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INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, PART B
https://doi.org/10.1080/21548455.2021.1971319

Family-focused campus-based university event increases perceived knowledge, science capital and aspirations across a wide demographic

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ABSTRACT

Creative ways of delivering informal science events in community settings are viewed as key to engaging new audiences and participants whom scientists find hard to reach, however, the impact of 'formal' setting events is often overlooked. Here, through a mixed-methods approach, we analyse a large-scale family-focused public engagement event hosted within a university campus setting. We aimed to explore the profile of visitors attending together with the impact and perceived knowledge gained. Analysis from two consecutive years of data collection found that the university-based event attracted new visitors annually, with almost half having not attended other science events/ attractions within the last year. An increase in perceived knowledge was shown amongst all study participants, being significantly amplified in those from low progression to higher education postcode areas. Both immediate and longer-term positive impact was reported by participants with increases in components of science capital observed as well as enhanced positive perception of the university and its students. This data exemplifies the benefit of university-hosted events in widening participation and public understanding of science.

Abbreviations: COVID 19: coronavirus disease 2019; IQR: interquartile range; POLAR4: Participation Of Local Areas (related to progression to higher education); Q: quintile; REF: research excellence framework; RQ: research question; STEM: science, technology, engineering and mathematics; UK: United Kingdom

ARTICLE HISTORY
Received 17 December 2020
Accepted 18 August 2021

KEYWORDS
Public engagement; widening participation; university; impact; low participation groups; informal family science learning

Introduction

Widening participation (or broadening participation) and public engagement are key to inspiring the next generation of scientists and ensuring representation in STEM education and careers from across all of society. The public report recognising the importance of science in their everyday lives (Campbell & Rudan, 2020; Wonnerberger et al., 2020), however, there is a lack of general understanding of how scientists conduct their work (Castell et al., 2014) and engagement surveys suggest

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that although public interest is high, only a small number actively engage in attending science-focused events (Lloyd et al., 2012).

The science-related 'resources' to which an individual has access, 'science capital' – economic, cultural, social and symbolic (Science capital is further described in the later section 'Study Framework') (Archer et al., 2015; Bourdieu, 1986) are reported as key to influencing participation in science (Archer et al., 2016). Through exploring science capital, such as (1) how individual's think about science, (2) what science they know and (3) their engagement with science-related activities, whether that be media or informal science learning activities, inequity in science-related capital amongst groups, e.g. ethnic minorities, disadvantaged communities have been identified and suggested to contribute towards explaining inequalities in science participation (Ceglie, 2021; DeWitt & Archer, 2017).

The importance of the involvement of the family unit in promoting and fostering aspirations and engagement with science also comes through strongly in the literature. Studies indicate that the way young people view their relationship with science and/or future science aspirations are influenced by their parents and family context, seen as 'family habitus' and collective 'science-related capital' (family habitus is further described in the later section 'Study Framework') (Archer et al., 2012; Aschbacher et al., 2010; DeWitt et al., 2016; DeWitt & Archer, 2015). Families with higher levels of science-related resources (capital) are shown to be at an advantage in terms of promoting and sustaining aspirations in science amongst young people (Archer et al., 2012; DeWitt & Archer, 2015). Along with parental involvement, participation in informal science events and activities outside of the school setting is also reported as key to inspiring consideration of further STEM education and careers amongst young people (Dabney et al., 2012, 2016) as well as making science seem relevant to themselves (McKinley-Hicks, 2020).

Widening participation and engaging audiences' scientists find harder to reach

With disparities in science capital reported to exist across society (DeWitt & Archer, 2017), scientists are constantly looking for successful ways to reach public audiences, particularly those who have existing low levels of previous engagement or whom scientists find hard to reach, for example from socio-economic disadvantaged areas, ethnic minorities or from low 'progression rates to higher education' areas. In the United Kingdom (UK) a measure of progression of young people to higher education is the POLAR4 (Participation Of Local AReas) quintile classification system. Here the population is split into five groups and assigned equally across five quintiles, where quintile 1 areas have the lowest rates of young participation in higher education and quintile 5 areas have the highest participation rates (Office for Students). By bringing science out into the community and working with non-STEM partner organisations, many new methods of delivering diverse science public engagement events have evolved. However, the success of such events in reaching new audiences and the impact on participants are frequently challenged in the literature (Canovan, 2020; DeWitt et al., 2016; Kennedy et al., 2018; Nielsen et al., 2019). With little research focusing on more formal setting event delivery (for example university-based) this study evaluates a large-scale family-focused university campus-hosted public engagement event, analysing the successes and limitations on visitor impact and reaching new audiences.

> *Research question 1 (RQ1)* – Does an established public engagement event hosted in a formal educational setting attract the same returning visitors who are already engaged in visiting science-based attractions (associated with high levels of existing science *capital*)?

> *Research question 2 (RQ2)* – Does hosting a public engagement event in a university setting mainly attract visitors from high progression to higher education areas?

> *Research question 3 (RQ3)* – What is the immediate and longer-term impact of attending a science public engagement event held in a university campus-based setting on young and adult visitors?

The key to knowledge translation is argued by some to be informality and accessibility (Bauer, 2009; Holliman et al., 2009; Navid & Einsiedel, 2012). With the public reported to have a high interest in science (Carter, 2017; Motta, 2019; Wellcome UK Monitor, 2018), but low levels of accessibility (Aitken et al., 2016; Miller, 2001) there is a clear narrative to undertake events in public spaces, such as cultural/art museums (Duckett et al., 2021), music festivals (Leao & Castro, 2012), theatres, cafes and pubs (Dallas, 2006; Paul & Motskin, 2016). Minoritised groups may feel that more formal settings, such as a university campus, are far removed from the communities and culture that they live in. This can lead to barriers to engagement such as concerns about how individuals should present themselves or anxieties around whether there will be people of a similar cultural, educational or socioeconomic background present (Dawson, 2018; Jolly, 2002). Findings from the Public Attitude to Science Survey (Castell et al., 2014) and the Wellcome Trust Monitor (2018), report that providers found it hardest to engage with family groups and members of the public from low educational areas, and that some felt that such events were just not for 'the likes of us' (Lloyd et al., 2012). Informal venue settings, such as cafes, are seen as accessible to those with perceived barriers to attending science events, having a friendly and less academic atmosphere (Dallis, 1999), contrasting to science communicated in a more formal way (e.g. lecture) or setting (Archer et al., 2016; Navid & Einsiedel, 2012).

