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'Explosions are always entertaining but…': investigating the impacts of science shows on high school students

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Submission date: 26 May 2023; Acceptance date: 20 November 2024; Publication date: 10 March 2025

How to cite

Phillips, S.R.P., Sullivan, M. and Grand, A. (2025) "Explosions are always entertaining but…': investigating the impacts of science shows on high school students'. *Research for All*, 9 (1), 3. DOI: https://doi.org/10.14324/RFA.09.1.03.

Peer review

This article has been peer-reviewed through the journal's standard double-anonymous peer-review process, where both the reviewers and authors are anonymised during review.

Abstract

Science shows are often posited as a route to encourage young people to engage with science. Using a mixed methods approach, our research investigated the impact of attending a science show on high school students' intentions to study science or pursue a career in science. We found that while a single visit to a science show has little impact on students' aspirations, it can reinforce students' confidence in their ability to succeed in science. In terms of design and performance, the best-received shows included 'real-world' content that students could identify as relevant to their lives.

Keywords science shows; science presentations; science careers; studying sciences

Key messages

- Although one experience of watching a science show is unlikely to have a significant impact on students' intentions to study science or pursue a STEM career, it can support individual students' existing enjoyment and interest, and their confidence in their ability to study science.
- Students prefer shows in which they can identify real-world content that relates to their own lives.
- High school students prefer shows where the interactions and engagement between them and the presenters are developmentally appropriate and respect their social sensitivities.

Introduction

High school students' engagement with science concerns governments globally, as they seek to develop STEM-competent workforces for STEM-focused innovations and new businesses (Freeman et al., 2019; Government of Canada, 2021; Green and Sanderson, 2018; House of Lords, 2012). In Australia, enrolment in STEM (science, technology, engineering and mathematics) subjects in the final years of high school has historically been in decline. Enrolment in higher level mathematics, chemistry, physics and biology significantly declined between 2000 and 2012 (Kennedy et al., 2014) before stabilising (DIIS, 2020), whereas STEM-related jobs and occupations are increasing. The Chief Scientist of Australia estimated that 75 per cent of the fastest growing careers required STEM skills and knowledge (Office of the Chief Scientist, 2013), and between 2020 and 2025 Australian STEM occupations were expected to grow by 11.6 per cent, while other jobs were projected to increase by just 7.5 per cent (National Skills Commission, 2022). While the decision to study STEM subjects in the final years of high school is necessarily personal, the levels of high school students' engagement with science is a concern for government and industry, supporting efforts to increase it. However, evidence that informal science education directly leads to STEM enrolments is slim. Bannerjee noted that the level of school-based science enrichment activities did not affect science (Bannerjee, 2017a) or maths (Bannerjee, 2017b) uptake, while Archer et al. (2021) noted the limited influence of individual one-off and short-term interventions.

Science shows as informal science education

Science shows are a common but poorly researched form of informal science education. The term 'science shows' describes a broad range of activities, from classroom demonstrations to scripted, narrative-driven plays (reviewed in Austin and Sullivan, 2018). Here, we use the term to describe a series of thematically linked science demonstrations. Demonstration-based shows are used in museums and science centres to engage visiting school students and families (Price et al., 2015; Schechter et al., 2010; Sosabowski et al., 2009; Walker, 2012).

Peleg and Baram-Tsabari (2011) posit two aims for science shows: teaching content knowledge and engaging the audience with science. For example, 'Sustain-ability! The Climate Change Show' focused on how audiences could take personal steps to combat climate change, with demonstrations used to communicate messages and model target behaviours (Walker, 2012). Austin and Sullivan (2018) discuss how previous evaluations of science shows demonstrate evidence of audience learning and increased science engagement, and are most effective when constructed strategically in terms of demonstration choice, use emotional connection to engage the audience, and maximise opportunities for audience interaction.

Opportunities for interaction allow audiences to test their assumptions, feel involved in the process, and clarify understanding of concepts (Milne and Otieno, 2007; Roth et al., 1997). Demonstrations should be chosen to achieve a purpose, such as eliciting particular emotional responses, relating a concept to relevant contexts or facilitating audience interaction (Sadler, 2004, 2021; Walker, 2012). Emotional connection is important for contextualising abstract concepts (for example, Donkers and Orthia, 2014), and it is often viewed by audience members as inseparable from the learning outcomes (for example, Lanza et al., 2014; Peleg and Baram-Tsabari, 2011).

The impact of science shows on school students

Most literature evaluating science shows examines the impact on general public audiences (Schechter et al., 2010; Walker, 2012), families (Peleg and Baram-Tsabari, 2017) or primary school-aged students (Lanza et al., 2014; Peleg and Baram-Tsabari, 2011). Children often enjoy science at primary school, but interest can diminish after the age of 10 (Bonnette et al., 2019), leading to inequalities in levels of science capital – encompassing science identity, attitudes and experience (Godec et al., 2017) – and consequent inequities in post-16 science participation and careers (Archer et al., 2015).

