International Journal of Science Education, Part B
Communication and Public Engagement

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/rsed20

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To cite this article: Cherry Canovan (20 Apr 2025): From curiosity to commitment: exploring the longevity of science festival impacts one year post-event, International Journal of Science Education, Part B, DOI: 10.1080/21548455.2025.2493371

To link to this article: https://doi.org/10.1080/21548455.2025.2493371

Published online: 20 Apr 2025.

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, PART B
https://doi.org/10.1080/21548455.2025.2493371

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From curiosity to commitment: exploring the longevity of science festival impacts one year post-event

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ABSTRACT

Science festivals are known to boost aspects of science capital in the short term, but little work has been done to determine their longer-term impacts. We surveyed festival participants one year after attendance, and found that a large proportion retained knowledge acquired during the experience. Many had also been prompted to take further science-related actions. Moreover, some respondents reported sustained impacts from other visits three or more years previously. As both 'what you know' and 'what you do' are key aspects of science capital, we conclude that festival attendance builds such capital over medium to long time frames of a year or more. We propose two mechanisms by which such a transient event can have long-term impacts; the role of curiosity in facilitating knowledge acquisition, and the experiential nature of festivals which allows them to form a stage of Kolb's cycle of learning. While the finding that science festivals have the capacity to boost aspects of science capital for a year or more after attendance is arresting, it highlights the importance of ensuring that such events are accessible to all, rather than just those with an existing interest, in order to widen participation in science.

ARTICLE HISTORY
Received 2 May 2024
Accepted 6 April 2025

KEYWORDS
Science festivals; science outreach; science capital; widening participation; informal science education

Introduction

The science festival sector has seen rapid growth in the last 30 years. Since the first such event, held in Edinburgh in 1989, the phenomenon has swept the globe, with large events now regularly held across Europe, North America, Asia and Australia, alongside smaller iterations elsewhere.

The academic literature surrounding science festivals has grown at a similar rate (Peterman et al., 2020; Ramsey & Boyette, 2021), addressing questions such as who attends these events (Kennedy et al., 2017; Nielsen et al., 2019), what their motivations are (Jensen & Buckley, 2014), and what the short-term impact is on the audience's perceptions of science (Canovan, 2019).

Another facet of investigation is into whether festivals can build science capital (Gathings & Peterman, 2021; Rawlinson et al., 2021). Science capital is a concept developed by Archer et al (Archer et al., 2015), and is commonly defined as 'the science-related knowledge, attitudes, experiences and resources' that an individual has (Enterprising Science, 2016); high science capital among young people is related to post-16 science study. However one question that has not, as yet, been studied extensively is whether attendance at such events can lead to longer-term impacts on facets of science capital such as sustained factual learning or persistent changes to science-related

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behaviours. Two recent studies have looked at the effects of festival attendance after an interval of around 3–4 months (Idema & Patrick, 2019; Rawlinson et al., 2021); in this paper we extend these findings to investigate whether measurable impacts are still seen after an interval of one year or more.

We also interrogate the mechanisms by which a transient experience, such as a science festival, might be able to lead to meaningful long-term effects, focusing on the curiosity-sparking and experiential elements of these events. Finally, we discuss the equity implications of science festivals' ability to have sustained impacts on science capital, given that the festival audience is disproportionately affluent and highly educated. This is important to understand, as if benefits are largely available to already overrepresented groups, the efficacy of science festivals in promoting science capital may serve to exaggerate existing disparities.

Theoretical framework

Science festivals can have a multitude of structures and formats (Ramsey & Boyette, 2021), as well as multiple and varied aims, but previous work (Canovan, 2020a) has shown that excitement, inspiration and factual learning are common goals of their organisers. These shared objectives have led some commentators (Gathings & Peterman, 2021; Jones et al., 2023) to suggest that, at root, the purpose of the science festival is to cultivate science capital among attendees.

Science capital, a concept developed by Louise Archer (Archer et al., 2015) based on the work of sociologist Pierre Bourdieu, can be defined as 'the science-related knowledge, attitudes, experiences and resources that you acquire through life' (UCL, 2018), and is strongly correlated with post-16 science study and, by extension, careers in science (Archer et al., 2020). It is often described in simple conceptual terms as being a 'holdall' comprised of what you know, who you know, how you think and what you do when it comes to science, and is useful in explaining why some social groups are underrepresented in scientific careers.

Science capital is a complex entity which is difficult to measure (Seakins & King, 2016) and to build; the Aspires 2 longitudinal study on science capital in young people aged 10–19 commented that 'building science capital in young people … cannot be achieved solely through short-term and/or "one-off" approaches' (Archer et al., 2020). When thinking about the benefits of science festivals, it is therefore germane to ask not only whether it is possible to detect boosts to elements of science capital from attendance, but also whether these can be sustained beyond the short term.

There have been some attempts made to measure gains in science capital resulting from science festival attendance (Gathings & Peterman, 2021; Rawlinson et al., 2021). These studies involved data collection by survey or focus group after an interval of between a week and a few months following festival attendance, and suggest positive impacts across various measures of science capital, such as being more likely to discuss science, and acquiring scientific knowledge.