Same crowd different place

Despite this shift in innovative event delivery, the promise of increased interaction and engagement with the communities that scientists find harder to reach, through community-based events, often does not materialise. Delivery of science events within designed public spaces such as museums, whilst having the potential to nurture science capital, visitor demographics are frequently skewed towards those already engaged (DeWitt et al., 2016) and not actually reaching new audiences but seeing the same core visitor demographics (Nielsen et al., 2019) i.e. participants with existing high science capital (Canovan, 2020; DeWitt et al., 2016; Kennedy et al., 2018). Studies suggest that designed spaces can be viewed as elitist by minoritised groups creating barriers to accessibility (Dawson, 2014; DeWitt & Archer, 2017). Where new audiences are reached, the visitors are not fully representative of the local community, with under-representation of ethnic minority groups observed (Duckett et al., 2021).

What is the value of university campus-based public engagement?

Since 2006 (although the Edinburgh Science Festival started much earlier in 1989), university campus-based science festivals have become increasingly popular, particularly in Europe and Northern America, aiming to create informal learning spaces with diverse cultural appeal for the public to attend and engage with science (Jensen & Buckley, 2014; van Beynen & Burress, 2018; Kersting et al., 2020). Many are hosted by city and university partnerships, so often combine informal and academic settings for activities. Literature evaluating the impact of these science festivals shows that participants report a perceived increase in knowledge and understanding (Jensen & Buckley, 2014) but they are still seen as quite a niche with only a small percentage of people visiting (Castell et al., 2014) and typically attracting educated science engaged visitors (Nielsen et al., 2019). However, informal science experiences in university settings can help people to feel associated with a university campus (AbiGhannam et al., 2016) thus highlighting the importance of these events in relationship building between the public and places of higher education.

Much of the published literature discussing event delivery focuses on taking science to the community (Dallas, 2006; Duckett et al., 2021; Leao & Castro, 2012; Navid & Einsiedel, 2012; Paul & Motskin, 2016), with very little analysing public engagement hosted in a university setting, therefore, leaving a gap in reported impact. Whilst the authors of this paper are active participants in community venue science events, here we evaluate the impact of our university campus-based family public engagement event Explore! Science and Engineering (Explore!) on the visitor demographics and participant impact. A greater understanding of our research questions will allow a more informed approach to designing and delivering family-focused science public engagement events and determine the role of university campus-based events in widening participation and public engagement activity.

Explore! Science and Engineering

Explore! was established in 2014 at Sheffield Hallam University with the aim of providing a platform for staff and students to engage with the local community in science and research developments. As a free to visit event during British Science Week, Explore! attracted 250 members of the public in its first year to an afternoon of interactive stands hosted by researchers and research students. The event has grown to become the University's flagship science week event and in 2019 attracted over 1500 visitors. Explore! now offers a plethora of hands-on activities, interactive talks and competitions across all areas of STEM hosted in the university buildings, labs and lecture halls.

Explore! is designed to be a family event catered towards parents and carers with children between 6–12 years of age but has elements designed for younger children as well as being suitable for adult-only groups or individuals. The event's interactive lecture theatre talks explore topical and engaging content such as the gut microbiome, fingerprint analysis and sports science, allowing topics of wider interest to be introduced to visitors in a fun and informative manner within the formal university education setting. The hands-on activities were primarily aimed at children, but often had a complementary element to allow the involvement of other family members and prompt discussion within the family unit. This interactive element allowed the opportunity for active learning as the children undertook short experiments to introduce scientific techniques or concepts. These hands-on activities were facilitated by university students, research scientists or members of academic staff and used as a platform to discuss more complex topics with older children and adults. For example, individuals were invited to obverse and interact with live snakes and scorpions to introduce the concept of natural product antimicrobial drug discovery. Water baths with small balls were provided to mimic the plasma membrane and then strings of wooden bead introduced to mimic the disruptive effect of antimicrobial peptides. Poster informatics were used to show current institutional research and promote discussion.

Study framework

Impact **–** The work described in this study draws frequently upon the notion of 'impact'. Defined, the impact can be viewed as 'something having a marked effect or influence on something or someone' (Oxford English Dictionary), measuring it however, in terms of collecting data on how impactful an event has been on a visitor or visitor group is somewhat challenging. Words such as 'meaningful', in relation to having fun in a higher education setting for example, are important and powerful in terms of impact (Archer et al., 2016) but a robust tool for measuring 'impact' in public engagement has not emerged. Whilst the research excellence framework (REF – aims to assess the quality of research within UK higher education institutes) case studies and citation analysis are the most commonly used methods to assess the value of research in society and the 'usefulness' of scientific studies to a researcher's peers respectively, no standard approach has been formed for assessing the 'impact' of science communication to non-peer/societal audiences (Bornmann, 2017).

Within the UK research landscape major funding bodies require pathways to impact statements as part of the application process with academic impact, 'the demonstrable contribution that excellent research makes to academic advances, across and within disciplines', is being distinct from economic and societal impacts 'the demonstrable contribution that excellent research makes to society and the economy' (RCUK, 2010). Impact case studies are now included within the REF assessment (REF, 2021) with impact defined as 'an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia' (REF, 2021).

Public engagement, whilst it can inform academic impact, is predominately seen as a vehicle to achieve economic and societal impact (Grand et al., 2015; NCCPE, 2021). Subsequently, the notion of impact has become commonplace with a desire for the researcher to evidence, quantify and evaluate the quality of impact (Davies, 2013; Grand et al., 2015).

Using impact as a framework for the evaluation and value of public engagement in science can be didactic and overlook the more subtle societal impact of public engagement outside of the direct impact on a research theme. Conversely, the impact lens encourages researchers to evaluate events, have qualifiable aims for public engagement initiatives and increases the value of high-impact public engagement.