There have been few attempts to segment or compare different potential audiences and consider their specific needs or motivations for attending science shows, and relatively little research investigating the impact of demonstration-based science shows on high school students. For high school-aged audiences, theatrical science shows (Austin and Sullivan, 2018) are more commonly evaluated than demonstration-based science shows, especially those used to prompt discussions about socio-scientific issues (Dawson et al., 2009; McKinley-Hicks, 2020; Wieringa et al., 2011).

As Varelas et al. (2022) have noted, shows built on scientific ideas and practices create contexts where students can reflect on their relationship with science and their views of themselves as scientists. Carpineti et al. (2011) surveyed high school students before and after watching a physics show. After the show, students were more interested in physics, had developed new ideas about physics, and were interested in exploring the topics covered. Walker et al. (2013) demonstrated that science shows can change the behaviour of high school students. Their show on safe-sex practices in relation to HIV/AIDS in South Africa created significant changes in attitudes to resisting peer pressure, wanting to learn more about, and talking to family about, HIV, sexual abstinence and self-efficacy to practise safe sex. In another study, Walker (2012) examined the impact of demonstrations on students' career intentions. They found that 'Burning Issues', a chemistry lecture with science demonstrations, significantly increased students' intentions to study chemistry and their interest in and excitement about, chemistry careers. For students from historically marginalised communities, dramatic performances in science classes can reduce inequities and help students identify themselves as members of the science community (Varelas et al., 2024).

Rationale

This study examines the underexplored relationship between the impact of science shows and high school students' career intentions. We investigated the impact of science shows performed at a science centre to Australian high school students in Years 7–10 (12 to 15 years old). There were two key research questions:

1) What impact do science shows have on high school students, particularly on career and study intentions?

2) What aspects of science show design and performance style appeal to high school students?

Methods

Design

This study used a mixed methods approach, employing qualitative and quantitative tools. This approach is valuable for its ability to support methodological triangulation (Creswell and Plano Clark, 2007), allowing the weaknesses of one approach to be supported by the strengths of another (in this study, using a survey to establish a composite description of students' views, and focus groups to deepen understanding of attitudes and experiences), facilitating the most comprehensive approach to answering the research question. Given that the student population from which our sample was drawn is neither random nor faithfully representative of the whole student population – 'rarely a feasible goal' (Jensen and Holliman, 2009: 60) – a mixed methods approach also facilitates generalisation to a wider population, especially when the qualitative and quantitative samples are directly linked (Hesse-Biber and Burke Johnson, 2015).

Context and recruitment

The research was conducted at Scitech, a science centre in Perth, Western Australia. Scitech has more than one hundred interactive exhibits and a programme of live shows performed in its Science Theatre, Puppet Theatre and Planetarium. Additionally, its 'Statewide' department travels around Western Australia, performing science shows, running workshops, and displaying activations at schools and community events. Schools book Scitech excursions and incursions throughout the year; approximately 20 per cent of bookings (around 5,000 students) are from high schools (A. Hannah, personal communication, 16 June 2017). This research was conducted exclusively with students attending shows in the Science Theatre.

Quantitative data collection involved pre- and post-show surveys of high school students during their visit to Scitech. Teachers booking Scitech excursions between April and December 2017 were asked whether they would be interested in allowing their students to participate in the study. They received an AU$50 voucher for the Scitech Discovery Shop to thank them for their assistance. To increase the number of participants, a free visit to Scitech was also offered to high school-aged, home-schooled students in the Scitech database. Before their excursion, teachers/carers were provided with participant information and consent forms, which requested parents' permission for their child to participate and the students' consent. Students who did not consent were not asked to complete surveys.

The show that students watched was decided by their teachers when they booked the excursion. The Science Theatre shows performed at Scitech are 'demonstration-based science shows' (Austin and Sullivan, 2018). One group (25 students) watched 'Things that Glow'; the other groups (99 students) saw 'Maths+Explosions'. Both shows were approximately 25 minutes long and used a combination of demonstrations and thematic interpretation (as described by Tarlton and Ward, 2006). 'Things that Glow' used chemistry- and physics-based demonstrations to explore the properties and applications of light, while 'Maths+Explosions' encouraged audiences to think about the practical applications of maths by testing their estimation skills while observing explosion-based experiments. 'Maths+Explosions' also used a PowerPoint presentation to provide visual aids. Students watched different instances of the shows, performed by different presenters.

