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Case study: co-creating Special Educational Needs and Disabilities (SEND)-friendly science resources for families

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This community case study presents the process a multi-partner project took to develop accessible and engaging science-related activities for children with SEND and their families. Designed for use in museums, community outreach events, or at home, these resources reinforce science learning beyond the classroom. The History of Science Museum, RAL Space and Iffley Academy—a specialist school for children and young people with complex special educational needs and disabilities (SEND)—co-created a suite of outreach activities to be used by educators, ambassadors, parents or guardians to engage pupils with SEND in science. The project followed a relational model of engagement with classroom consultations with the same 11 pupils over several months, guided by a community outreach officer. Students made direct, significant contributions to the design and content of the resources. Co-creation ensured the resources were accessible and fostered an inclusive whole-family learning experience. The project has influenced the museum's and RAL Space's approaches to inclusive resource development and evaluation, while significantly improving the students' science capital and social-emotional development.

KEYWORDS

SEND, co-creation, informal science learning, space education, science museum, accessible resources

1 Introduction

1.1 SEND in England

Special Educational Needs and Disabilities (SEND) is a widely used term in England for government, social and health care professionals, cultural organisations and the public. It encompasses a wide range of physical, sensory, intellectual, cognitive and mental health conditions. Persons with disabilities (PWD) may be understood in broader global usage; in this article the authors focus on SEND as the UK-specific term, appropriate for the communities involved in resource development and evaluation.

The Children and Families Act 2014 defines SEND as:

"A child of compulsory school[1] age or a young person has a learning difficulty or disability if they have:

- a significantly greater difficulty in learning than the majority of others of the same age, or

1 https://www.legislation.gov.uk/ukpga/2014/6/part/3

- a disability which prevents or hinders them from making use of facilities generally provided for others of the same age in mainstream schools or mainstream post-16 institutions."

The SEND Code of Practice 2014 and the Children and Families Act 2014 guide education, health and social care and local authorities to ensure that children and young people with SEND are properly supported. Those with the most complex needs can apply for an education, health and care (EHC) plan from local government. State funded specialist schools can only take pupils awarded with an EHC plan.

1.2 Accessibility of science for young people with SEND

There is increasing recognition of the importance for young people with SEND to engage with science outside of school—an area that has traditionally had limited provision in the UK.

In England, young people with SEND are less likely to progress into scientific or technical careers; they need better, accessible science education and engagement, which can be developed partly in informal science learning places. As of June 2025, there are over 1.7 million pupils (18.4%) with an identified SEND and the number of pupils has continually increased since 2015 (Department for Education, 2025c). Yet, just 4% of A Level science students have SEND (Department for Education, 2025b). Of those, 16% are likely to enter future training or employment in STEM (science, technology, engineering, maths), compared to 22% of non-SEND science pupils (Hodge et al., 2024). In the UK space sector, people with disabilities are underrepresented: they make up 8% of the space sector compared to 13% in the total UK workforce (Thiemann and Dudley, 2021).

This issue of underrepresentation and exclusion pertains specifically to STEM: "There is lower representation of disabled higher education students in STEM than in non-STEM fields" (Lightyear Foundation, 2024). The Lightyear Foundation (LYF) is the only UK charity focused on improving access to STEM for disabled and neurodivergent children and over the past 13 years they have supported 15,041 children (Lightyear Foundation, 2025). Many science centres and museums host dedicated quiet or accessible sessions, and workplaces connect with charities such as LYF to facilitate engagement with children with SEND. While these programmes are impactful, there is a reliance on location and local services such as transportation. There are persistent barriers such as lack of funding for outreach organisations, lack of staff training in scientific concepts or in working with people with SEND, lack of suitable SEND-friendly resources or their prominence, and socio-economic factors.

There is a strong correlation between economic and social disadvantage and SEND. More SEND pupils are proportionately eligible for the Pupil Premium award (a UK government grant awarded to schools to mitigate disadvantage) than the general school population (Department for Education, 2025a). This correlation suggests that disadvantaged students are disproportionately affected by learning and/or physical and mental health challenges.

Young people need multiple opportunities outside the classroom to raise their science capital to help them pursue careers in science (Science Museum Group, 2020). Since the launch of the Children and Families Act 2014, the UK museum sector has been improving provisions for SEND families, with campaigns from organisations such as Kids in Museums and SEND in Museums[2], quiet or autism-friendly openings, and bespoke family activities (Bowen, 2023). Science organisations are also increasingly aiming to engage SEND learners by developing resources with student activity and teacher guides (British Science Association, 2024).