Gathings and Peterman (2021) used a secondary analysis of evaluation data to demonstrate that the survey instruments used were capable of measuring at least some of the constructs that make up science capital. This was the case both in a situation where attendees were self-selected, that of adults at science festival-type expos, and one where participation was not a choice, in the case of pupils at school 'meet a scientist' events. The study found that participants who reported interacting with a scientist had higher science capital scores, as did those from ethnic groups underrepresented in STEM, a finding that is supported by research showing that meeting a scientist is particularly impactful for festival visitors (Fallon et al., 2023; Manning et al., 2013). However the authors note that the findings represent a snapshot, rather than a measure of change, and that more work is needed to tease out the causality of these relationships. In addition, data were gathered either on the day of the event or within one week of it, so can yield no information about longer-term impacts.

Rawlinson et al. (2021) also looked at selected elements of science capital to study how adults and children were impacted by science festival attendance, both on the day and four months afterwards.

On the day, the research team found 'an immediate, strong, positive' effect on measures such as prompting science discussion and perceived learning. In focus groups held four months after the event, visitors were still able to recall facts, and some reported changing behaviours, mainly focused on children's science-related activities. In addition, there were reports that family discussion had continued in the intervening period. These findings can be interpreted as evidence of increased, sustained science capital.

Idema and Patrick (2019) also looked at the longer-term impacts of science festival attendance, although without specific use of a science capital framework. To date, this is the only tracked longitudinal study of which we are aware. Families were surveyed on their learning during an ocean-based festival, and then followed up using interviews with both adults and children three months later. The study probed memories of the event among both groups, and found that participants had significant experiential recall after this interval; adults' memories mainly revolved around their children's experience, but children recalled learning facts such as 'Sea turtles only come on land when they lay their eggs.' Additionally, all parents reported family discussion of the festival experience after their visit. These findings – increased knowledge and discussion of science – can be interpreted as building facets of science capital.

There is some evidence, therefore, that elements of science capital can be built in a sustained way by science festival attendance. This paper aims to discover if this finding is replicated over a longer term of one year post-festival.

We also take the analysis a step further by considering the mechanism by which a visit to a science festival, an essentially transient experience, might contribute to science capital formation in the medium-to-long term. Our thesis focuses on two primary characteristics which may be held to boost learning: the science festival as a driver of curiosity, and as an active experience. Both of these aspects are core to the idea of the science festival, and are considered in turn.

The science festival as an incubator of curiosity

A frequently stated aim of science festivals is to stimulate curiosity among attendees; in fact, there are instances of events where 'curiosity' is literally in the name, such as the Nottingham Festival of Science and Curiosity, or Glasgow's 'Curious About … ' event. Festivals state that they aim to 'Spark curiosity'[1] and invite participants to 'Dare to be curious'[2] or 'Unleash your curiosity'.[3] Meanwhile, research has shown that this aim is shared by festival audiences; studies with both schoolchildren (Kececi, 2017) and family groups (Jensen & Buckley, 2014) found that a primary aim of those visiting was to develop curiosity about the science on show.

Curiosity is well-known to be a key factor in learning and associated memory. As early as 1973, Bull and Dizney (1973) showed that curiosity arousal was associated with improved information retention. Pluck and Johnson (2011) state that: 'It is almost axiomatic to suggest that curiosity generally enhances academic learning.' Kang et al. (2009) undertook an fMRI study which suggested that '… curiosity may enhance memory for surprising new information', while Gruber et al. (2014), also using fMRI, found that 'In both immediate and one-day-delayed memory tests, participants showed improved memory for information that they were curious about and for incidental material learned during states of high curiosity', adding that the findings 'highlight the importance of stimulating curiosity to create more effective learning experiences'. The related concept of interest, another common theme of festivals, is similarly found to be related to learning and retention (Fastrich et al., 2018; McGillivray et al., 2015).

One might expect that a science festival setting would not be optimised for developing fact retention, given the limits imposed by the transient nature of the event. Unlike the guided repetition and retrieval which might be considered best practice for school-based learning (Kang, 2016; Roediger & Butler, 2011), the festival experience typically offers no opportunity for follow-up of any kind, unless guided by the participant themselves.

However, as curiosity and interest are proven to positively impact learning and memory, we would expect that an experience which centres these concepts as primary objectives would lend itself to greater-than-expected knowledge acquisition and retention.

The science festival as a site of experiential learning

Experiential learning, defined by its most prominent exponent David Kolb (1984) as 'the process whereby knowledge is created through the transformation of experience', occurs in spaces where the learner is able to actively participate in the learning process. The description can include literal hands-on activities, which feature heavily in many science festivals; indeed, guides for successful festival stands include instructions such as 'Give them something to touch' and including 'high tech' or 'low tech' interactive tasks (USA Science & Engineering Festival, 2018). However the broader festival experience, the act of purposefully visiting and interacting with a novel environment, is also in itself experiential.

Kolb's statement of experiential learning theory (ELT) can be depicted as a cycle as shown in Figure 1, involving a recursive process of experiencing, reflecting, thinking and acting:

> Immediate or concrete experiences are the basis for observations and reflections. These reflections are assimilated and distilled into abstract concepts from which new implications for action can be drawn. These implications can be actively tested and serve as guides in creating new experiences.