Overall, 124 students participated. They comprised a group of high school-aged, home-schooled students (n = 25), and students from four high schools: two in Perth (one in a higher socio-economic area, and one in a lower) and two from regional Western Australia (Geraldton and Kalgoorlie) (n = 99). Anecdotal evidence from teachers showed that most students were selected for the excursion based on academic performance or science interest, except for one metropolitan school that brought the entire Year 8 cohort. There were roughly even numbers of students from Years 7 and 8 (12–14 years old), with slightly fewer students from Year 9 (14–15 years old) (see Table 1). Most students were in lower high school, and many could not choose their STEM subjects (n = 40) or were unsure if they could choose them for the next year (n = 43).

Survey design

At Scitech, students were asked to complete a survey before seeing the show and a second survey afterwards (see 'Data availability statement'). The surveys used a 5-point Likert scale to measure participants' attitudes towards science, science study intentions and overall experience of the show.

Table 1. Survey respondents: age and science show watched

Age	Gender			Science show		Total
	Male	Female	Prefer not to say	'Things that Glow'	'Maths+Explosions'	
Year 7 (12–13 years)	17	21	4	0	42	42
Year 8 (13–14 years)	16	20	11	12	35	47
Year 9 + (14–15 years)	8	21	5	13	21	34
No response	0	1	0	0	1	1
Total	41	63	20	25	99	124

When designing a survey, incorporating questions from existing instruments enhances a later survey's credibility and reliability by enabling cross-comparison with other datasets (Brossard et al., 2005). We adapted the Likert-type items from the 'Burning Issues' survey (Walker, 2012), which was developed to investigate high school students' post-16 chemistry study and career intentions. The wording of the questions was adjusted to change the focus from 'chemistry' to 'science' (for example, 'I'm really interested in chemistry' became 'I'm really interested in science'). Questions related to the presenter were removed from the post-show survey, to reduce its length and to maintain focus on students' science attitudes, study intentions, confidence and enjoyment of the show.

Statistical analysis

Quantitative survey data were analysed using SPSS v24. The Likert-type data were analysed using non-parametric tests, because the data were measured on an ordinal scale and were less likely to fit the normal distribution model required for parametric statistics (Pallant, 2011). The Wilcoxon Signed-Rank tested for significant changes in attitudes between the pre- and post-show surveys. The Kruskal–Wallis test compared the continuous, dependent Likert scores between multiple groups within the independent, categorical variables, including responses based on age, year level, changing perception of science, STEM subject choice and show score. Items from the Kruskal–Wallis tests with statistically significant *p*-values were analysed *post hoc* using the Mann–Whitney U test to calculate effect size, to determine the strength of significant relationships. Effect sizes (r) were calculated using the equation $r = z/\sqrt{N}$, where <0.1 = small effect, 0.3 = medium effect, and 0.5 = large effect (Pallant, 2011).

Even with careful scales design, Walker (2012) observed that ceiling effects (where audiences consistently score highly on a measure, making it difficult to compare groups) were present and likely to be an ongoing problem for science show research. To combat this, we used a long scale for overall show satisfaction and compared groups between scores at the higher end of the scale (that is, scores of 6 or lower compared to scores of 9 and 10), rather than using the entire scale.

Following Walker (2012), Cronbach's alpha was used to test the reliability of different Likert scales (see 'Data availability statement'). Coefficients of 0.7 or higher are usually accepted (Pallant, 2011), suggesting that all scales were reliable, except the 'Show curiosity' scale.

Open-ended text responses in the survey were not sufficiently detailed for thematic coding, so content was coded using word frequencies and primarily used to corroborate students' answers to closed questions (as suggested by LaDonna et al., 2018). Note that the number of responses provided for a code may be higher than survey totals, as responses could fit multiple codes or include several mentions of the same topic.

Student focus groups

Qualitative data were collected through focus groups with students who had attended a science show and completed the survey. As noted above, incorporating questions from earlier research can increase reliability; therefore, the focus group question prompts (see 'Data availability statement') were based on survey responses (Sadler, 2004).

Two to three weeks after the students had seen the science show, a subsample participated in focus groups to gather more in-depth information about their attitudes towards science and their perceptions of the show. Teachers nominated students to participate in the focus groups based on their consent to participate and their ability to verbalise their opinions. One focus group was adapted into a semi-structured interview, because only one participant attended. In total, 35 students, drawn from the two metropolitan schools and the group of home-schooled students, participated. Each focus group included between 4 and 11 students and lasted 5–10 minutes. Students received confectionery as a thank you. The focus groups were short due to the non-talkative nature of the participants. The moderator (first author) used follow-up and prompting techniques to encourage students to talk in more detail, but most students' responses were brief. All focus groups were audio-recorded and transcribed by the first author.