Capital and Family Habitus – Through science public engagement activities, we aim to inspire engagement with science and create a dialogue through which the public can become empowered and build trust in science, seeing the value of science within society (importance in everyday lives). Science-related *capital* and *family habitus* are used within this study as a measure of 'impact' on participants following attending our events.

Science capital, a conceptualisation of the Bourdieusian theorisation of capital (Bourdieu, 1986), brings together social, economic and cultural capital that relate to science (Archer et al., 2014). Simplified, the dimensions of science capital can be grouped into four main areas – what science you know, what science-related activities you do, who you know (science related) and how you think about science (DeWitt et al., 2016). Archer et al go on to describe how the *science capital* lens can be used as an analytical concept in qualitative data analysis when attempting to understand an individual's identification, engagement or aspirations to participate in science (Archer et al., 2015).

A complex interplay between an individual's *capital* with *habitus* (dispositions that guide future actions, providing a practical 'feel' for the world, framing ways of thinking, feeling and being – how an individual is socially constructed) are described within the Bourdieusian theory (Bourdieu, 1986), with work by Archer et al. (2012) supporting an interaction between *family habitus* (how a family collectively forms a relationship with science, weaving it into everyday life) and aspects of *capital* in promoting aspirations in science.

This study utilises a component of *science capital*, namely 'Science-related behaviours and practices' and more specifically 'Participation in out-of-school science learning contexts' (Archer et al., 2015) as an indication of existing *science capital.* We also draw on dimensions of *science-related cultural* and *social capital* to analyse the impact of the event described on individual participants. As our event has a strong family focus, we also utilise the *family habitus* lens to explore any impact on the family unit.

Data collection and evaluation

A mixed-methods approach was used to collect feedback on the events, allowing analysis of the impact of Explore! on adult and child attendees. Basic visitor profile information was collected at the two entrance points to Explore! which included a number of attendees and age group of visitors. Group exit questionnaires, children's post-it note capture and post event longer-term impact adult and children's focus groups were used to evaluate both outcomes (knowledge gained and impact) and outputs (e.g. number of participants in profile groups) (Spicer, 2017). Taken together, this triangulation methodology allowed the strength of individual methods to compensate for weaknesses in others by using overlapping methods on the same subject and a comprehensive approach to elucidating the responses to our research questions (Jensen & Buckley, 2014) (Table 1).

Explore! was situated in several large open spaces within a city-based university campus, having several egress points and a free flow around the site. Due to this, participants' location within the

Table 1. Overview of the nature and purpose of data collection strategies.

Research question	Method	Construct and Example	Example
RQ1: Does an established public engagement event hosted in a formal educational setting attract the same returning visitors who are already engaged in visiting science-based attractions?	Exit questionnaire [EQ]	Science capital lens: science-related behaviours and practices	'Which of these have you visited or attended in the last 12 months' [followed by tick boxes of various science and non-science activities] [EQ]
RQ2: Does hosting a public engagement event in a university setting mainly attract visitors from high progression to higher education areas?	Exit questionnaire [EQ]	Science capital lens: science-related behaviour and practices	'What is your postcode' (used to determine (POLAR4 quintile) [EQ]
RQ3: What is the immediate and longer-term impact of attending a science public engagement event held in a university campus-based setting on young and adult visitors?	**Immediate impact:** Exit questionnaire and children's post-it note evaluation **Longer-term impact:** Adult [AFG] and child [CFG] focus groups	Impact on family habitus	Likert Scale 'I am more likely to I am more likely to discuss science with family & friends' [EQ] After Explore! did you tell anyone about it? What did you talk about? [CFG]
		Science capital lens: science-related cultural capital (scientific literacy, science dispositions)	'How much do you know about the following before and after visiting' [list of topic areas and 1–5 knowledge ranking] [EQ] Throughout the event there were examples of *[anonymised]* research. Can you remember any and if so what were they? [AFG]
		science capital lens: social capital (knowledge, future affinity and science-related behaviours and practices)	Likert scale 'I have an increased interest in current scientific research' [EQ] Since visiting Explore! how do you feel about science? At school? [CFG]
		Impact – meaningful enjoyment	'Tell us something from your visit that you found particularly interesting' [free text response] [EQ] What do you remember about your visit to the Explore! day? [CFG]

Note: The abridged research questions are mapped to the research methodologies used within the study, along with the constructs described in the theoretical framework and example questions from exit questionnaire and focus groups. [EQ] exit questionnaire; [AFG] adult focus group; [CFG] child focus group.

site was not indicative of either their progression through or time spent at the event, therefore a pragmatic approach of opt-in, self-selection was utilised for the exit questionnaire and children's evaluation by which attendees were directed back to a central hub for a children's goodie bag and to enter competitions or simply post their response. This self-selection approach allowed a large sample size of the exit questionnaires, capturing a breadth of opinion (Spicer, 2017) whilst ensuring participants were likely to be committed to take part in the study (our main visitor profile of families with young children who had spent a number of hours at the event), which was especially important for recruitment to the subsequent focus groups (Sharma, 2017).

Exit questionnaire

Event feedback was collected over two consecutive years by a mixed-methods questionnaire. This questionnaire was based on that used in previous Sheffield Hallam University public engagement events (Duckett et al., 2021) to allow the organisers to utilise an existing, validated tool, with the possibility to draw more meaningful conclusions (Boynton & Greenhalgh, 2004). Modification of the questionnaire between events was undertaken to allow for more focused feedback collection.

The design of the questionnaire was structured and quick to complete and was aimed at adult visitors. A combination of question styles including simple tick boxes to gain information such as visitor profile (including gender, age group and ethnicity), Likert-style questions for information such as perceived knowledge gain, and free text boxes for comments was used. Drawing on our study framework, questions were designed to align with the research questions with the constructs highlighted in Table 1. An optional contact slip could be completed which included permission to be contacted about future events or, for the 2019 questionnaire only, to be invited to post-Explore! impact focus groups. This slip was detached immediately after the event and stored separately, allowing questionnaire responses to remain anonymous during analysis.