The learning created in a setting such as a Science Festival, therefore, is not just stimulated by participation in the experience; it also stimulates a cycle of reflection, thinking and acting, continuing the knowledge acquisition process.

The efficacy of experiential learning in science has been explored in a number of studies. Bell et al. (2009) provide a thorough review of learning in settings such as museums and science centres, finding that various different types of science knowledge acquisition are supported by the experiences inherent in visiting such a venue; for example, the authors note 'clear evidence for learning science content … in the form of factual recall after experiences in designed settings. Recollection seems to be supported by experiential linkages that ground abstractions in sensory experiences'. Meanwhile Bauerle and Park (2012) found that students who participated in a tree-climbing experience during a horticulture field trip did significantly better in a subsequent homework task than those who did not.

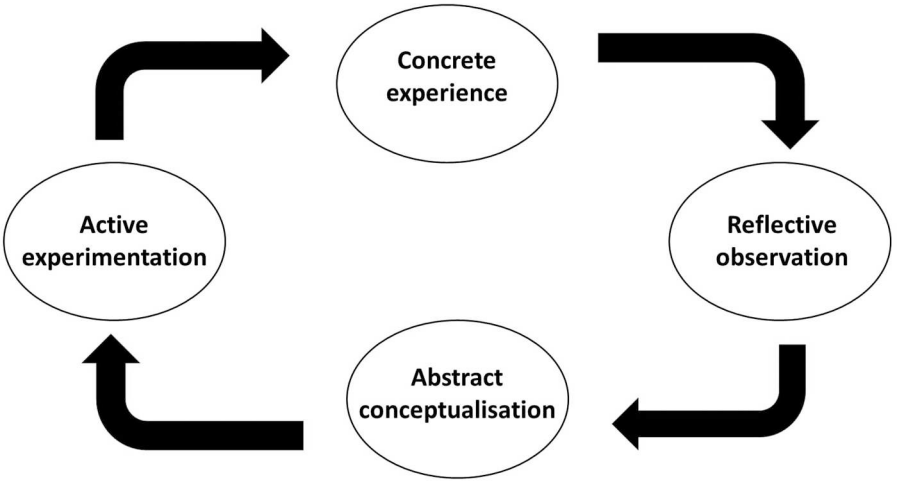

Figure 1. Graphical representation of Kolb's experiential learning cycle.

ELT has been used to study the science festival experience (Idema & Patrick, 2019); as the authors note, participants do not complete the cycle during the festival, but further steps taken in the aftermath can help to solidify learning. It follows that if the science festival is as effective a site for experiential learning as we suggest, we should be able to see evidence that attendees have completed other stages of the cycle in the period following the concrete experience of their visit.

The science festival audience

When considering questions related to science festival attendance, it is important to note that the audiences for such events are frequently unrepresentative of the general population. In particular, studies in both the US and UK have found that attendees are disproportionately middle class, highly educated and with an existing interest in science (Canovan, 2020b; Kennedy et al., 2017; Nielsen et al., 2019). While attracting a more representative audience is a priority for some festival organisers, this is difficult to achieve, and the benefits of science festival attendance need to be considered in this context.

Research questions

The above discussion leads us to ask the following questions:

(1) How much retention and recall of learned information is apparent one year after an informal science experience designed to engage interest and curiosity?
(2) How do the experiential aspects of science festivals play into the long-term learning that takes place?
(3) Given the above, how effective do experiences such as science festivals have the potential to be in building science capital among different audiences?

Data pertaining to the first two questions are discussed in the Results section of this paper. The implications of these findings, and their relevance to question 3, is addressed in the Discussion section.

Methods

The Lancashire science festival

All data collection for this study took place amongst visitors to the Lancashire Science Festival (LSF). The festival has been running annually[4] in various forms since 2011, with a hiatus for Covid, and staged its 10th full edition in 2023. It is aimed at younger children and their parents, with two days devoted to visits from primary school parties and a third public day for local families. Hosted by the University of Central Lancashire in Preston, its main audience is from the city and surrounding area, although visitors do attend from as far away as Scotland and the south of England. Around 160 school parties visit each year, with more than 5000 visitors on the public day.

Data collection

Data for this study was collected in two stages, as shown in Table 1. The initial phase took place in June 2018 at Valley Primary School,[5] which was preparing to attend that year's edition of LSF. Valley is a

Table 1. Data collection schedule.

Cohort	Date data collected	Date of prior LSF visit
Valley Primary Y6 pupils	June 2018	June 2017
Adults who visited LSF 2021	October 2022	October 2021

small school with mixed-age classes, and some of the Year 6[6] pupils had attended the June 2017 festival almost one year previously. Data were audio recorded and transcribed before analysis. During the discussions, previous festival attendees described their experiences in some detail to the other pupils, and obviously had a clear recollection of the event. We analysed this data and found it interesting; we then decided to build on it by investigating what a group of adult attendees could recall a year after attending, in order to see if this effect was replicated in different visitor groups.