Thematic analysis, as described by Braun and Clarke (2012), was used by the first author to identify patterns across the dataset, reading and rereading multiple times to develop initial themes and refine them into codes and subcodes. This approach, described by Braun and Clarke (2012: 333) as 'coding reliability TA' allows for the use of intercoder reliability as a measure of coding quality. The second author then coded a randomly selected sample of approximately 25 per cent of the focus group transcripts (O'Connor and Joffe, 2020). Intercoder reliability is used in qualitative analysis to increase validity of analysis, describing agreement when independent coders analyse the same text and come to the same conclusion (Kurasaki, 2000). This process was repeated through several rounds of discussion of discrepancies, followed by further refining of the codes, until the coders recorded an intercoder reliability of 75 per cent. The final codebook is available (see 'Data availability statement').

Presenter interviews

To gather additional data on how science shows are designed to appeal to high school students, semi-structured interviews were conducted with presenters (Sadler, 2004). Interviewees were recruited from Scitech presenters who performed in the Science Theatre and Statewide. At the time of this study, there were 11 Science Theatre presenters (including the first author) and 23 Statewide presenters. Not all presenters were available to interview; some were new, with insufficient experience; some Statewide staff were touring regionally, and others were purely administrative. In total, 11 presenters were interviewed (one-third of the full presenting staff); 6 from the Science Theatre and 5 from the Statewide team. All had at least one year's experience performing science shows at Scitech, and 6 had experience writing shows (see 'Data availability statement'). Some of the presenters interviewed had performed for the school groups surveyed; others had not.

The interviews ran for 10–15 minutes on average, and participants were offered a hot beverage in thanks. All interviews were audio-recorded and transcribed by the first author. Like the focus groups, thematic analysis (Braun and Clarke, 2012) was used to develop themes and refine into codes. The second author reviewed a randomly selected sample of approximately 9 per cent of the total transcript word count, achieving intercoder reliability of 86 per cent. A smaller percentage of the interviews was checked for reliability as the interview texts were longer than the focus group texts and agreement between coders was reached more quickly. The final codebook with examples is available (see 'Data availability statement').

Results

Quantitative results

Overall, the shows were well received, with an average score of 8.12 out of 10. Of the students, 25 did not give a post-show rating; their responses were not included in analysis related to show ratings. Nearly all students used only the top half of the scale, so scores were grouped for analysis to distinguish between 'high' (7 or 8 out of 10) and 'very high' (9 or 10 out of 10) ratings, to account for ceiling effects.

Students who scored the show more highly (suggesting greater satisfaction) also rated stronger agreement with measures of science attitudes and study intentions *before* watching the show (Table 2). *After* watching the show, students who scored the show more highly had correspondingly higher agreement on scales measuring enjoyment, relevance, curiosity, attitudes towards science and study intentions (Table 3), with medium to large effect sizes. In both Tables 2 and 3, some effect sizes appear larger or smaller than would be expected based on the percentage difference in agreement; this is perhaps due to differences in the linear relationship or to outliers, both of which can affect *r*-values.

As shown in Table 4, there was a consistently small but significant change in five items between the pre- and post-show surveys regarding intentions to study science, motivation, and confidence in science. However, attitudinal and measures relating to careers in science were unchanged (Table 4). Students' choice over their STEM subjects the following year had no significant impact on survey responses ($p \geq 0.125$). The influence of gender was not analysed, as a high proportion of students reported 'Prefer not to say' (see Table 1).

Qualitative results

Open responses in the survey complemented students' responses to the closed questions. For example, when asked about their least favourite part of the show, most said 'nothing' or 'I enjoyed everything' (n = 86). Despite their enthusiasm, most students (n = 80) said that the show did not change what they thought about science; 13 students did not answer the question. Students who responded 'no' either said that they already enjoyed science (for example, 'I liked science before anyway', n = 5) or had seen the experiments performed before (n = 2). Of the 31 students who said that the show changed how they thought about science, the most common responses were realising science was enjoyable (for example, 'I didn't think science could be cool and interesting', n = 17) or that the show helped them understand the relationship between maths and science (n = 2), and the relevance of science to their everyday life (n = 4).

Table 2. Level of agreement with Likert items *before* the show that significantly related to final show rating

Likert items*	Final show scores out of 10			*p*-value	*r*-value
	9 or 10 (*n* = 48) (%)	7 or 8 (*n* = 38) (%)	6 or less (*n* = 13) (%)		
(S) I would like to study science at university	64.5	52.6	38.5	0.004	0.372
(S) I want to learn more about science	85.4	76.3	69.2	0.045	0.256
(S) I would like to find out more about science careers	60.4	52.6	7.7	<0.001	0.462
(S) I will choose science when I get to make subject choices	47.9	60.5	23.1	0.044	0.258
(S) Science is not something I'd consider as a job	29.1	34.2	61.5	0.004	0.368
(A) I find science really inspiring	75	52.6	30.8	0.005	0.364

*S: study/career, A: attitude
p-values are from the Kruskal–Wallis test across all three groups.
r-values are calculated based on post hoc Mann–Whitney U tests comparing '6 or less' and '9–10' groups, except where specified. *r*-values represent effect size, where <0.1 represents a small effect, 0.3 represents a medium effect, and 0.5 represents a large effect.