They also need to feel that science is relevant to them and that they can identify with scientists by the time they are 10 years old (Archer et al., 2015, 2020). Young people with disabilities specifically need inclusive education programmes that enable them to interact with science in ways that suit their needs, support their aspirations, and connect them with relevant role models (Senhem Heck and Ferraro, 2025). Co-production is a method of resource development that empowers students with greater ownership of their learning (Geurts et al., 2024). Direct inputs from children with SEND and their supporters to their science education are therefore vital for developing quality resources that are truly relevant and form part of their personal learning journeys. The currently limited range of opportunities for children to learn science alongside their family members and carers is a likely factor preventing them from pursuing STEM careers.

To address these issues, the authors proposed a collaboration between informal science learning places, science and technology institutes, and the communities with lived experiences to co-create multi-layered, versatile, inclusive learning resources, provided at no cost to families. This project is part of the broader cultural movement to open up heritage, culture and science to a wide audience. As Sam Bowen notes "The variety of family make ups means some may visit with more than one SEND child and most will have non-SEND or neurotypical siblings. If a museum does not cater for the needs of the SEND child, the whole family is unlikely to visit." (Bowen, 2023).

This case study presents the co-creation process and approach of developing accessible science resources: backpacks, "Explore at home" booklets and "Science and Magic" outreach shows, co-created with pupils with SEND. The authors present the value of the relational model of engagement and the resources' impacts to date on both the advisory class of students, and the resource users. The details of the science resources that were developed for this project are to be published in a separate case study.

2 Context

This project was a three-way partnership between the Iffley Academy specialist school teachers and pupils, the History of Science Museum (HSM) and RAL Space, all based in Oxfordshire. The long-term relationship between Iffley Academy and the Gardens, Libraries and Museums (GLAM) division of the University of Oxford (of which the HSM is a member) was important for the success of the project, together with scientific input from RAL Space, part of the Science and Technology Facilities Council (STFC), which funded the project.

2 https://sendinmuseums.org/

2.1 Iffley Academy

Iffley Academy[3] is a community specialist school in Oxford, currently attended by 180 children and young people aged 11–18 years old with complex SEND. Some, though by no means all, children with SEN in England will also have disabilities, and this is the case of many pupils attending Iffley Academy. The students have a range of needs, but primarily Moderate Cognition and Learning Difficulties, Autistic Spectrum Disorder and/or Social, Emotional and Mental Health difficulties. 50% of pupils attending Iffley Academy are in receipt of Pupil Premium funding compared to around 25% of pupils nationally (Department for Education, 2025a).

Iffley Academy students are unable to access the curriculum in mainstream schools. They need additional support in almost all curriculum areas. Students are in small classes of 10–11 pupils, and the school prides itself on taking an individual and person-centred approach. A teacher is often supported by two teaching assistants. Students spend all day with the same teacher for most subjects who knows their students' needs and is an expert in enabling them to make progress within all subjects.

Multi-sensory learning opportunities are often most successful for children with SEND. They are often keen to learn and share their ideas about science topics when they are presented with relevant and engaging activities; a stated purpose of the school is to enable the pupils to become 'active citizens within a community'.

2.2 Oxford University Gardens Libraries and Museums

GLAM has been working with Iffley Academy since late 2016. Initially the programme focused on arts-based learning, particularly the visual arts. The partnership expanded to:

- Science learning using the GLAM collections
- School co-curation programmes
- Teacher training
- Qualifications: Arts Award and the Artsmark programme.

The programme adopts a relational practice model, prioritising building strong relationships based on trust, honesty, reciprocity and integrity (SEND in Museums, 2022). These relationships aim to meet all learners where they are. It is individualised so that all learners have the opportunity to take risks and experience success.

The partnership uses a blended model of outreach and visits to GLAM sites to enable students to have rich and memorable learning experiences. It is managed by a member of the GLAM community and outreach team, an Arts engagement officer specialised in SEND provision. It is a unique role in museum learning in the UK, but valuable in relationship building and advocacy for SEND access and engagement.

2.3 History of Science Museum

HSM has a year-round programme for adults with learning difficulties; workshops for blind and partially sighted adults; school-based outreach initiatives; and the development of resources for children with SEND to use during visits from mainstream schools. The informal learning programming includes regular Autism-friendly openings and the creation of materials to support visits, such as pre-visit Access and Easy Read Guides[4], ear protection and magnifying sheets. The development of inclusive science backpacks was an important addition to the museum's offering.

The role of museums has changed over recent decades, with widespread acceptance of their role in combating social inequality and acting as agents for social change (Zakaria, 2023). This is reflected in the International Council of Museums' definition of museums: "museums foster diversity" and are "accessible and inclusive" (International Council of Museums, 2022).

