on kitchen science that can be done at home alongside presenter.
Physiotherapy	Learning the parts of the body and how physiotherapists can help with health.	Lecture	Moved from hands-on to a pure lecture.
Chinese handicraft	Video with instructions on how to make origami animals.	Hands-on	Video instruction rather than face-to-face instruction; children needed own supplies.
Merlin the Electron Microscope!	Demonstration on how an electron microscope work, and creation of 3D models of cells.	Demonstration	Demonstration only rather than demonstration and hands-on (children were able to look into the microscope).
Wildlife friendly coffee	The story of coffee production and how it helps wildlife.	Game	Video game rather than live interaction with scientist explaining about coffee production.

Data analysis

We categorised the online videos and live events as hands-on ($n = 7$), demonstrations ($n = 13$), virtual tours ($n = 3$), lectures ($n = 24$), podcasts ($n = 4$), and games. Some activities were presented in different types and with different videos. For games, we do not have information on the number of unique viewers who accessed them as they were hosted by external providers. We only have information on the game introduction videos that were uploaded on Panopto ($n = 4$). We used generalised linear mixed models with a number of unique viewers as dependent variable fit to a Poisson distribution for count data and activity type as fixed factor. We used the group that developed the activity as a random effect in the model to control for the fact that some activities were done by the same research group and on similar topics. We used the function 'glmer' in the package 'lme4' for R v 4.0.4.

Results

Online Science Bazaar 2021

The number of unique viewers depended on the type of resources online (Figure 1; random effect: variance = 0.71, SD = 0.84). Demonstration activities had more unique viewers than lecture-like activities, hands-on activities and virtual tours had the highest number of unique viewers, statistically higher than lecture-like activities, game introductions, and podcasts (Table 2). From Figure 1, it is evident that there were some outliers with a much larger number of views than the rest of the activities. These were Bright Sparks Science (229 unique viewers) for demonstrations, Racing Cars (94 unique viewers) for lecture-like activities and Jungle Explorers (118 unique viewers) for the virtual tours. We do not have data from the external links connected to the game introductions videos, although the Wildlife Friendly coffee game has been played more than 100 times, but the number of

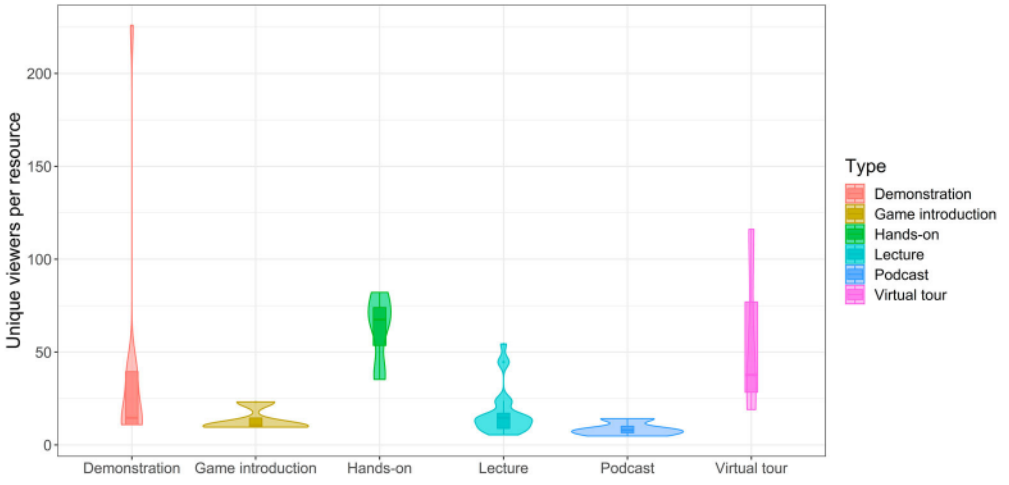

Figure 1. Box plots embedded in violin plots showing the predicted number of unique viewers per resource used, divided by resource type, in the online Science Bazaar 2021. Predictions are based on a generalised linear mixed model.

unique viewers is unavailable. The online activities were watched after the Science Bazaar, with an average of 4.9 ± SD 9.8 unique views (range = 0.0–55.0). The Chinese handcrafts were the most watched activity after the end of the Science Bazaar and the only one that was watched more than ten times.

Comparison with physical events

In the online Science Bazaar, we presented 38 activities, 28 of which were pre-recorded and 10 live. The number of activities presented was higher than the activities in physical events until 2019 and was similar to the 2020 physical event. The estimated number of participants was lower in the online event than in the physical events (Table 3). The proportion of people who filled the feedback form was also considerably reduced in the online event. From the feedback forms, we found that the duration of the visit and the number of people in the group (or who accessed the computer) were

Table 2. Pairwise comparisons following a generalised linear mixed model to estimate the influence of the activity type on the number of unique viewers who accessed the resources used in the online Science Bazaar 2021.