Table 3. Level of agreement with Likert items *after* the show significantly related to the final show rating

Likert items*	Final show scores out of 10			*p*-value	*r*-value
	9 or 10 (*n* = 48) (%)	7 or 8 (*n* = 38) (%)	6 or less (*n* = 13) (%)		
(E) The show was funny	95.8	81.6	38.5	<0.001	0.545
(E) I had fun for the entire show	91.7	71.1	23.1	<0.001	0.589
(E) The show was interesting	100	94.7	53.8	<0.001	0.587
(E) I enjoyed the show	100	100	76.9	<0.001	0.638
(E) There were things in the show I have a personal interest in	75	44.7	30.8	0.006	0.355
(R) I could see how the show related to things in the outside world	100	86.8	61.5	0.002	0.396
(R) The show was relevant to my life	66.7	42.1	23.1	0.003	0.377
(R) The show had ideas that I can use myself	79.2	39.5	30.8	0.001	0.421
(R) The show helped me understand things in everyday life	70.8	34.2	30.8	0.003	0.386
(R) The information in the show was important to me	60.4	23.7	7.7	<0.001	0.496
(C) The show made me curious	83.3	28.9	46.2	0.001	0.407
(C) I was surprised by some of the experiments	81.3	68.4	53.8	0.008	0.338
(C) Parts of the show reminded me of things I've seen or done	75	57.9	38.5	0.009	0.336
(A) I'm really interested in science	91.7	68	53.8	0.002	0.412
(A) Science can be a lot of fun	95.8	94.7	84.6	0.006**	0.299
(A) I find science really inspiring	77.1	71.1	30.8	0.006	0.356
(S) I'd be willing to learn more about science in my spare time	75	50	38.5	0.003	0.383
(S) I would like to study science at university	52.1	50	0	<0.001	0.487
(S) I want to learn more about science	87.5	65.8	61.5	0.038	0.273
(S) I would like to find out more about science careers	56.3	55.3	15.4	0.002	0.404
(S) I think science would be an exciting career	72.9	65.8	53.8	0.033	0.277
(S) I will choose science when I get to make subject choices	60.4	65.8	23.1	0.001	0.453

*E: enjoyment, R: relevance, CS: curiosity/surprise, A: attitude, S: study intentions.
p-values from Kruskal–Wallis tests across all three groups except items marked ** which were not significant when comparing '6 or less' and '9–10' groups but were significant between '7–8' and '9–10' groups.
r-values calculated via post hoc Mann–Whitney U tests comparing '6 or less' and '9–10' groups, except where specified.
r-values represent effect size, where <0.1 is small, 0.3 is medium, and 0.5 is large.

Thematic analysis of student focus groups and presenter interviews identified key themes around audience engagement, including enjoyment (particularly of explosions), understanding, relevance, presenter collegiality and long-term impacts.

Table 4. Changes in survey item results before and after watching the show

Likert item*	Survey mean scores (1 = *Strongly agree*, 5 = *Strongly disagree*)		*r*-value	*p*-value
	Pre-survey	Post-survey		
(A) I'm really interested in science	2.02	1.97		0.555
(A) I think science is boring	4.07	4.12		0.411
(A) Science can be a lot of fun	1.56	1.60		0.271
(A) I find science really inspiring	2.26	2.17		0.321
(S) I'd be willing to learn more about science in my spare time	2.45	2.33		0.153
(S) I want to learn more about science	1.96	2.03		0.121
(S) I think scientists have a great job	1.98	1.96		0.942
(S) I would like to find more about science careers	2.47	2.52		0.332
(S) I think science would be an exciting career	2.21	2.15		0.355
(S) Science is not something I'd consider doing as job	3.10	3.29		0.106
(S) I would like to study science at university	**2.86**	**2.69**	**0.266**	**0.005**
(S) I'm motivated to work hard in my science subjects	**2.14**	**1.98**	**0.206**	**0.021**
(S) I will choose science when making subject choices	**2.52**	**2.32**	**0.216**	**0.016**
(C) I get good marks in science at school	**2.02**	**1.92**	**0.195**	**0.030**
(C) I am confident when it comes to learning science	**2.05**	**1.91**	**0.185**	**0.038**

*A: attitude, S: study/career, C: confidence.
Significant values are bolded. *r*-values represent effect size, where <0.1 is small, 0.3 is medium, and 0.5 is large.