UK funders often insist that museums demonstrate that their programmes are accessible. Arts Council England (the body which invests public money from government and the National Lottery to support organisations, including GLAM and HSM) stipulates that museums must demonstrate how their engagement programmes are "inclusive and relevant". These funding sources are important to national, local-authority and university museums which do not charge admission. Arts Council England's accreditation programme states that all museums must have an access plan to improve "the physical, sensory and intellectual access to your collections" (Museum Accreditation, 2018).

2.4 STFC RAL Space

As the UK's national space laboratory, RAL Space plays a significant role to drive scientific innovation and serve its communities including government and the general public, advancing the understanding of the Universe, the planet and the environment. They work in partnerships to deliver an inspirational engagement programme and aim to champion space as accessible for all, prioritising activities for under-represented audiences with high quality public engagement and evaluation. This is delivered through STFC's Wonder Initiative[5] and includes school workshops, lab tours, public open days, teacher training and training for early career researchers and engineers to undertake outreach. RAL Space has participated in many of its projects for diverse communities and young people from socio-economically deprived areas, however there were no RAL Space projects specifically with people with disabilities. This collaboration was a pivotal opportunity to learn from people with lived experience and knowledgeable, local partners to improve the programme, while contributing technical expertise in space instrumentation. STFC's position as a funder, delivery partner, and advocate for public engagement practise nationally provides the platform to improve access to suitable science resources for pupils with SEND.

3 https://iffleyacademy.co.uk/

4 https://hsm.ox.ac.uk/access

5 https://www.ukri.org/what-we-do/public-engagement/public-engagement-stfc/our-support-for-public-engagement-stfc/public-engagement-wonder-initiative/

3 Methodology and outputs

3.1 Funding and project scoping

This work was possible through the successful application of two competitive public engagement grant awards, neither of which are specifically for SEND audiences. The project was initially funded through a 7-month Royal Society Public Engagement Fund awarded in 2021, as a "proof of concept" led by RAL Space in collaboration with HSM. Activity backpacks were made for children to borrow with their families at HSM in Oxford and understand key properties of light. This was achieved through hands-on exploration of the different ways that light can be modified and observed. Materials such as mirrors and filters were incorporated, which are fundamental optical components of telescopes and can be understood by children in their everyday uses. These materials were linked to examples in both modern-day space instruments that RAL Space has contributed to, and historical instruments at HSM. Establishing a collaboration between RAL Space and HSM leveraged expertise in developing museum activities, space science education and communication, and technical space instrumentation development. The project allowed the development, testing, and evaluation of the new outreach materials, however feedback from backpack users highlighted the need for more inclusive resources to engage young people with SEND.

3.2 Establishing an equitable partnership

GLAM staff have an established partnership with Iffley Academy and expertise in engagement with SEND students. By extending the HSM-RAL Space collaboration to include GLAM staff, the project could be designed specifically to include the development of SEND friendly science materials. This was realised to be a multi-year project to ensure rigorous consulting and evaluation with SEND students, and for sufficient iterations of the resources. A 3-year STFC Spark Award led by HSM was awarded in 2023 to develop SEND friendly materials.

This length of time allowed seven sessions at the school and HSM, with a specific class of 11 students who were secondary-school aged. This class was taught by the school's science lead who is keen to find ways to engage pupils with science both in school and with the families outside school. The class and their teachers were already familiar with GLAM and HSM staff through the existing relationship and all were keen to continue working together in the relational model of engagement (SEND in Museums, 2022).

Although these pupils' families weren't directly involved in the consultations, the authors sought feedback from general public families via pilots at HSM and RAL Space listed in Section 4.2; this constraint is described in Section 6.

The consultations resulted in the creation of 12 backpacks, an "Explore at home" science booklet aimed at children and their families, and prototype kits for a "Science and Magic" show. The time also allowed for follow-up activities: school assemblies, a careers Q&A with RAL Space scientists, and visits to their laboratory.

The first sessions took place in familiar classroom surroundings at the school and as much information as possible was provided to the school beforehand including photos of all the staff due to attend. In the initial workshop the team introduced themselves to build trust before introducing the project and the topic of light. Children carried out simple experiments in their classroom to find examples of reflection in everyday objects and made a simple kaleidoscope. These activities allowed the team to check the levels of knowledge and understanding that the students already had through informal discussions and observations, and helped them select an appropriate range of activities for subsequent sessions. The process of building trust with the pupils was as follows, as observed by adults in the group of the pupils' confidence, excitement and levels of participation. Affiliations are Miranda (GLAM), Helen (HSM), Vicky and Elin (RAL Space):