Children's evaluation

Whilst younger visitors to Explore! could contribute towards the answers provided by their accompanying adult in the exit questionnaire, post-it note capture was also undertaken. Briefly, this was an oversized periodic table wrapped around one side of the evaluation desk, alongside where adults returned their completed questionnaires. Children were invited to indicate on a post-it note what they had enjoyed during the afternoon and stick it onto an element of their choice. Parents and guardians were required to add a sticky dot to the post-it note, indicating their consent for the information provided by the children to be used in the analysis and publication of event feedback.

Longer-term impact: focus group event

All respondents to the 2019 exit questionnaire who consented to further contact were invited via email to participate in a focus group evaluation event. The focus groups took place 4 months after the Explore! event to allow participants time to reflect on their visit and for any impact of the event to emerge. Participating families (adults n = 25 and children n = 28) were randomly allocated to two groups, and each undertook a 20-minute focus group with the children followed by a 20-minute focus group with the accompanying adults. Participants were then invited to take part in an exclusive laboratory activity. Focus group discussions were based on a list of predetermined questions (aligned with constructs in Table 1) and were audio-recorded followed by transcription by an independent external company (White Transcription Services Ltd., UK).

Ethics approval

Ethics for this study was acquired through the Faculty of Health and Wellbeing ethics committee following the Sheffield Hallam University Research Ethics Policy (reference numbers: ER6381561 and ER1343822).

Participation in the exit questionnaire and post-it note capture was optional. Completion and submission of the questionnaire was taken as consent to be part of the study and a statement to gain parental consent was displayed in the location of the post-it note collection.

In the second year of the study, participants who indicated that they could be contacted for longer-term evaluation were invited by email to participate in the focus group event. Consent was obtained from individual adult participants as well as parental consent for the children's involvement.

Data analysis

Exit questionnaires and children's post-it note data were transferred into Excel by an independent researcher for coding and data analysis to take place.

To investigate the assumption that public engagement events held within universities are attracting visitors already engaged in science events, Explore! respondents were asked to indicate whether they had visited a range of science and/or non-science-based attractions during the 12 months prior to attending Explore! As an indication of existing science *capital* (science-related behaviours and practices), adult participants were categorised as either 'science' (attended a science-based attraction e.g. a science festival, science museum, planetarium or having worked in the science industry) or 'non-science' (no science-based attractions/activities selected) attendees (Duckett et al., 2021). Participants were also given a POLAR4 classification based on partial post codes provided. The ethnicity of the participants group was reported via the exit questionnaire and Explore! visitor demographic was compared to Sheffield region census demographics (Office for National Statistics, 2011). Statistical significance was determined with X^2 analysis.

Bivariate analysis was undertaken to determine the effect of different levels of science capital and the impact of the event and perceived learning. Responses to Likert scale questions were converted to numbers from 1 to 5 for statistical analysis (assumption of equidistance in perceived learning questions), with 1 representing the most negative response to the question (e.g. strongly disagree) and 5 the most positive (e.g. strongly agree). Self-reported increase in knowledge for each zone of Explore! was combined to create an overall perceived learning score. Due to the ordinal nature of this data, analysis was undertaken as a modal average and graphically presented as a median with interquartile ranges (IQR) presented with statistical significance determined. When comparing multiple groups, the Kruskal–Wallis H-test was used, followed by pairwise Conover-Iman analysis and Mann–Whitney U-tests between groups where appropriate. Statistical significance is indicated by asterisks throughout the manuscript; * indicates $p < 0.05$.

Free text responses from the exit questionnaires and children's post-it notes were coded by open coding to complete a thematic analysis and responses categorised into themes, which we created through an iterative approach linked to the evolution of the theoretical framework (Jones et al., 2010).

Transcripts of the focus groups were analysed manually by two researchers independently using NVivo. Briefly, a grounded theory (Strauss & Corbin, 1994) approach was taken with line-by-line open coding to identify key categories within the data, followed by axial coding to identify links between these categories and the theoretical framework (Strauss & Corbin, 1990). Direct quotes for each category were then identified. A triangulation approach was taken to ensure a valid and comprehensive approach to analysis (Mays & Pope, 2000).

Analysis and impact

Explore! participants are from a wide demographic

Explore! attracted an increasing number of visitors over the study duration, with ~950 visitors in 2018 and ~1550 in 2019. A total of 226 group exit questionnaires were collected and analysed over the two events (99 and 127, respectively). Over both years, visitor profile analysis showed that the largest number of visitors were adults aged between 35–64 (36%) and children between 5 and 11 years of age (39%). Analysis of reported science-related behaviours and practices over the previous 12 months determined 48% of questionnaire respondents were classified as 'non-science visitors' (i.e. those who had not visited any science-related event/attraction in the previous 12 months). In addition, 68% of participants indicated that they had not previously visited Explore!

POLAR4 postcode analysis (Sheffield City Region participants) showed that a higher proportion of participants were from quintile 5 (19.5%) compared to the proportion of the population in quintile 5 in the Sheffield City Region (9.8%, $p < 0.05$ X^2 test)' although the events attracted large numbers of participants from lower POLAR4 quintile areas (>65% overall participants were from quintiles 1 and

Table 2. Explore! POLAR4 participant profile.

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Visitors to Explore!*	36%	29.2%	8.7%	6.6%	19.5%
Sheffield City Region	37.1%	29.6%	12.7%	10.8%	9.8%
Non-science visitors*	31.5%	26.8%	10.4%	6.7%	24.6%
Science visitors	40.2%	30.9%	7.3%	6.5%	15.1%

*Indicates $p < 0.05$.

Note: POLAR4 quintile analysis (young participation in higher education by local area) of participant postcodes to Explore! compared to Sheffield City Region and comparisons of science and non-science visitors. Quintiles 1 and 2 represent postcode areas where young people are least likely to progress to higher education, whereas quintile 5 represents highest progression rates. Non-science visitors had not attended any science-related attractions in the previous 12 months, whereas science visitors had engaged with at least one science-based activity in the last year (n = 226). 2018 and 2019 Explore! participants vs Sheffield region POLAR4 profiles: X^2 (4, n = 226) = 11.12, $p < 0.05$. Non-science visitors vs science visitors X^2 (4, n = 226) = 9.66, $p < 0.05$.