Students' survey responses showed that dramatic demonstrations, particularly explosions, were the highlight of the show (*n* = 165). Asked about their ideal science show demonstration, most students suggested larger or more impressive versions of the demonstrations used in the show:

> You gotta go full out Michael Bay, makin' really bad Transformers movies, turn into a Teenage Mutant Ninja Turtles, all that, all those explosions put together.

While nearly all presenters interviewed wanted the shows to be entertaining and fun, and to provide students with a generally positive association with science, they perceived explosions and 'crowd-pleasing demonstrations' as mainly for entertainment, amid concerns about the long-term impacts:

> … explosions are always gonna be entertaining to everyone, but it's what people are gonna take out from that?

> You've definitely got your crowd-pleasing demonstrations … they're typically more entertainment than education … it's difficult to judge them in isolation and not as part of a whole show.

Students also enjoyed moments when they learned something new or the demonstration made them think: '[I enjoyed] the parts where I had to use my brain more because it got me thinking'. This was reflected in the presenters' opinion that, compared to science shows for young children, high school shows were more 'content-heavy' and used 'higher end language', which allowed for 'really great conversations'.

Relevance was raised repeatedly by both students and presenters. Students' survey responses showed that they enjoyed finding that 'maths had a practical application'. During focus groups, they suggested that they preferred demonstrations that they could 'relate to, like real life' even more than explosions. Over half of the presenters interviewed noted that demonstrating how science is 'relevant to their [students'] lives' was a key purpose of science shows. There was a balance, however, between creating relevance and conversation and keeping the show moving. In focus groups, students noted that in 'Maths+Explosions', significant time was spent talking about the demonstrations instead of performing them; they considered certain sections 'too long' and 'boring'.

During interviews, presenters often defaulted to referring to 'kids' when discussing audiences. However, they clearly recognised high school students as a distinct audience, not just in terms of content, but in terms of specific emotional needs. Presenters believed themselves able to change their performance techniques and style to suit different audiences, with one interviewee explaining that 'we just went on tour for three weeks, did the same show 33 times, but I would say the focus of each show was different'. Presenters were adamant that high school students should be respected, noting that they disliked being patronised or treated as children. This was reiterated in the student surveys; some students were unimpressed when one presenter 'spoke to us like we were toddlers'.

Presenters conceptualised respect for high school students in two main ways: building rapport, particularly through humour, and using a lower energy performance style. For primary school shows, presenters typically used a very high-energy style: '[being] the big, loud, crazy person'. With high-schoolers, this was seen as 'cringey' and ineffective; high school students were perceived as having 'a natural resistance to getting excited'. Instead, 'being yourself' or 'being genuine' was seen as the key to rapport building:

> with a high school that's [high energy] kind of condescending and they just see right through that … it's a bit more honest and raw – like, you actually have to be yourself.

Presenters could still express their enthusiasm and passion for science, but in 'a bit more of a collegiate style', leading to a show that is 'more conversational [and] not as performancey', using techniques including sarcasm and humour to engage the audience. These techniques were reflected in student survey comments such as '[the presenters] were really good' and 'I really enjoyed the jokes'.

Presenters also used a conversational style to reduce social anxiety among students. For high school students, presenters recognised the fear, embarrassment and shame associated with speaking up or being singled out. Rather than volunteering to do a demonstration or ask a question, high school students were seen to 'prefer the idea that everyone's contributing', hence using a conversational style was a way to make students 'comfortable' and allow them to 'get their questions answered … without having to ask'. Students' survey answers reinforce the presenters' views that they have a low tolerance for embarrassment: '[I didn't like] the bits where they choose people 'cause I got nervous that I would get picked'.

More than half of presenters felt that a key purpose of science shows was to inspire students, especially those 'kids who are traditionally seen as difficult to engage' into science, and to encourage them to be more self-directed, for example, 'getting them to go away and do science' or 'educate themselves in their own time'. However, no students said that they had done further investigation. Many had discussed the show with their family, but this often seemed to be instigated by parents; for example, 'I dunno, my parents always ask how my day was, so I just put that in there as well'.

Presenters disagreed on whether science shows have a long-term impact on students. Many believed that creating positive experiences with science led to long-term effects:

> … at the time it might seem like a really small thing of 'Oh, that was cool, that was science!', but I think that can actually have a really long-term impact …

https://doi.org/10.14324/RFA.09.1.03

Others were more circumspect:

> … to be honest, I probably don't think that a single science show is going to make that much difference to a student's life …

This is reflected in students' focus group and survey comments. Although many intended to follow a career in science, for most this came from an interest in science that pre-dated watching the show, and they did not relate their intended career to the experience of the show: 'Well I liked science before anyway', 'No, I still like science a lot', 'I've always just liked maths'.