1. Existing awareness of students and teachers at Iffley Academy of GLAM/HSM. Through seeing Miranda and Helen in school—some of the children and teachers participated in previous projects, visited GLAM venues, saw the co-curated displays of objects in school, heard GLAM discussed at assemblies. Parents will also have received communication about GLAM in the past.
2. Relationship with the teacher. The teacher was aware of a past GLAM project and was keen to work with Miranda, so was able to prepare students in advance about this new project. It was framed in a way that students would have been excited that their class had been selected by the headteacher to work on a new project that sought out their views.
3. First school visit. The session was set up to make introductions with Helen and Miranda rather than starting on consultation immediately. It was explained that the team were going to be making new resources to help make family visits to the museum fun and give people the opportunity to learn more about science. The authors established the theme of "how light works" by simply investigating reflections in the classroom, watching a short video and then making kaleidoscopes together that children could take home. Students at the start of the session were quite nervous, particularly those who hadn't met the team before and gave limited eye contact or responses to questions. By the end of session, they seemed more relaxed, some said goodbye. The project staff explained they would be returning the following week with more activities, pre-empting students' expectations.
4. Introducing RAL Space staff. Prior to this next session Elin and Vicky sent photos of themselves so the teacher could show them to the class and let them know they would be joining Miranda and Helen. The children were excited to see Miranda and Helen again, expressed through facial expressions. Small groups of students and the assigned adults worked through the activities, as described in the next subsection.
5. Second school visit. The session started with a re-cap of previous activities and voting results. In small groups the partnership shared information to the class about different styles of bags and content for information cards. At the end of the session the students were keenly anticipating what the prototype backpacks would look like at the next session.

6. Work experience Q&A. The partnership continued where there were clear synergies between the participating organisations' objectives and capabilities. The authors set up a work experience Q&A between Elin, Vicky and several other classes at the school. They deepened the relationship further and allowed students to better understand their role working with space science at RAL Space. This session occurred organically from conversations between the teacher and the project team and wasn't part of the initial project plan.
7. Third school visit. The project team returned to share the prototype backpack in school and get feedback about the resource. Pupils were now at ease with the four staff on the project team, and used their names. At the end of the session, they explained they would be visiting HSM and shared pictures of the museum.
8. Museum visit. The students visited the museum to see the setting in which the backpacks would be used. Many of the students were typically anxious at visiting a setting outside of school; this was helped by seeing photos beforehand and the presence of familiar adults.
9. Fourth school visit. The team ran consultations on the booklets and the science and magic show in class. The students were familiar with the way of working (small group feedback) and felt relaxed with the idea of being shown a magic show by Helen and Elin. Children laughed and seemed genuinely thrilled by the illusions and interested in the scientific explanations.
10. RAL Space visit. The class visited RAL Space to tour the labs, learn about the solar system planets and paint hand-made planets with creative skills. This was another activity outside of the original project plan; from the feedback form, 70% of students were "definitely interested" to learn more about space in future and all students named a part of the day that they enjoyed.
11. Recognition of co-creation. To finish the consultation period, there was a presentation of certificates to the class recognising their contribution from the museum director.

The development period lasted a whole school year and the partnership continued. Helen led a school assembly and reported on the success of backpacks in the museum 6 months later. HSM and RAL Space returned to the school the following year to present activities for the annual family open day, including some resources from the backpacks. Many children recognised and interacted with the team, bringing their parents and friends. Since this project Miranda has undertaken further projects with the school's science lead.

3.3 Co-creation sessions

In the classroom sessions, the authors set up a carousel of hands-on exploratory activities linked to the topic of light and optics that could potentially feature in the backpacks. In groups of about 3 students each with a teacher or project team member, students were guided to explore each material and had the freedom to choose which one(s) they wanted to spend more time with, express which one(s) they enjoyed and any particular reasons. Meanwhile the adults observed and noted the engagement level, student quotes, and any ease or barriers and discomfort in physically handling objects. See Figures 1, 2 of authors Miranda and Vicky facilitating these activities. Students with the greatest needs e.g., non-verbal students were assigned to school staff with the expertise to engage them effectively.

3.3.1 Backpack activities

As an example, one of the themes was to explore coloured light. The activity choices were torches, crayons, colour paddles, cellophane sheets and paper spinning tops. Adults observed the most positive reactions to the spinning tops as the prospect of play was exciting, the kinaesthetic learning in action to initiate the spinning was effective, and students would choose their favourite colour when making them, adding a personalisation to the process. The crayons had the most negative reactions; one student said: "It was boring, I know how to use crayons", implying a lack of stimulation. The colour paddles were the most ergonomic for handling especially compared to the cellophane sheets, and the paddles showed the clearest colour mixing. Most students could predict and demonstrate back to the adults the result of mixing two colours with the paddles, and expressed satisfaction that they understood this concept well. Students gave feedback and voted for the activities they enjoyed the most, using visual voting sheets and sticking dots on them. As a result, the authors included the paddles and spinning tops in the backpack resource, and also the spinning tops in the "Explore at home" booklet. Having a choice of two activities in the backpack for this theme enables people to use the item(s) that best suit their individual learning style, in line with the project's aim of multi-layered approaches.