This second stage was conducted in 2022 and comprised a survey of adults who had attended LSF one year previously. The survey included questions about learning and knowledge recall, queries looking at follow-up actions taken by the participant, and items asking about recall from even earlier iterations of the festival, where attended. The questionnaire pool was made up of adults who had booked their family's festival attendance in October 2021. Where we held emails for these individuals and they had consented to further contact, we sent out an invitation to complete an online survey in October 2022, exactly one year after the 2021 event. In total 1030 individuals were invited to complete the survey and we received 108 usable responses, a response rate of 10.5%.

Consent

Informed consent was gathered from all participants in this study. In the case of the school focus group, information sheets were sent home and parents gave written consent for their children to take part in a study looking at learning at science festivals; child participants were asked to give verbal consent at the beginning of the session. Adult participants were sent an introductory email containing a link to the online survey; the first page of the survey gave information about the purpose of the study and required the respondent to consent before completion. The design of both parts of the study were approved by the ethics committee of the University of Central Lancashire.

Impact of COVID-19

The Covid pandemic was both a help and hindrance in this study. There was no festival in 2020 and the family day ran in 2021 but at a different time of year than usual. Due to organisational constraints, it was then not run again until 2023. The hiatus in 2022 allowed us to contact visitors exactly one year after their 2021 attendance without complications caused by promotional activity for the next festival, which was beneficial.

However, the school days ran online rather than in person in 2021 and were severely disrupted by the 'class bubble' system operational at the time which meant that a single case of Covid saw the whole class sent home. This meant that in 2022, when the bulk of data collection for this study took place, there were no children who had experienced a normal festival a year previously as part of a school group. The data in stage 2 of the study was therefore gathered exclusively from adult public-day participants, which was not originally the intention.

Data analysis

Quantitative data gathered were very simple and was analysed using Microsoft Excel. Qualitative data were analysed manually using inductive thematic analysis, an iterative process designed to identify patterns and themes in textual data. Researchers begin by familiarising themselves with the data and then through an initial coding, systematically assign labels to top-line themes. These codes are then grouped together to form broader themes that capture the underlying patterns and concepts present in the data. This iterative process of coding and theme development allows for a detailed exploration and interpretation of the data, leading to rich insights.

Profile of adult respondents

As mentioned, science festival audiences tend to be more affluent and have a greater interest in science than the general population, so it is of interest to look at whether this was the case for our adult sample.

We collected postcodes of participants as a proxy for socioeconomic status; respondents were evenly split across the upper and lower halves of the deprivation distribution, using IMD,[7] although the most affluent groups (IMD deciles 8–10) were overrepresented, as is common among science festival audiences.

Although we did not ask specifically about interest in science, a large majority (87%) of our survey respondents stated that they had attended the LSF on at least two occasions (in 2021 and one or more previous editions), indicating a pro-science inclination. In addition, several respondents mentioned that they and/or their children had an existing interest in science before attending the event.

A note on adult and child perspectives

Due to Covid impacts, as detailed above, our participants were mainly adults who had accompanied their children to the festival. It is therefore important to understand how parents' comments about their child's experience should be interpreted.

It is often the case that parents, when asked about their own science festival experiences, instead report their perception of the impact on their children. For example, Rawlinson et al.'s (2021) participants told researchers on the day that attendance had increased their children's interest in science, while in another study (Canovan, 2019) parents at a science festival reported that their child had an improved perception of science even when asked explicitly about their own experience.

However in the longer term, it may not be wise to rely on parental perceptions of children's experiences. Idema and Patrick (2019) compared the accounts of adults and children three months after a science event and found marked differences in what was recalled, noting that 'The perspective of the adult is not necessarily the child's perception of the experiences. In reality, children remembered more about Ocean Festival than adults believed.' On the other hand, while parents recalled post-event family conversation, children did not. Given this disparity, it follows that when we are looking at sustained impacts of festivals, it is wiser to only consider adult's reports of their own longer-term experiences. In this study, therefore, we largely disregard parental reports of children's beliefs, knowledge and thought processes, unless there is supporting evidence to corroborate these.

Results

Q 1: How much retention and recall of learned information is apparent one year after an informal science experience designed to engage interest and curiosity?

Scientific knowledge gained in the festival context can be demonstrated in a variety of ways; via facts retained, improved understanding of scientific processes or the scientific method, or improved understanding of scientific education and careers. In our survey of adult visitors, we asked a number of questions about recall of such information, and then categorised the answers. In total, 78/108 participants (72%) stated that they remembered something they had learned at either the 2021 festival or a previous iteration, and when we analysed their free text responses, 61/108 (56%) gave at least one answer that we would classify as demonstrating retained knowledge from 2021 or before.

Science facts and processes

We asked respondents if they could remember information about either science facts, science processes, or scientists and science careers that they had learned at the 2021 festival. In total, 62/108 participants (57%) stated that they were able to remember information of this nature from the

2021 festival. Of these, 46 stated that they could remember a scientific fact learned at the 2021 festival, and 43 said they remembered something about scientific processes or careers. However when analysed, some of the memories were experiential in nature; in total, 51/108 (47%) of participants recalled learning something in 2021 that could be construed as a 'science fact', information about a science process, or careers knowledge.