Discussion

Students enjoyed the shows they watched, and they were especially enthusiastic about the bolder demonstrations. Presenters were concerned that demonstrations were more about entertainment, with little long-term impact. Both agreed it was important that content showed the relevance of science to students' lives. Although a key motivator for presenters was their hope that the shows would inspire students to choose science subjects or careers, no students reported following up on the shows' topics or an impact on their intention to follow a career in science.

The impact of show satisfaction was moderated by expectations: those who already liked science enjoyed the content, and those whose enjoyment surprised them increased their positive attitudes. We found little evidence that science shows increase students' general engagement with science or directly contribute towards intent to follow science careers, although they can have some impact on students' perceptions that they have a place in science (Varelas et al., 2024). Most students had already set their general career direction; indeed, most of those who wanted to be scientists had made the decision by the end of primary school (DeWitt and Archer, 2015; Prieto and Holbrook, 2021).

Rather, the science show increased students' confidence, motivation and intentions to study science, including a significant increase in agreement with the item 'I get good marks in science at school'. Clearly, the show could not change students' existing grades and there is limited evidence on how participation in out-of-school science activities can positively affect students' achievements in science (Burns et al., 2023). The post-show reinforcement of students' confidence in their abilities to learn and understand science is consistent with Falk et al. (2014). Although grades provide a narrow interpretation of what it means to be 'good' at science (McKinley-Hicks, 2020), students' confidence in their grades is particularly relevant given that perception of difficulty is an important determiner of subject choice, with science subjects rejected because they were 'too hard', or students believing that they could get better grades in other subjects (DIIS, 2020; Venville et al., 2010). Students' belief that they were good at science was the second-highest reason for choosing a science career (Venville et al., 2013). Participants in the Millennium Cohort Study who changed their career aspirations to science pathways between ages 11 and 14 typically had higher self-confidence in maths and science versus those who moved away from science careers (Sheldrake, 2020). Students' science capital, including confidence in their science abilities and 'science identity', is a strong predictor of aspirations to study STEM after age 16 (Archer et al., 2015). Students with lower science capital are less likely to pursue STEM study and career pathways, reinforcing the importance of continuing to support confidence, understanding and identity with STEM (Archer et al., 2015).

Consistently, the main reason that students aim for a science career is *long-term* interest (DIIS, 2020; Prieto and Holbrook, 2021; Venville et al., 2013). Although the science show did not directly affect science career intentions, it contributes to the experiences students require to reinforce their enjoyment, interest and confidence in science on the long pathway to a science career. While Walker (2012) did not discover significant increases in students' confidence studying science, for the high school students who watched 'Burning Issues', post-16 STEM aspirations increased. Walker (2012: 224) also noted that bold demonstrations ('exciting explosions and bright-coloured flames') may have influenced students' motivations. Thus, the presenters' conflicting opinions on a science show's impact were both correct:

science shows have the potential for indirect long-term impacts, but the impact of a single show is not enough to change students' career intentions. As Archer et al. (2021: 69) note: 'while one-off experiences can be worthwhile experiences, it is important to be realistic about what they can achieve by themselves – and thus to maximise the opportunities they offer and their potential by linking to other aspects of young people's lives and experiences'. The combination of informal science experiences and formal science education in students' learning ecology (Bronfenbrenner, 1979) helps develop aspiration to science careers and keeps them on that pathway. Given that intentions to study STEM drop gradually between 12 and 17 (DIIS, 2020), simply maintaining interest is a positive result for this age group.

Both students and presenters noted the importance of making the show relevant to real-life situations; understanding the practicality of science in the real world increases students' interest in science (George, 2007) and leads to increased likelihood to pursue science careers (Venville et al., 2013). Similarly, Sadler (2004, 2021) found physics students were more likely to be interested in 'Mechanics' demonstrations that explained how things work and real-world applications of science. Since most students in this study were already highly interested in science before watching the science show, this suggests that they would be more likely to be curious about the real-world relevance of STEM. Although students and presenters were broadly aligned in their view that shows should be designed to capture attention and respect the audience, presenters overestimated their influence in reaching unengaged students and inspiring students to pursue science in their own time, perhaps because students view excursions as one-off, enjoyable activities that do not necessarily link back to their studies or home life (Hayes, 2018). As Zipin (2009) suggests, connecting young people's home and community 'lifeworlds' to their school-worlds supports the development of their identification with science and whether they are recognised by others as being a 'science person' (Carlone and Johnson, 2007).

The high school students liked the performance style to be age-appropriate, clearly disliking anything that they saw as patronising; they did not like being singled out of the crowd, and they preferred action to talking. It is known that adolescents have a heightened sensitivity to being socially evaluated (Somerville, 2013). The presenters understood the need to suit their performance style to their audience, by incorporating rich content that allowed everyone to contribute to discussions rather than posing questions, using humour and building rapport through conversational interaction rather than high-energy performance. However, although the presenters seemed to understand what students wanted, they might not always apply it in practice, as demonstrated by some students stating that they felt patronised, or that the presenters spent too much time talking.