2). Interestingly there was a larger percentage of POLAR4 quintile 1 participants who had already engaged in a science-related attraction during the past 12 months compared to the POLAR4 quintile 1 non-science attraction group (40.2% and 31.5% respectively, $p < 0.05$ X^2 test). Those visitors in the non-science group represented a larger percentage of the POLAR4 quintile 5 group compared to the science group (24.6% and 15.1% respectively, $p < 0.05$ X^2 test) (Table 2).

As minority ethnic groups are often underrepresented at STEM events (Canfield et al., 2020; Dawson, 2014; Duckett et al., 2021; Feinstein, 2017), the ethnicities of participants were collected and compared to the demographic of Sheffield, based on the 2011 census data. Overall, white and mixed ethnicity participants were overrepresented at Explore! (89.9% (white) and 3.9% (mixed ethnicity) when compared to the demographic of Sheffield for these two groups 83.7% and 2.4% respectively. Asian / Asian British and Black / Black British participants were underrepresented at Explore! compared to the Sheffield demographic (4.6% and 0.9% compared to 7.0% and 3.6% respectively) (X^2 (3, n = 429) = 11.05, $p < 0.05$).

Visiting Explore! has an immediate, strong, positive impact

To determine the immediate impact of Explore!, exit questionnaires asked self-selecting participants a series of questions exploring their views on the immediate impact of visiting the event. When asked if Explore! had a 'beneficial effect on people's lives' 89% strongly agreed or agreed and 95% of respondents reported that they were likely to return to a future Explore! event, despite almost half of the respondents stating that they had not attended another science-based exhibition or museum in the past year.

The exit questionnaire in 2019 was expanded to include additional statements aimed to gain a wider insight into the impact of Explore! on both adult and child participants (Figure 1). 90% of participants agreed/strongly agreed that Explore! had made their child(ren) more likely to engage in science at school and 93% agreed/strongly agreed that Explore! had increased their child(ren)'s interest in science. When asked about habitus, 89% of participants agreed/strongly agreed that Explore! had led to them being more likely to discuss science and 86% agreed/strongly agreed that Explore! had increased their interaction with current scientific research.

Comparison of science visitor against non-science visitor impact responses did not show any significant difference between individual impact statements. When comparing participants' residential areas based on their likelihood of progressing to higher education, there was no difference observed in responses to individual impact statements between POLAR4 quintiles.

Attendance at Explore! leads to an immediate increase in perceived learning, enhanced in POLAR4 Q1

In both years, visitors were asked to rate their perceived knowledge of key areas before and after the event; self-reported increase in perceived knowledge for each section of Explore! was combined to

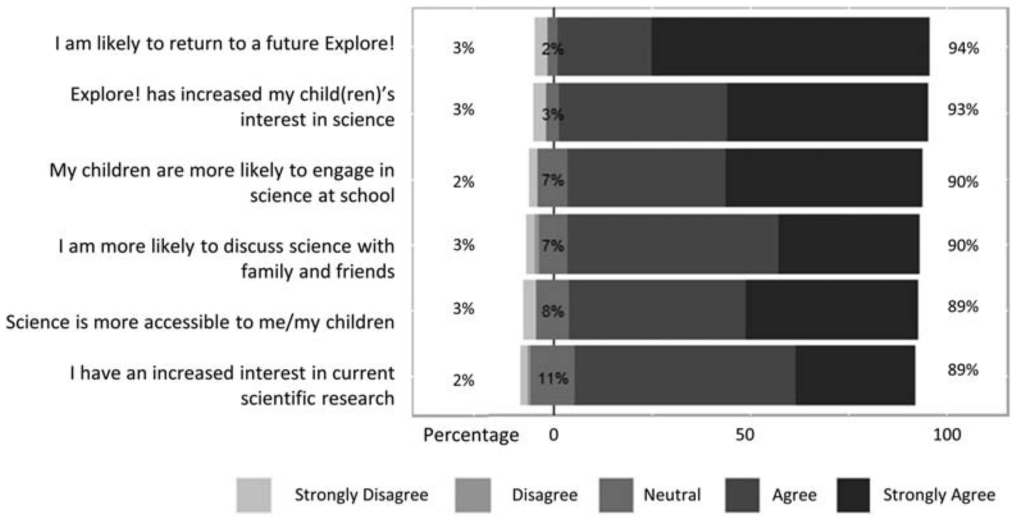

Figure 1. Aggregated Likert scale responses to impact statements from Explore! visitor exit questionnaires. Very light grey indicates strongly disagree, light grey indicates disagree, grey indicates neutral, dark grey indicates agree and black strongly agree (2019 exit surveys, n = 127).

create an overall perceived learning score. The median perceived learning score for all survey participants was 5 (IQR 7). No significant difference was found between the median perceived learning score for science (median = 6, IQR 7) compared to non-science (median 4, IQR 9) visitors. When comparing POLAR4 perceived learning scores the quintile 1 visitors (median = 7, IQR 6) were shown to have significantly higher reported perceived learning than quintile 5 visitors (median = 4, IQR 6) ($p < 0.003$, Mann–Whitney) (Figure 2).

Explore! participants self-reported enjoyment, knowledge gains and increased science capital

Within the exit questionnaire of Explore! 2018 and 2019, an open text box was included with 'Tell us something from today that you found particularly interesting.' Responses were systematically searched through, grouped into themes set out in our theoretical framework and enumerated (Table 3).

Explore! 2019 included a children's free text response where they were asked 'Tell us about something that you have particularly enjoyed.' Responses were systematically searched through, grouped into themes and enumerated (Table 4).

Both the adult and child free text questions asked the participants what they particularly enjoyed. Even though most of the adult and child responses in both data sets were centred around specific activities (129/178 and 62/69, respectively), several had learning (8/178 and 3/69, respectively) and an increase in components of science *capital* (1/178 and 4/69, respectively) as elements they enjoyed. Interestingly, adults also commented that their children's interaction and enjoyment of the event was what they particularly enjoyed (19/178) indicating the family focused nature of Explore!.