Examples of facts recalled, in the participants' own words, include:

- 25% of bones in body are in our feet.
- That cornflour and water makes a non-Newtonian liquid.
- Jupiter is a gas giant.

In terms of scientific processes, some examples include:

- How to stain cells in order to see them through a microscope.
- That scientists are working on a bionic skeleton that can help the military.
- Embryo [is] created by Y cell from dad and X cell from mum.
- I learnt a lot about fireworks and how they make colours and more specifically the shapes, i.e. the twinkling stars.

For careers or science education knowledge, we looked for comments that demonstrate learning about the range of scientific careers that are available and the many types of people who can fill these roles. Participants reported finding out about educational opportunities such as computer gaming-related courses, and discovering jobs in fields that they had not previously realised existed, such as exoskeleton design or pyrotechnics.

Longer-term memories

We also took the opportunity to delve back further in time to look at how knowledge persists. We know that the LSF attracts many repeat visitors (Canovan, 2020b), so we asked respondents 'Had you ever attended the Lancashire Science Festival BEFORE 2021? If you answered yes, do you remember anything you learned on that occasion?'. Participants were thus being asked in autumn 2022 to recall events from summer 2019 or earlier.

As previously stated, a large majority (94/108 participants, 87%) of respondents told us that they had attended LSF prior to 2021. Of these, 48 stated that they remembered something they had learned on this occasion, with half of these (24/94, 26%) citing a recollection that we would classify as factual information. Examples include:

- I remember learning the parts of the brain by drawing them on balloons.
- How shaking milk breaks the fat cells to thicken it.
- [About] the diversity of undersea creatures.

The longer-term recollections of others were more experiential in nature, which we discuss in a later section.

Learning recall, interest and curiosity

In their comments, both adults and children ascribed the level of recall they were able to produce to the curiosity and interest stimulated by the festival experience. In our pupil focus group, after a comment from the facilitator that they seemed to remember the events of the previous year's LSF clearly, the children became interested in why this was and began a spontaneous discussion on this point:

Child 1: I think the main reason why I remember it is because it was a good way of showing it to us.

Child 2: And it was interesting.
Child 1: Because at school sometimes I don't really take some of the things in because it's just not shown that interestingly, but sometimes it is.
Child 2: Yes, and all you do at school is talk about science, and sometimes you do stuff.
Child 3: Practical stuff, like video games.
Child 2: But not all the time because we're in year five and six.
Child 1: But when we were there we could actually do stuff, it was quite – we found it fun and intriguing.
Child 4: Intriguing.
Child 3: Practical, I would have said.

Although we did not directly ask adults about why the festival was a good site for learning, some volunteered their thoughts, particularly with respect to the learning that they perceived that their children had acquired. Comments included the following:

- Taking science out of books and making it live and fun is the best way for them to learn.
- The practical aspects of the festival have more impact than a more theoretical classroom discussion.
- Seeing real life demos really helped their understanding rather than reading a book.

Q 2: How do the experiential aspects of science festivals play into the long-term learning that takes place?

We sought evidence that attendance could trigger or form part of a cycle of experiential learning, leading the participant to build on the gains experienced on the day itself during the subsequent period and thus enhance knowledge accumulation and retention.

Before we consider the evidence that the ELT cycle is activated or continued by science festival attendance, let us take a look at the amount of experiential recall evinced by both adults and children in our data.

Children's recollection of the festival experience

In our focus group at Valley Primary, pupils spoke freely about their experiences at the LSF almost one year previously, needing little prompting and with almost all children contributing. It was immediately clear that participants had a vivid memory of the event, with the group repeatedly embarking on long discussions on a variety of topics. The extent of the detail which was recalled can be seen in this exchange:

Child A: My favourite thing there was, you know the live show that we watched? And he made his own video game and then he showed us loads of science tricks that were related to it. And then –
Child B: Oh yes, how you breathe in, you only get a small amount, you breathe away and you get a massive amount.
Child C: It's amazing.
Child A: Yes, in the tube and then how the funnel disappears when you put it in the oil because of the light refraction.

This conversation may be difficult for the outsider to parse, but many members of the group recalled the events with enough precision to immediately understand the context and add to the narrative.

Adult recollections

There is abundant evidence in our data that adults have vivid recollections of what they did and saw at the festival over an extended period of three years or more. While we asked about specific facts recalled from the 2021 LSF, those who had attended in 2019 or earlier were asked for more general recollections, with responses largely given in experiential terms. Many adults were able to describe

encounters and observations, sometimes in detail, demonstrating significant recall of events from several years prior:

- We did the UV clue search as a forensic detective scene of crimes. My eldest still talks about that.
- Video of rockets that did not work/failed to launch. Testing our reaction time. Paramedic ambulance – putting grandson on stretcher. Static electricity making people's hair stand on end.
- Wearing the virtual reality glasses and crossing a plank of wood on a high building. It was scary!

Another important facet of the experience was the ability of visitors to interact with individual scientists. This led some adult participants to find out facts about the life of a scientist and what sorts of people inhabit these roles; the reported engagements humanised the scientists in the eyes of our respondents:

- Two of the scientists at LSF have dyslexia.
- They have a passion for their work and use multiple ways to express that and engage young people.
- [My children] remember talking to an engineer about fairground rides. It is so important to meet real people working in STEM. Talking to the people opens up possibilities.