The students clearly enjoyed the demonstrations in the shows they watched, and they would have liked them to be even bigger and louder. However, demonstrations are not enough by themselves; high school students also want content that makes them think, and science that is relevant to their lives.

We did not explore the effects of inequities (for example, age, gender or socio-economic status) on the impact of science shows, due to the constraints of using a convenience sample of Scitech excursion bookings, which does not represent a full student cohort. Many teachers chose to bring students who were already doing well in science, as a reward for high achievement, reflecting the structural and science capital barriers that exist for students aspiring towards science careers (Archer et al., 2015; DeWitt and Archer, 2015). Young people from minoritised backgrounds are less likely to visit informal science learning (ISL) spaces in their spare time, even if they have a strong interest in STEM (Godec et al., 2022). Dawson (2014) reflects on how ISL practices can 'other' visitors who do not fit 'ideal' standards, including school excursions. This highlights the risk of reproduction of social disadvantage in ISL, especially if teachers select students who they believe are more likely to be better behaved or receptive to the content. Future studies should make efforts to capture data from entire cohorts of students where possible, to understand how *all* students respond to science shows, not just high achievers and those with existing high science capital.

We also did not examine for differences in outcomes for students who watched different shows, due to the contrast in sample sizes (n = 25 for 'Things that Glow' versus n = 99 for 'Maths+Explosions'). Walker

(2012) noted that one of the key motivational features of science shows is 'value' (personal relevance), suggesting that linking concepts in the show to people's daily lives has a stronger influence on science show audiences than differences in performance style or content. Future studies could examine these effects in more detail.

We did not collect data on how teachers reflected the visit into the classroom experience, which can influence student attitudes (Hayes, 2018). It would also be interesting to examine the effects of repeated exposure to science shows, and whether there is a point where attitudes plateau (Falk et al., 2014). Archer et al. (2021) suggest that one-off interventions might have a place in the ecology of learning, contributing towards the maintenance of science identity and aspiration, while noting that evaluation of the impact of one-off interventions is difficult, especially if the changes are subtle. This suggests that there is scope to develop methods to more fully reflect the impact of 'one-off' science shows.

Long-term cohort studies such as Bannerjee (2017a, 2017b) should also be conducted on younger age groups, various equity measures, and in different countries, especially considering the impact of national curriculum design on science uptake (Mellander and Lind, 2021).

Conclusions

There are limits to the extent to which a single experience, such as a visit to a science show, can affect students' attitudes and their choice to continue studying science. Notably, presenters overestimated the influence of the show in drawing in unengaged students and inspiring students to pursue science in their own time; when they saw the science show, the students had already decided their educational path, and their attitude to science had probably been set long before. However, our research suggests that although one experience of watching a science show is unlikely to have a significant impact on students' intentions to pursue STEM study or careers, it can support individual students' existing enjoyment, interest and confidence in their ability to study science.

High school students' and presenters' views on the design of science shows largely coincided. They agreed it was important to include real-world content that students can connect with their own lives. They also held similar views on the value of developmentally appropriate interaction and engagement that respects the audience's sensitivities by focusing on conversation rather than questioning. However, some discrepancies between what presenters aim to do and what students observe suggest that these strategies are not always applied in practice.

In summary, science shows and other one-off interventions are unlikely to change minds or attitudes, but they can support high school students' confidence in their ability to understand and succeed in science and reinforce existing intentions to study science at a higher level or follow a science-based career.

Acknowledgements

Thank you to the students who participated in this study and their teachers who helped facilitate their involvement. A special thank you to all the Scitech staff members who helped by taking part in interviews, arranging excursions and generally supporting the process of informal science organisations actively participating in research.

Data availability statement

The survey questions and details of the analysis, interview schedule and codebook are available from our research repository: Phillips, S. (Creator), Sullivan, M. (Creator), Grand, A. (Creator) (2024): '"Explosions are always entertaining but…": investigating the impacts of science shows on high school students', the University of Western Australia (https://doi.org/10.26182/np9j-fj75).

Declarations and conflicts of interest

Research ethics

The authors declare that research ethics approval for this article was provided by the University of Western Australia Human Research Ethics Committee to ensure ethical conduct during data collection (reference number RA/4/1/8790).

Consent for publication statement

The authors declare that research participants' informed consent to publication of findings – including photos, videos and any personal or identifiable information – was secured prior to publication.

Conflicts of interest statement

Ann Grand is a member of the NCCPE. All efforts to sufficiently anonymise the authors during peer review of this article have been made. The authors declare no further conflicts with this article.

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