Explore! attendance leads to longer-term impact of increased knowledge, enhanced science capital and a better perception of university

To determine the longer-term impact of the event on both adults and children, as well as undertaking triangulation methodology to strengthen previous observations, focus groups were

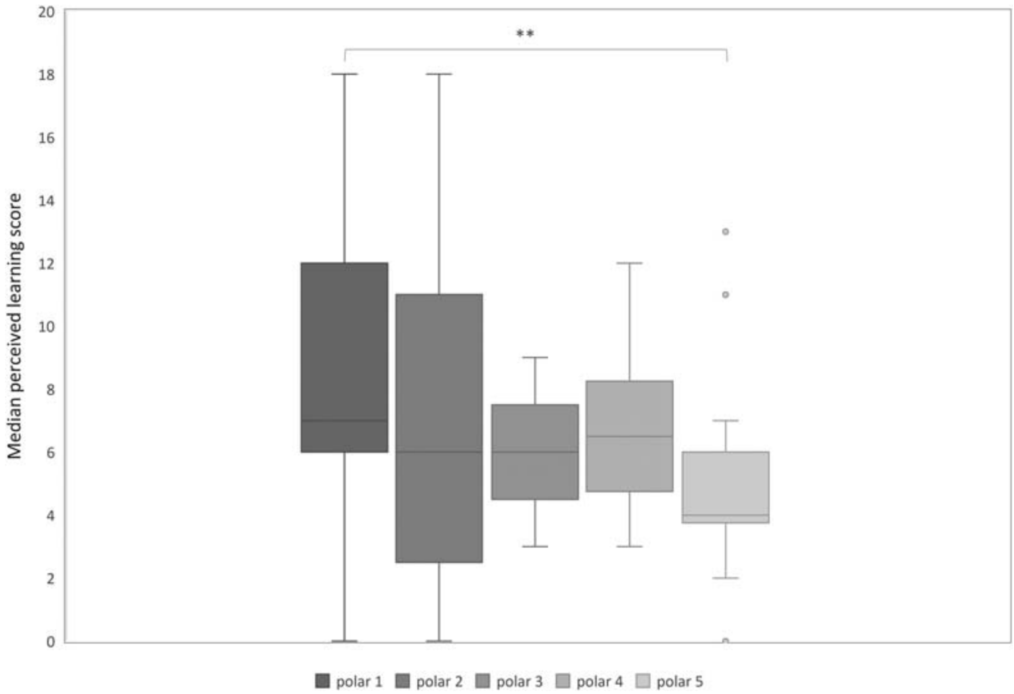

Figure 2. POLAR4 quintile analysis of overall perceived learning scores reported by Explore! visitors. Visitors ranked their perceived knowledge of each area before, compared to after, visiting on a scale of 0 (none) to 5 (a lot). All quintiles showed an overall increase in perceived learning. ** $p < 0.005$ Mann-Whitney (2019 exit surveys, $n = 127$).

Table 3. Qualitative analysis themes.

Theme	Response frequency	Free text example
Impact: meaningful enjoyment – specific activity	129	*'the rubix cube – solving robot was fascinating'* *'I found the slime being in the different states of matter very interesting'*
Impact: meaningful enjoyment – family focused	19	*'The anatomy park – great for kids to understand'* *'Engaging children through well planned activities.'*
Impact: meaningful enjoyment – hands on elements	30	*'how interactive all the stations were'* *'making slime and fingerprints'*
Science-related cultural capital: scientific literacy	8	*'Dolphins have bigger brain than humans'* *'That fingerprints are all different and have different patterns'*
Science cultural capital: scientific related dispositions	1	*'understanding the relationship between science and the everyday world. Hearing about research which could have a huge impact for the future'*

Note: Comments from Explore! exit survey questionnaire 'Tell us something from today that you found particularly interesting' were blinded, thematically analysed, coded into each category and enumerated. Example comments are given for each theme ($n = 178$).

undertaken. Both adults ($n = 25$) and children ($n = 28$) had a strong recall of the activities at Explore! (2019) and reported meaningful enjoyment.

> Adult: 'The whole event made science more interesting than it did when I was at school, because at school it was boring. I never liked it, but I really enjoyed it.'
> Child: 'I remember stroking a pig's tongue'

Knowledge and an appreciation of how science works (scientific literacy) as well as reports of an increased appreciation of the value of science in society (science-related dispositions) were reported by both adults and children, suggesting that participation had increased aspects of science-related cultural *capital*.

Table 4. Qualitative analysis themes from children's Post-it note feedback.

Theme	Response frequency	Free text example
Impact: meaningful enjoyment: particular activity	62	*'I liked the forensic science and fingerprints'* *'My favourite bit was putting on a t-shirt and using an app that allows me to see the inside of my body.'*
Impact: meaningful enjoyment: overall event	19	*'I had a brilliant adventure and my favourite bit was all of it'* *'Today was an amazing experiment experience'*
Science-related cultural capital: scientific literacy	3	*'how big your lungs are'* *'I learnt new things'*
Science-related social capital: future science affinity	4	*'Today made me want to be a Scientist'* *'Great for young scientists'*

Note: Comments from children's Post-it notes answering the question 'Tell us about something that you have particularly enjoyed' were blinded, coded into each category and enumerated. Example comments are given for each theme (n = 69).

Child: 'I now know how many cells are in your body'
Child: 'A pig's liver is bigger than a humans'
Adult: 'everything now that we do you can direct to an awareness as to how that is science'
Adult: '… I think she's got more of an understanding of science separate than just an experiment'

Participants were asked about changes in science-related behaviours and practices as a direct result of attending Explore! both as a family unit (indicative of increased family habitus as well as *capital*) and individuals. Mixed responses were observed in adult and child focus groups with some participants reporting changes in behaviour whilst others stated that they had not changed their behaviour. Where behaviour had changed, this was focused on children's activities.