In later sessions the students were invited to test the bags in the museum and made further modifications. The pupils tested different styles of bags and unanimously voted for a backpack instead of a shoulder bag, for its comfort whilst walking around the museum. The girls liked the cloth shoulder bags but boys didn't like these at all and said they looked like shopping bags. In choosing the pouches to hold specific activity materials within the backpack, students preferred the drawstring style pouches which were familiar in their similarity to their swimming kit bags, rather than zip bags which the authors had originally assumed would be easier to open.

Instruction cards were also shared to gather feedback and direct inputs on the language, vocabulary and images from the students. The students asked for a larger font size and shorter sections or paragraphs of text, which was implemented. Students liked the symbols next to the written instructions which helped those who struggle with reading. The final backpack is shown in Figure 3.

3.3.2 Explore at home booklet

The complementary "Explore at home" science booklet was developed with the 11 students, who annotated draft copies of the booklet themselves or with an adult facilitator. Examples of their comments and the outputs included the following:

- "Amount of text a bit overwhelming for non-readers." The authors reduced the volume of text and split it into shorter sections.

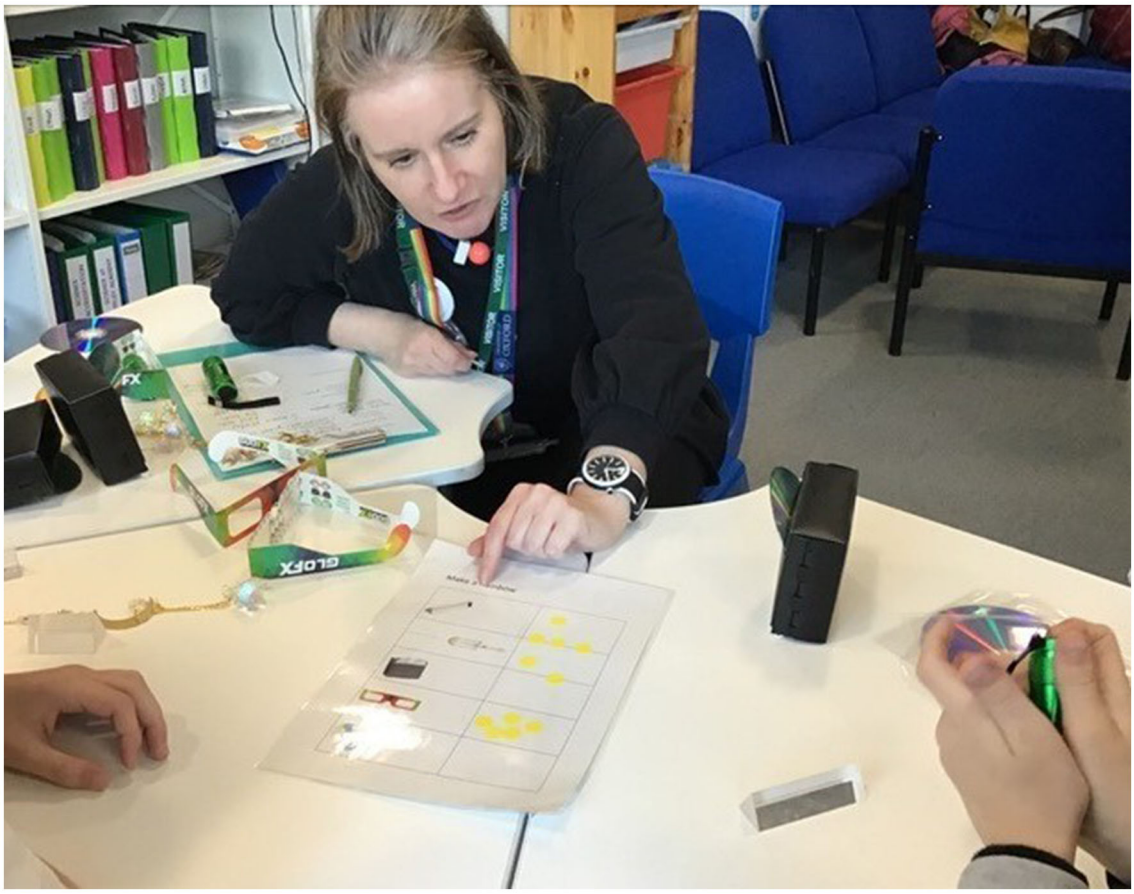

FIGURE 1
Miranda Millward helping Iffley Academy students explore and vote for their preferred activities to make rainbows.