This finding echoes previous work (Fallon et al., 2023; Manning et al., 2013) showing that the experience of interacting with a scientist is particularly impactful for festival attendees.

Evidence of the ELT cycle in action

When learning is consolidated from a memorable experience such as a science festival, we expect the ELT cycle to be engaged, with participants following their visit by reflecting, and then by thinking and acting. We looked at the responses to our survey in an attempt to identify instances of the latter two stages in the cycle.

Thinking: Instances of 'thinking' were identified in comments where respondents talked about changes in attitude towards science and science careers. There were a few comments where the participant talked about themselves in this manner; for example, one visitor said the festival had 'inspired me to work towards being able to apply for [university]'.

However, most of the examples of this kind of thought process were given by parents discussing their children's views, either in terms of their aspirations or their attitudes towards science. Examples include:

- My son now wants to be a science teacher at school.
- I think it's allowed [my children] to apply science to real jobs.
- Think it helped them understand the variety of scientific-related jobs, and that science can be fun and interesting.

As discussed in the Methodology section, such results need to be treated with caution, and the literature tells us that 'Adults may not be aware of child learning or long-term impact of [a science festival] experience' (Idema & Patrick, 2019). Statements such as 'My daughter is more open to learning more about science', may reflect parental affect rather than the child's thoughts. Meanwhile, some parents in their responses also seemed to be making quite broad assumptions about links between their children's behaviour and LSF attendance, for example: 'They continue to explore science, and are doing well in school due to that interest from the event.'

But although these parental reports of children's attitudes may be problematic, such responses *can* undeniably tell us something about the adult's own thought processes. It is clear that the parents making the statements above directly attribute children's science interest, choices and effort to

festival attendance. This positive attitude towards the festival may in turn prompt the next stage in the cycle, action.

Acting: We asked adult visitors: 'Was there anything you found out about at LSF 2021 that you followed up in some way afterwards?' A total of 55/108 of our respondents (51%) recorded concrete actions that they or their child had taken following their visit to the festival, with a total of 75 actions recorded. The most common action, taken by 25 participants, was discussion. This was followed by career/educational actions noted by 16 people; other categories were science-related purchases (9), research (9), experimentation (6) and media consumption (6). Let us consider some of these.

Participant discussions: Discussions among family members were frequently mentioned, as were conversations with friends. Here are a few typical comments:

- I attended with my grandson and have had frequent discussion about what he learnt that day.
- We discussed LSF in the Scout group that I am a part of.
- Discussing and encouraging friends to attend with their children.

Another, linked, theme emerges from the data; things that the child 'still talks about':

- My children still talk about attending the day and what they learnt about animals and the cycles of life they learnt.
- They remember the black hole experiment with the marbles and still talk of the play they watched.
- Hand cleanliness and the DNA bracelet stand, they still talk about today.

Career and educational actions: A small number of adults told us that they had made, or planned for, a return to education following the festival experience. Comments included:

- [I am] looking at courses in forensic science.
- Reviewed courses at UCL an suitable for a career change.
- [I am] studying computer science.

As previously mentioned, parents frequently ascribed educational and career aspiration behaviours among their children to festival attendance. In addition, several also directly associated their child's decision to opt for, for example, triple science GCSE or Chemistry A level, with LSF attendance. Such claims must be treated with care, as it is likely to be the case that at least some of the families attending did so because of their existing high science capital, which would have made it more likely that their children would have chosen such options anyway. However, there are indications of a concrete educational impact on some young people, for example where their parents have noticed a sustained uptick in effort, or taking on new roles:

- My daughter now wants to be a pathologist and she has really focused on her science lessons as a result.
- He is now science ambassador at his school.

Research and experimentation: Perhaps the action that encapsulates the ELT cycle in its purest form is being prompted to learn more as a result; both research and experimentation are an expression of this. Comments in this vein included:

- [We] looked up about exoskeletons.
- My son was very interested in the asteroids and research took place after the visit.
- Started to research about the magnet energy and its function in the real world.
- We carried out some of our own experiments by making circuits.

- [My son] conducted experiments, read books and searched YouTube.

Discussion: How effective do experiences such as science festivals have the potential to be in building science capital among different audiences?

In this section, we briefly discuss the implications of the data gathered in response to research questions 1 & 2, and then discuss how these findings support the value of the curiosity-stimulating and experiential nature of science festivals in building science capital among attendees.

Q 1: How much retention and recall of learned information is apparent one year after an informal science experience designed to engage interest and curiosity?

Our data shows that well over half of visitors to the festival could recall some substantial piece of learning from a visit a year or more previously. Our respondents could recall information that we would classify as a 'science fact', as well as displaying retained knowledge of scientific processes. Participants had also gathered education and careers-related information, including data about the types of people who become scientists, which served to position them as approachable or as realistic role models. This learning was at times very long-lived, with a quarter of those who had attended a festival iteration in 2019 or earlier still able to remember a fact, while others remembered their experiences.