Adult: 'One of the girls wanted me to buy a sheep's eye and dissect it with them and then they chickened out and said it was too gross, but they were inspired to do it from this and just said 'can you get an eye' and I said 'yes I probably could … '
Child: 'I wash my hands better … because we were learning about the virus and how you wash your hands properly'
Adult: 'I've asked for science kits for Christmas and stuff for her'
Child: 'I asked for a science party'

From both child and adult focus groups, strong themes emerged around science-related social *capital* in how the event had led to individuals talking to others about science as well as stronger science identity and future affinity/aspirations.

Adult: 'She decided she wanted to be a scientist because of these events'
Child: 'I feel a lot more confidence with science now … I like it way more because of what I've experienced here'
Child: '… did a show and tell about it … at school and Rainbows'
Child: 'I told my friends at school … that we learnt about a virus'
Child: 'At school when … I was studying I was like oh no I've done it wrong and all that and now I feel much more confident'
Adult: 'Another reason I wanted to come is because … just (to) open up university (to my daughter)'

Family discussions about science had continued during the time between Explore! and the focus groups indicating that stronger family relationships with science had begun to form (family habitus).

Adult: 'I remember the genetics because we, that's sparked a big conversation between our whole family'
Child: 'We talked to, at home daddy, all family'
Adult: 'lung capacity test because we all, my wife and my youngest daughter, we all did one so I think the fact that we all did meant we can compare each others. That was, had quite an impact.'
Adult: 'So we would talk about the day or an event, something that we see on TV or something that maybe we wouldn't have linked to science in the same way but you can talk to the kids now about it.'

In addition to increasing meaningful enjoyment, elements of science capital and family habitus, Explore! had inspired children to consider attending university in the future. An unexpected but positive outcome was that student volunteers at the event had also positively impacted the view of the visitors in terms of the university as an entity and the students as young adults.

> Adult: 'Just sitting in a lecture theatre, walking up that stairwell, was just wow to someone who's 10, again didn't understand education could be like that'
>
> Adult: 'It makes me view university in a better light, because normally the only contact we have with universities are the students … in student areas and stuff, so that's usually fairly negative so it's nice to have a really positive (experience) … '
>
> Adult: 'I thought the undergrads were really impressive.'

Taken together, focus groups show the participants had a positive recall of the event four months afterwards and that Explore! had stimulated conservations around science within family groups and between their peers. The event increased both adults' and children's confidence in science as well as components of science-related social and cultural *capital* and habitus indicating longer-term impact.

Discussion

This study set out to evaluate how successful a public engagement event hosted in a university setting is in reaching members of the public not already actively engaged in attending science events and those from low progression to higher education participation regions of the Sheffield City Region. Evidence was collected of immediate impact, particularly around meaningful enjoyment, which then expanded to explore the wider and longer-term impact on components of *science-related capital* and, due to the family focus of the event, *family habitus*.

Visitors to a university campus-based event

Our analysis (as indicated by POLAR4 quintile analysis), shows that family focused, university-based public engagement events do not exclusively cater to middle-class, educated families that are already engaged in science outreach, as some narratives claim (Archer et al., 2016; Campbell & Rudan, 2020; Castell et al., 2014; Lloyd et al., 2012). Instead, the university campus hosted Explore! events attract new visitors, many of whom are not already actively engaged in attending science events nor have high rates of progression to higher education within their communities. Explore! has little barriers to access based on location, due to ease of transport to its location in the city centre, however visitors still need to overcome any barriers they may have to enter the university setting. Our study indicates that the public are willing to engage with science set in a formal venue and it does not solely attract those with existing high *science capital* as some have argued with other events such as science festivals (Kennedy et al., 2018).

Not only are individuals and family groups from communities with the lowest rates of progression to higher education willing to 'come to the science' in our university setting, analysis of questionnaire responses showed that a significantly higher amount of perceived learning was amongst this group of study participants. This is of particular interest as it reinforces the notion that university-held events positively impact individuals that have limited previous engagement with higher education. Whilst our low progression to higher education quintiles 1 and 2 visitors had a higher percentage of 'science visitors' compared to those participants from higher progression areas of the city region, from a theoretical standpoint, the majority were still classified as having low levels of science capital as indicated by science-related behaviours and practices. It is acknowledged that this single measure does not provide a detailed lens through which to measure existing participant *capital*, but our findings are an encouraging indication that university-campus events are able to contribute towards reducing social inequalities in science-related *capital* and allow an accessible opportunity for participants from all areas of society to develop further science-related interest and engagement, thus building on any existing science-related *capital*.

Whilst we showed the university-hosted event described here attracts a diverse audience in terms of previous science engagement, and has a positive impact on low higher education progression groups, unfortunately, the same cannot be said for the ethnic diversity of attendees. In addition, whilst the events welcome many participants from POLAR4 quintile 1 and quintile 2 areas, there is not proportional attendance of POLAR4 quintile 1 and quintile 2 participants compared to the city region. This is comparable to other public engagement events hosted outside of universities that observe a disproportionately low engagement from those of an ethnic minority background and lower socio-economic groups (Duckett et al., 2021.; Kennedy et al., 2018; Nielsen et al., 2019). Public engagement is vital to allow the public to understand, impact and direct scientific research as well as forming part of the widening participation work of many universities, where students from communities and backgrounds who historically have been unable to completely access higher education are actively encouraged and supported to progress to study and excel at university. If as a sector we are failing to fully engage discrete communities from our public engagement activities we are not only failing to communicate our own research with these groups, but they will be excluded from the discussion as to the direction of science in the UK and alienated further from STEM in general.

Hosting a university campus event

With many scientists reporting that a lack of time, resource and funding are key barriers to their participation in public engagement events (National Forum for Public Engagement with STEM survey, 2019; Sadler et al., 2018; Stofer & Wolfe, 2018), the support provided by external collaborators is highly valued. Collaborating with an established event (e.g. festival) or community organisation (e.g. museum) also has the benefit of the scientist getting support with factors such as logistical arrangements and marketing (Illingworth, 2017). However, there is the not insignificant challenge of 'transporting the science'. Whilst many activities can be redesigned to be small and transportable, this all takes a considerable amount of time and development on behalf of the scientist. There are the additional costs of transport, lack of space/familiarity/suitability and extra time commitment, so that taking an event away from the scientist's place of work can be a substantial barrier to engagement and success, especially when confidence and time are listed as leading barriers to delivery of science communication activities (Sadler et al., 2018; Stofer & Wolfe, 2018; Wellcome Trust, 2018). Here we have shown that the public positively engaged with the Explore! event, indicating that campus-based events offer a time and cost-effective method of engaging with large numbers of visitors, whilst having the hidden advantage of building positive perceptions of a university and its students as well as having a positive impact on widening participation.