- Specific vocabulary changes to make it easier to understand images of space hardware. One caption changed from "Artist impression of the Ariel telescope. Light is being focused down the mirror." to "Artist drawing of the Ariel telescope. Light from objects in space is collected on the mirror."
- Students found background branding designs distracting so these were removed to make the presentation less complex visually.
- Specific images labelled by students were enlarged to enhance details and support those with visual impairments.

The students were very engaged and asked to take home the draft copies that day because they felt they could do the activities shown in the booklet themselves. When referring to the materials one student said: "This is good. We could do this at home—we have all of the things." The teacher commented: "Makes science accessible for all. Lots of our parents would not be able to do this independently so this booklet is hugely enabling for family activities." The booklets were updated with the students' inputs, published and distributed for free to all Iffley Academy students and their families, HSM visitors, and families attending public days at RAL Space.

In the last consultations, the teams trialled materials for the science outreach show. Figure 4 shows a moment of the resulting interactive show at a public open day on Harwell Campus where RAL Space is based, with Helen as the magician, and Elin (not shown) as the scientist.

4 Evaluation

The partners followed consistent metrics to evaluate the impacts on end users, and how the co-creation process influenced the Iffley Academy pupils. The participant outcomes and the feedback methods were based on best practice guidance from STFC's Evaluation Framework (STFC, 2025). Namely, the outcomes focus on aiming to inspire young people with science and open up further opportunities in STEM, rather than explicitly raising participants' scientific or technical knowledge.

4.1 Impact on advisory class

To assess the impact of taking part in the resource development project on the 11 students in the consulting class at Iffley Academy, the authors asked the class teachers to report back "Yes" or "No" on

FIGURE 2
Vicky Hall trialling colour filters with Iffley Academy students.

the number of students who achieved the following outcomes after the final session:

- Explored key science concepts
- Felt inspired to learn more about science
- Understood how science can be found in the world around them
- Developed questioning skills
- Valued being asked for their views on the resources.

The teachers' observations were valuable to overcome communication barriers with some students, and therefore provided overall fair feedback across the class. At least 70% of these pupils achieved all the outcomes, indicating that it was a beneficial co-creation process.

4.2 Impact on end users

Once produced, the backpacks, booklet and the outreach show were issued for use at public events at HSM and RAL Space and have reached 742 people at the time of writing.

Pictorial postcards were used to assess the use of backpacks in the museum; they could be completed by one family member on behalf of the group, making it easier to share feedback, overcoming potential communication barriers for young people with SEND. An example is shown in Figure 5. Visitors were a mix of general public and the feedback postcard asked whether they enjoyed using the backpack and learning about science via circling varying levels of sad or happy faces. There was an open comment box, and people were asked to self-identify how many in their family/group had any type of SEND. In this evaluation, 97% of all

FIGURE 3
The final backpack design with some of the constituent materials.

families enjoyed using the backpacks in the museum, and 97% of the subset of families specifically with a SEND member enjoyed them. This equal proportion suggests that the backpacks are truly accessible to the intended audience. One parent commented: "It was wonderful to have physical objects the kids could use and interact with the exhibits. My older son really enjoyed the mini microscope, and as a child with ADHD & autism, this worked really well."

At the public open day with RAL Space in June 2024, 117 families watched the "Science and Magic" show (shown in Figure 4) and were asked to complete a feedback postcard. 50% of families had a member with SEND. All the surveyed families enjoyed both the show and learning about science, and 92% of them wanted to continue learning by taking home the supplementary booklet. The multi-layered approach of engaging young people with science via multiple adapted formats and involving their families was successful in this project.

5 Discussion

5.1 The heterogeneity of SEND

The papers featured in the first volume of this research topic focus largely on physical and sensory disabilities, specifically deafness and hearing disabilities, blindness and visual disabilities (Ferreira et al., 2023; García-Terceño et al., 2023; Fernandes and Norberto Rocha, 2022). This project focused on working with, and creating resources for, young people with mixed needs across SEND as defined in Section 1.1, who have some physical or sensory disabilities but primarily moderate cognition and learning disabilities, Autistic Spectrum Conditions and/or Social, Emotional or Mental Health Difficulties. These can be considered as invisible disabilities and emphasise the heterogeneity of people with SEND (Norberto Rocha and de Abreu, 2024). Autism is a particularly broad category: its conceptualisation has evolved over decades from a narrow definition to a much wider diagnostic criteria which recognises the co-existence of many conditions (Happe and Frith, 2020).