We posit that the breadth and longevity of such learning in a transient setting is enabled by the interest and curiosity evoked by the experience, an explanation which chimes with existing research citing these factors as beneficial for learning. It is particularly interesting to note that our respondents seemingly agreed with our analysis. Whilst we did not ask either adult or child participants about why the festival might have provided a good platform for learning, both groups spontaneously attributed this to its interest- and curiosity-provoking characteristics. In addition, both adults and pupils compared their learning experience to typical classroom teaching, represented as 'theoretical' science 'talk' which is modulated by 'books', in contrast to the festival which was 'interesting', 'intriguing', 'practical' and 'live and fun'.

Q 2: How do the experiential aspects of science festivals play into the long-term learning that takes place?

It is clear from both our survey and focus group responses that the LSF experience is hands-on, memorable and out-of-the-ordinary; comments stating as much were made by both adults and children. A year after attendance at LSF, one might therefore expect to see evidence of 'thinking' or 'acting' to demonstrate that the ELT cycle has been initiated.

As discussed, parental ideas regarding children's thoughts about the festival are often volunteered yet need to be treated with caution. However, these responses in themselves illuminate the learning cycle for *parents*, illuminating their thinking about their offspring's relationship with science. If parents believe that attending an event such as a science festival has had a concrete impact on their child's knowledge or behaviours, this can lead them to take further related actions, as suggested by Kolb.

When it comes to 'acting', many adults and families took practical steps to follow up attendance, with just over half of survey respondents reporting some sort of tangible action. Despite the warning above, there is some interesting data from parents suggesting that children continued the ELT cycle once they returned from the event via their actions, for example by conducting their own experiments; this is more compelling evidence than parental reports of what their children think, as it is more difficult to be mistaken about the practical things that people do than about their thoughts. In addition, the recurrent theme of things 'they [children] still talk about' is of interest; it is, perhaps,

harder to have an inaccurate impression about the things someone says as opposed to the things that they think or know.

The above findings are evidence that Kolb's learning cycle was in play in the post-festival period, with both the 'thinking' and 'acting' phases being evidenced in our data. What is less clear, however, is whether it was attendance at the 2021 festival which sparked the cycle in the first place. As previously mentioned, one interesting aspect of this study was the very large proportion of respondents – 87% – who had attended more than one edition of LSF. This indicates that 2021 LSF attendance was not, for these individuals, the catalyst that began the ELT cycle, but rather part of an ongoing learning process. Participants were involved in a cycle of experiential learning – a concrete experience sparking another concrete experience.

This is by no means a negative finding; on the contrary, the fact that science festivals offer an opportunity to act for those who have an existing interest is likely to energise science engagement, and make it more likely to lead to societally positive outcomes such as increases in numbers of scientists being trained. However, there are implications for equitable engagement in science which underlie this finding; these are discussed in the next section.

Q 3: Given the above, how effective do experiences such as science festivals have the potential to be in building science capital among different audiences?

As noted in our review of the literature, the foundational researchers of science capital state that it cannot be built solely via one-off approaches. However, as we have argued, it is nonetheless valid to ask whether some types of individual event which boost curiosity/interest and provide experiential learning can make a lasting contribution to its accumulation. It is also relevant to ask who is most likely to benefit from such an experience.

Here we consider the areas in which science capital could be built by science festival attendance in terms of the four simple attributes of what you know, who you know, how you think and what you do. It is clear from our data that festival visitation has a measurable impact on some of these characteristics, particularly 'what you know' and 'what you do', at a timescale of one or even three years post-event. Let us recapitulate the evidence for each aspect in turn:

What you know

More than seven in 10 participants stated that they remembered something they had learned at the 2021 LSF, and after analysis, 47% volunteered recalled information that we would classify as factual learning. In addition, 26% of those who had attended three or more years ago gave evidence that they still 'knew' something factual that they had learned on that occasion.

Who you know

In describing science capital, 'who you know' is usually taken to mean an individual's relevant social contacts and networks. We would not expect science festival attendance to influence this aspect, although we see evidence in the current study that some participants have clear memories of the experience of meeting a scientist, and that this had led them to form some theories about what sort of people scientists are.

How you think

In answer to questions related to thinking about science, many adult participants told us what their children think or thought in relation to their science festival experience, for example telling us that it had been the catalyst for a young person to decide to pursue a career in science. As noted, such perceptions are problematic, and we should be cautious in placing too much weight on them.

However, these parental interpretations of their child's ideas give an insight into the thought processes of the adult themself; they attribute their child's interest in science at least partly to science festival attendance, which in turn makes them more likely to take actions such as arranging attendance in later years, or pursuing related discussions.

What you do

Just over half of participants gave evidence that they had taken some type of concrete action prompted by their festival attendance. Of these, the most common was discussions with family members and friends, and these were sustained over time, as evidenced by the cohort of respondents reporting that their children – and by inference, themselves – 'still talk about' a variety of subjects. A significant number also reported active learning actions such as research and experimentation. Although parents attributing their children's educational and career choices to festival attendance is problematic as outlined above, there were also some instances of adults having decided to pursue further education or retrain following their visit.