Impact on participants

Immediate and longer-term impact analysis showed positive responses from visitors (children and adults) in questionnaire and focus group responses, with participants reporting meaningful enjoyment both as individuals and family groups. Questionnaire impact statements and longer-term focus group responses indicated an immediate increase in components of science capital amongst visitors, whereby participants have increased scientific literacy and future affinity with science. Participants stated that they and their children had increased communication around science topics between their family and peers and a raised confidence in science as well as altered behaviours, agreeing with others who state that interactions with informal science exhibits foster children's confidence and identity with science (Rennie & Howitt, 2020). By offering events with a strong family focus, encouraging the family unit to engage with activities together, our study contributes towards the existing literature, such as that described by Archer et al. (2012), highlighting the importance of family in nurturing engagement in science and developing science-specific *capital* collectively as a family.

Our young visitors also reported an increased interest in informal science activities (science-related behaviours and practices) after attending Explore!. Participation in informal science activities outside of the formal learning environment of the school (McKinley-Hicks, 2020) and higher levels of science *capital* are associated with an increased interest in STEM disciplines at university and STEM-based careers (Dabney et al., 2012; DeWitt & Archer, 2017; Moote et al., 2019; Moote et al., 2020). Archer et al. (2015) showed that students (11- to 15-year-olds) from more disadvantaged backgrounds were less likely to have high science capital compared to their more privileged peers, therefore it is considered a success that our event is attracting a diverse audience and evaluation shows evidence of increased science capital across a wide demographic.

Participant view of university host

Focus groups revealed how the event had positively impacted on the way participants viewed the university and university students. Whilst some had attended Explore! with the hope of inspiring their children to aim one day to study at university, thus using science capital to promote an educational advantage (Archer et al., 2015), others commented on the positive influence the setting and host scientists had, independent of an initial goal of raising aspirations for future higher education study.

Meaningful enjoyment was a central defining aspect of the visit to Explore! reported by many participants. The comments made by visitors within this area had a predominance of fun and enjoyment, and whilst fun is not necessarily an indicator of wider value (Archer et al., 2016), we would suggest that having 'fun' in a higher education institution has a more subtle impact of reducing barriers to access and allowing participants, both as individuals and families, to see themselves within a university in an enjoyable way. By opening their doors to the public and welcoming large groups of visitors from diverse backgrounds, universities are not only encouraging engagement with science as a subject but also helping to break down barriers of engagement. Here we have shown university campus-based public engagement events showcase positive attributes of universities and the university students, whilst simultaneously raising aspirations. It is tempting to speculate that if barriers to increased attendance of ethnic minority communities could be removed that the events would have an enhanced positive impact on these participants as seen with those in low POLAR4 score communities. Future work will focus on a blended approach to community and university campus-based public engagement, with target audiences specifically engaged within their home communities to build science capital with the aim of increasing their participation at Explore! and the benefits this brings in enabling equity and access to science.

Limitations

Conclusions made within the study regarding participants from various demographics may have been impacted by knowledge of the event within communities. Promotion for the events was undertaken, in the main part, by individuals not involved in the research project and involved advertisements on social media, emails and flyers to schools and community groups already in contact with the university as well as information on the university's website and by word of mouth. It is acknowledged that knowledge of the events may have been different within different populations, which may have affected the demographics of participants at Explore!.

Within our methodology, the questionnaire was opt-in and thus susceptible to self-selection bias (Sharma, 2017). In addition, participants attending in the first and second year of the study may have completed the questionnaire on both visits. Whereas this does not undermine the data analysis, some additional data, such as impact over two events was missed. The questionnaire was based around that used in Duckett et al. (2021) and designed to be accessible with simple language and a variety of question types as well as being relatively short (one side of A4 paper). That said, questionnaires are not without ingrained bias, examples of such bias are *social desirability bias* where a participant being drawn to something that looks like the perceptive right (Van de Mortel, 2008).

As with the questionnaires, adult participants in the focus groups were self-selecting, which was required within the authors' ethical framework but as previously mentioned, this is not without bias and it is possible that these participants were more engaged with either the event itself or had higher levels of existing science capital and/or habitus. Focus groups were also undertaken on a single Saturday within the university, thus excluding those that could not attend on this specific day and being more accessible to those most comfortable with revisiting an academic setting.

Throughout the process of this project, the focus of the study evolved from focusing on impact, to science capital and family habitus. Thus, in retrospect a more comprehensive measure of the existing science capital of participants could have been included and will be included in future evaluations.

Conclusion

Due to the COVID-19 pandemic, face-to-face public engagement and widening participation events have been cancelled or postponed at a time when the need for public understanding of science has intensified (Ngai et al., 2020; Taragin-Zeller et al., 2020). The communication surrounding virology, epidemiology and vaccinations by governments and scientists has been hampered and undermined by fake news and misinformation (Nguyen & Catalan, 2020). The impact of the pandemic on the understanding of and confidence in science will be felt for many years, as will behaviours of the public. Public engagement and widening participation will need to make steps to rebuild confidence in science, increase understanding of the scientific method and enhance engagement in dialogue around key issues such as vaccinations. In the short term at least, widening participation and public engagement events will be hosted online, but as we look further into the future to a reopening of events and public spaces, university campus-based events can be utilised as a venue to share knowledge, create and nurture aspirations and offer opportunities for families to explore science together as well as open up access to and enhance confidence in universities across a wide range of participants.

Acknowledgements

The authors would like to thank Ms Karin Glockle and the Sheffield Hallam University Schools and Colleges Engagement team for their support in the organisation of data collection and running of the Explore! events.

Disclosure statement

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

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