Within the small group of consulting students in this project, there was a range of reading abilities, communication, interaction, cognitive, physical and sensory needs. This had implications for the strategies the authors used to gather feedback and authentic insights from the students. In contrast to other types of consultations with groups with different disabilities, written feedback or online forms would not have been appropriate for the 11 advisory students. Personal interaction and allowing opportunities for the students to build trust with the project team over an extended period of time was key.

FIGURE 4
Helen Pooley performing the Science and Magic show at a public open day; role playing as a magician and revealing magic tricks that are explained by science. Photo consent was obtained from the audience members. Credit: STFC.

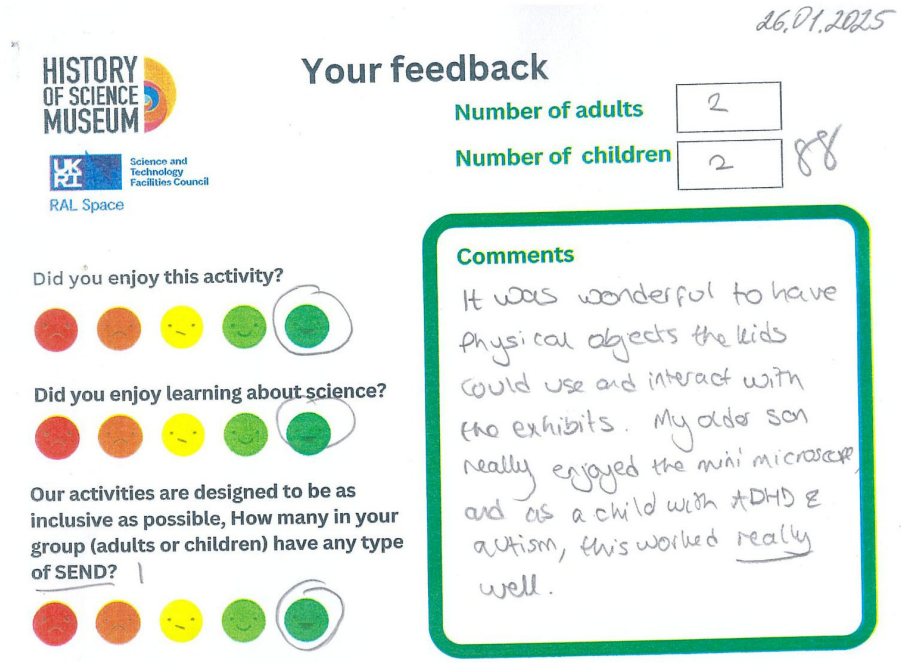

FIGURE 5
Pictorial postcards used for backpack evaluation in the museum.

5.2 Creating layers of accessibility

A key objective of the school sessions was to understand the varied student needs better, so that the authors could find ways to create layers of accessibility and experiences for young people wanting to engage with science. A multi-layered approach enables a range of valid outcomes, rather than one set method which can cause frustration and disengagement from activities.

This was important in the backpack development. The consultations helped the authors understand what would be a good range of activities to include. In general, the approach was to pair a more immediately accessible activity alongside one that was less obvious. For example, a pair of refracting rainbow eyeglasses allowed a user-friendly outcome to experience diffraction of light as mini-rainbows by wearing the glasses, alongside an acrylic prism with a torch, requiring more focused experimentation to split the light. This allows for an immediate sensory engagement that is relevant to the topic and allows for a deeper dive into more complex concepts. Both engagements are equally valid.

The text on the activity cards was also layered, with short instructions paired with pictograms on the front of the card, and a slightly more detailed explanation about space science and how it related to the activity on the back. While the explanations and concepts were curriculum-linked, the text and images assumed no prior knowledge of key science concepts.

While the backpacks were developed with secondary school children with SEND, they were intended to be used by general family groups visiting the museum i.e., multigenerational groups of adults and children, with and without SEND. HSM staff and volunteers who issued the backpacks to families had informal conversations with visitors and made observations that the hands-on experimental nature of the activities worked well for a range of children, from 5 years old upwards, as observed by volunteers and museum staff. The backpacks were therefore marketed generally to family visitors, and not specifically for families with SEND-members or children of certain ages.

Adult members of visiting groups were able to take on the role that the volunteer explainer (a museum staff member) might take in informal learning contexts, including travelling science centres (Ferreira et al., 2023). Parents/Guardians/Carers are vital to support personal interpretation of the activity for specific needs of their children with SEND. In this context, the instruction cards in the backpack acted as an aid for adults to engage with the science without needing specific prior scientific knowledge. These cards could be used directly by the young person with SEND and/or be a foundation for the adults to then facilitate relevant interpretations for that young person. Likewise, the "Explore at home" booklet provided a framework for adults supporting their children doing experiments at home, as a follow-on from museum activities or the "Science and Magic" show.