It is clear from the above evidence that attendance at a science festival has the capacity to lead to gains in at least some aspects of science capital that are observable at a point one year or more after the event, particularly in the areas of 'What you know' and 'What you do'. This challenges the statement that one-off events are generally not capable of producing sustained improvements; our results show that the nature of the science festival, including a combination of curiosity-sparking and experiential activities that stimulate learning and catalyse the ELT cycle, can lead to concrete science capital growth.

It is, however, important to be clear that in many cases, attendance at a science festival may not be the initial catalyst that begins the learning cycle. In fact the vast bulk of our participants – 87% – had attended the LSF in 2019 or earlier as well as in 2021. It may be the case that for these participants, a previous LSF visit had been the event that set the cycle in motion; however another possibility is that first attendance was prompted by an existing interest in science.

Conclusion

In this study, we gathered information from science festival participants a year after their visit, focusing on their recall of the experience, the knowledge they had retained, subsequent actions they had taken, and also about their memories of previous festivals three years or more prior. We found that more than half of respondents could recall something they had learned a year previously, be this in the form of scientific facts, information about scientific processes, or education/careers-related knowledge. Participants also talked about their experience as fun and practical, and some attributed their learning to these characteristics. Their responses show evidence of Kolb's experiential learning cycle having been active over the year since their visit, with responses that indicate both the 'thinking' and 'acting' stages of the cycle had taken place. Analysing the data using a science capital lens shows that science festival attendance had given a measurable boost to at least some facets of the concept, particularly 'What you know' and 'What you do'.

Our findings demonstrate, therefore, that events such as science festivals are capable of generating long-term boosts to key aspects of science capital, particularly in terms of knowledge acquisition and science-related activity. We show that for a considerable proportion of attendees, gains are sustained over a term of 1–3 years or even longer.

In this piece of work we build on and extend a small body of evidence comprising studies that looked at the medium-term impacts of science festivals over a period of a few months. However, we also aim to develop a theoretical understanding of the mechanism by which attendance at a transient event could lead to such long-term impacts, proposing two processes via which this might occur.

Firstly, the engagement of interest/curiosity, which is known to stimulate learning and associated recall, is a key feature of festivals, and our participants both demonstrated knowledge acquisition and ascribed their sustained learning to this phenomenon.

Secondly, the experiential nature of these events can stimulate or continue the ELT cycle, whereby attendees are prompted to reflect and think about their visit, with implications for associated actions. Again, we saw significant evidence that festival attendance fed into such a cycle, with a large proportion of our respondents sharing their thoughts with us, and detailing the further actions they had taken as a consequence of their experience.

It has been argued that science capital is difficult to build via one-off experiences; however as we demonstrate, there are unique aspects to the science festival format that provide ideal conditions for such capital to grow in a sustained manner. However, the question of who is able to profit in this way is a pressing one, given the generally affluent and highly educated festival audience. Given that our findings demonstrate that science festival attendance can lead to long-lasting gains in science capital, it becomes fundamentally important to ensure that underrepresented groups have the opportunity to grasp such an experience. As is evident from the literature, including the current contribution, the science festival audience is much more highly educated and interested in science than the general population, factors which suggest high levels of existing science capital. If boosts to science capital are largely available to those who already have it, that lessens the potential of the festival experience to widen participation in science.

The answer to the question of how effective science festivals can be to build science capital among different audiences is therefore 'very, for some'. How can we widen this impact until it comes closer to 'very, for all'?

Many festival organisers are already aware of an equity issue in their provision, and some have sought to address it in a number of ways, for example by incentivising certain audiences to visit or by building relationships within target communities (Canovan, 2020b). Such strategies come with significant challenges; for example, incentives often have a limited reach, due to cost implications, while network contacts in relevant communities may be very time-consuming and resource-intensive to build. Despite these issues, our results make it even more imperative that science festivals find ways to ensure that all audiences have the opportunity to benefit from this potent combination of curiosity and experience that can lead to long-term science capital gains.

Organisers need to develop strategies to attract underrepresented groups to their events as a matter of urgency. Consideration should be given to community outreach, incentivisation, transport provision and festival location amongst other things in order to ensure that a wider range of the population can, and wish to, participate in these events. If this issue is not addressed, the undoubted benefits of festival attendance will continue to be largely felt by those with existing high science capital, potentially exacerbating inequality where there is the undoubted capacity for it to be lessened.

Ethics statement

This study gained ethical approval from the BAHSS2 ethics panel of the University of Central Lancashire. The approval number is BAHSS2 0369. Informed consent was gained from all participants; written consent was obtained from adult participants via a statement at the start of the survey instrument, while parental consent was obtained via paper forms for child participants, together with verbal consent of child participants themselves.

Notes

1. https://sciencefestivals.uk/festivals/the-times-cheltenham-science-festival-2/
2. https://www.scienceeurope.org/news/biggest-student-science-festival-in-estonia/
3. https://news.wisc.edu/unleash-your-curiosity-at-the-13th-annual-wisconsin-science-festival/

4. As of 2023, the festival will be held every other year.
5. Valley Primary is a pseudonym.
6. The last year of primary school; pupils are aged 10-11.
7. The Indices of Multiple Deprivation are datasets used to classify relative deprivation of small areas across the UK.

Disclosure statement

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

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