Pairwise comparison	Ratio Mean	95%CI
Demonstration/game introduction	1.36	0.88–2.11
Demonstration/ hands-on	0.88	0.68–1.13
Demonstration/lecture	1.33	1.04–1.70*
Demonstration/podcast	1.49	0.84–2.66
Demonstration/virtual tour	0.77	0.48–1.22
Game introduction/hands-on	0.65	0.44–0.96*
Game introduction/lecture	0.98	0.67–1.41
Game introduction/podcast	1.10	0.66–1.84
Game introduction/virtual tour	0.57	0.31–0.98*
Hands-on/lecture	1.51	1.30–1.76**
Hands-on/podcast	1.70	1.02–2.94*
Hands-on/virtual tour	0.87	0.54–1.41
Lecture/podcast	1.13	0.67–1.90
Lecture/virtual tour	0.58	0.36–0.92*
Podcast/virtual tour	0.51	0.25–0.97*

*$p < 0.05$ based on Bonferroni-Holm pairwise comparisons.

significantly lower in the online Science Bazaar than in the physical Science Bazaars (Table 3). The Science Bazaar had a good turnover (~50–60% of new people each year) both for physical events and the online event. The audience for physical events was almost exclusively related to schools in Oxfordshire and Buckinghamshire, while online videos were also accessed from other countries (Bulgaria, Japan, South Africa, USA, Zimbabwe).

Discussion

In this study, we aimed to understand which were the most engaging activities in an online format of the Oxford Brookes Science Bazaar compared with the face-to-face one. Overall, the most engaging activities in the online science festival were the hands-on activities, demonstrations, and virtual tours. Hands-on activities have been considered the most engaging ones also by attendees of face-to-face science festivals (Chen, 2014; Jensen, 2012). A personal interest often sparks from the interaction with the environment; with hands-on activities, students do practical work and this might lead to perceive the content as more engaging and more realistic (Franklin & Peat, 2005; Holstermann et al., 2010). This was particularly evident from the Chinese handcrafts video that was one of the most viewed activities and the one that was watched more after the end of the Science Bazaar. We must note that visitor engagement is also dependent on the content of the activity, and this is evident from the outliers for each activity format. Electric Racing Cars, for example, was a very successful activity during physical events where children could experience a virtual reality tour simulating the use of a racing car; it was also successful during the virtual event as a lecture on the history of racing cars. Similarly, Jungle Explorers was also successful at the physical events and had significantly higher views than the other virtual tours. Bright Sparks was the most successful activity and one of the most successful activities at the physical events. The activity is organised by Bright Sparks Science, a Community Interest Company based in Oxfordshire that is specialised in the development of fun and entertaining activities for children of different ages. Thus, other factors such as activity content and previous positive experience with the activity during physical events have influenced the success of these activities also in the virtual event.

We offered two options for feedback: one specifically for Rocket Cars, and another for the festival in general. For the latter, participants could enter a prize draw after they completed feedback. Rocket Cars has been a very popular hands-on activity in the face-to-face Science Bazaar. As a recorded hands-on activity, it retained the above-average unique viewers. We sent, prior to the event, a thousand kits to replicate the face-to-face activity to schools, but only around 20% of the schools shared back the activity-specific feedback form. Furthermore, despite the potential to win prizes, we received a significantly lower number of completed feedback forms both related to the Rocket Cars activity and to the online Science Bazaar in general. This might be due to the absence of the researcher when filling in the form, as research presence can have a positive impact on the quality of the responses (Webster, 1997). From the feedback of the Rocket Cars, it was evident that some schools had difficulties in assembling the Rocket Cars, thus having the presence of researcher is beneficial as teachers might not have the knowledge to help students for complex tasks.

Table 3. Comparison between physical and online Science Bazaars.

	Physical			Online
	2018	2019	2020	2021
N activities	23	20	36	28 recorded + 12 live
Estimated *N* participants	2000–2200	1200–1500	1200–1500	700–1000
Participants who filled the feedback form (%)	16.4–18.0	15.2–19.0	15.0–18.8	3.3–4.7
New participants (%)[a]	76.4	58.2	38.7	52.4
Holding time (mean ± SD in h)[a]	2.9 ± 1.2	3.1 ± 1.4	2.8 ± 1.1	2.2 ± 1.4*
N people in the group[a]	4.0 ± 1.7	3.8 ± 1.5	3.7 ± 1.3	2.4 ± 0.9*

[a]Data based on feedback forms.
*$p < 0.05$ based on Mann–Whitney test between online and physical events.