5.3 Funding for SEND activities

A notable theme in the first volume of this research topic is the issue of funding activity programmes for SEND in museums. In writing about Egyptian museums, Zakaria noted that there was "considerable evidence" in the responses received by those interviewed of "very confined financial resources in practising inclusive programmes for PWDs," with many free programmes operating on a short-term basis (Zakaria, 2023). This is in contrast to longer-term Egyptian programmes that were available year-round and were charged. Whilst in Brazil, it has been noted that many of the travelling science centres are initiatives created by universities or public institutions that "have a very tight budget" (Ferreira et al., 2023).

This project benefited from two external grants; the first for the initial pilot from the Royal Society (a registered UK charity with an interest in increasing diversity in science, technology, engineering and mathematics) and the second larger grant from STFC, a non-departmental government body. These grants allowed the backpacks, the show and the booklet to be accessed free of charge by families. Without these funding sources it would not have been possible to create such high-quality resources.

In addition, the museum trained a team of volunteers who administer lending the backpacks to families. STFC funds permanent public engagement professionals, engagement training for early career staff, and facilitates volunteers to take part in outreach through STEM Learning's national STEM Ambassador programme[6]. This systemic support enables high quality, inclusive engagement activities (Terry, 2023).

With many SEND children and their families suffering disproportionate financial disadvantage, free, year-round access to informal learning resources was an important aspect of the project. The backpacks are available at monthly autism-friendly openings, should families prefer to visit during quieter times. The resources are also available to RAL Space for their public open days, training, and advocating for public engagement.

The collaboration presented here has had significant benefits for all partners in learning from each other's expertise, creating greater capacity to engage students with SEND, producing better resources that address the above challenges, helping pupils raise their confidence and attitudes towards science, and building lasting equitable relationships that have led to more projects and sustained a cycle of more opportunities for SEND children to engage with science.

6 Conceptual and methodological constraints

There were many advantages of working with a specialist school: the children knew each other; they had a trusted adult in the form of a teacher who supported science learning and encouraged children to express themselves; the authors were able to meet in the familiar surroundings of school; there was continuity of attendance; and the small class size allowed for in-depth engagement and relationship development. There would have been difficulties in establishing a new group of families with complex special educational needs including autism, due to the likely anxiety of visiting a new venue and inability to commit to regular meetings outside school hours.

6 https://www.stem.org.uk/stem-ambassadors

There were also disadvantages: the small class size meant that they weren't necessarily representative of the entire range of needs in that school, let alone in the wider community. Although some students had issues with their fine motor skills, generally this cohort did not have physical disabilities and they could verbally articulate their views. If some students were wheelchair users for example, this might have influenced the consultation and final outputs. Evaluating the impact on the advisory students also missed potential insights from their parents or carers outside of school.

The authors started this project mindful that the resources may be used in a different way by families at the museum and outreach events to the way they would be used in a school setting. However, the aim was to learn what activities engaged the children and how, to get a better sense of what the young people could engage with independently and where they might need adult support, and therefore improve supplementary instruction cards. Once the backpacks were created, they were then tested with families who were invited via open invitation to trial them in the museum. Future funding could potentially enable more feedback from families to be incorporated into the backpack contents.

Creating the resources was an important step towards developing an inclusive informal learning approach by the partners. However, they need to be seen as part of a long-term strategy to make spaces welcoming for all visitors, including raising awareness of available resources. For example, through social media sites, newsletters and websites that families of children with SEND frequent. In 2019, Ecclesiastical published the results of a survey of UK museum visitors; 42% of parents with a SEND child said they had been made to feel unwelcome by staff members or other visitors (Ecclesiastical, 2019). Although it was not originally planned, training HSM volunteers who worked with the backpacks to understand the needs of visitors with SEND was an important part of making this project successful. Staff training should be "a museum-wide commitment to ensure access and inclusion to all on an equal basis" (Zakaria, 2023). In future project applications this would be a core aim for HSM.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the studies involving humans. The studies were conducted in accordance with the local legislation and institutional requirements. The Ethics Committee of the University of Oxford waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because the study is public engagement rather than research. Written informed consent was obtained from the individual(s) for the publication of any identifiable images or data included in this article.

Author contributions

HP: Resources, Data curation, Project administration, Conceptualisation, Writing – review & editing, Methodology, Writing – original draft, Funding acquisition. MM: Writing – review & editing, Methodology, Writing – original draft, Resources. VH: Resources, Writing – review & editing, Writing – original draft, Data curation. EM: Conceptualisation, Writing – original draft, Funding acquisition, Writing – review & editing, Resources.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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