Boyette and Ramsey (2019) found that attendees who interacted with scientists in science festival had a positive impact in the evaluation of the event compared to those who did not interact with scientists. Furthermore, the interaction with scientists allows the general audience to depict scientists more accurately (Woods-Townsend et al., 2016). It has also been shown that attendees after interacting with scientists increased their awareness regarding STEM-related careers (Boyette & Ramsey, 2019). These aspects can have positive implications in a more realistic perception of the role of scientists and thus leading students to increase their willingness to pursue STEM careers. Jungle Explorers was an activity that a biologist researcher delivered in both the face-to-face and the online formats. The activity method, however, changed consistently when moved online. In fact, in the face-to-face format the activity was delivered as a lecture while in the online format, it became a virtual tour. The researcher also experienced numerous questions during and after the virtual tour, and due to time constraints managed to reply to only a small number of them. The virtual tour was delivered using Zoom webinar, meaning that the participants were not visible. This could also have positively influenced the students to ask questions to the scientist without feeling the pressure that may happen instead in the face-to-face format. The opposite outcome resulted with the Augmented Reality activity, it was delivered as a hands-on activity in the face-to-face format and changed to a lecture activity in the online format. The activity was very popular in the face-to-face format and was consistently less engaging in the online format. Students, during these unusual times, might have perceived the online lecture as something less engaging and similar to their daily activity with remote learning.

The online Science Bazaar allowed researchers to interact with the public audience and to keep this valuable annual informal activity available during a time when otherwise it would not have been possible to deliver. The online festival had a relatively lower number of participants when compared to the face-to-face ones. By looking at the country from where participants logged in, however, the online festival included participants from overseas. Online festivals can lead to a broader audience, even if it is pivotal to consider the constraints related to the Internet accessibility and technological equipment from families (Morgan, 2020). Participants stated that the main drivers to participate in science festivals, despite acquiring new knowledge, are the different engagement formats and the different levels of social interactions with scientific researchers (Jensen & Buckley, 2014). By moving scientific festivals online, it is thus pivotal to maintain this unique combination offering a large range of formats and allowing social interaction between a scientist and the public and within the public itself. Baber (2020) found that the lack of social interaction is one the weak points in online learning and may undermine its effectiveness. The use of Zoom platform by the creation of break out rooms might overcome this issue (Baber, 2020). The use of podcasts might also attract a different type of audience that is composed of teenagers (Evans, 2008). Teenagers might also be encouraged to engage in online events and not in physical events considering the anonymity and the lower social pressure. Also, as noticed in the Electric Racing Car activity, teenagers might find appealing the activities led by undergraduates as they may be more relatable. Thus, the Science Bazaar should better target these new audiences that can emerge using virtual platforms. Keeping these resources online can increase the reach to different publics, since the festival itself normally targets primary and secondary schools. This aspect resulted in a lower number of views for activities targeting teenagers such as podcasts.

Conclusions

The benefits to physical science engagement events are well established and so, when it is safe to do so, it is important that a return to this format is prioritised. That being said, there are a number of clear benefits to virtual events, such as, travel time, increased public reach and convenience of pre-recorded content, mean that virtual events are rapidly becoming the 'new' normal forum for meetings and conferences (Roos et al., 2020). In the future, STEM institutions should consider creating hybrid events, with both virtual and in-person content, to reach a larger audience (e.g. physical Science Bazaars usually target children aged five to twelve years, but some online formats can

reach teenagers as well). Virtual events are still limiting as they are not fully inclusive considering that audience must have access to a PC/Internet to be able to engage. As the Science Bazaar is ultimately a community-focused event, a solely virtual event would not fit with our principles. In this paper, we provided useful suggestions to practitioners who wish to adapt their science festival activities to a virtual or hybrid format. We highlighted the importance of considering the activity type and content to increase the engagement of online science festivals. Hands-on activities, demonstrations and virtual tours were the preferred activity types, and activities that were popular during physical events had also more engagement during the virtual event. Virtual events also offer the opportunity to reach a different audience that is usually not engaged during physical events. Virtual events also offer the opportunity to access activities after the end of the event, and this can be beneficial both to students and practitioners that can access a variety of activities as they need. Further long-term studies should be conducted to evaluate which teaching methods are more effective when moved online, contributing to the highest level in keeping students motivated and willing to pursue a STEM career. We are confident that online events may add additional value to this powerful informal learning methods characteristic of science festivals.

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No potential conflict of interest was reported by the author(s).

Data availability statement

The data that support the findings of this study are available from the corresponding author, KAIN, upon reasonable request.

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