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Someone Like Me: A Trial of Context-Responsive Science as a Mechanism to Promote Inclusion

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This paper provides evidence gathered from two suites of non-formal science activities that were intended to increase engagement in science by culturally diverse groups. Both studies involved the delivery of science activities that were designed, implemented and evaluated to show culturally contextualised science. The activities were run in two very different contexts (urban and very rural areas) and were designed to be of relevance to two distinctive cultural groups (those with links to South Asia, and those being educated through the medium of Gaelic, an indigenous minority language in Scotland), while also actively engaging with those beyond the target group. The link between language identity and culture was incorporated into the design of both sets of activities as well as the qualitative evaluation. The latter considers how the participants' assessment of the interventions, implemented by writing or drawing on a blank postcard, was designed to provide unstructured responses and explores what the resulting data revealed about the impact of the interventions. The findings suggest that the set of activities that most strongly engaged participants on the value of diversity in the creation of scientific knowledge, as well as increasing their focus on the consequences of scientific activity, were those that facilitated a more exploratory approach to the subject matter. By contrast, activities that had to be done according to a standard scientific protocol produced growth in subject-specific knowledge. The present paper explores the principles of the inclusive pedagogies that informed the design of the activities and discusses how these were operationalised in two very contrasting cultural contexts. The key finding was that presenting science as social practice, rather than as being socially neutral, is key to promoting engagement, along with the benefits of explicitly demonstrating the relevance of science to participants' daily lives.

Keywords: inclusion, equity, culture, diversity, context-based science

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Nekdo kot jaz: preizkus naravoslovja, prilagojenega kontekstu, kot mehanizem za spodbujanje inkluzije

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V prispevku so predstavljeni dokazi, zbrani na podlagi dveh sklopov neformalnih naravoslovnih dejavnosti, katerih namen je bil povečati vključenost kulturno raznolikih skupin v naravoslovje. Obe študiji sta vključevali izvajanje naravoslovnih dejavnosti, ki so bile zasnovane, izvedene in ovrednotene tako, da so prikazovale naravoslovje, kontekstualizirano s kulturo. Dejavnosti so se izvajale v dveh zelo različnih okoljih (mestna in podeželska območja) in so bile zasnovane tako, da so bile pomembne za dve različni kulturni skupini (člani prve imajo vezi z južno Azijo, člani druge skupine pa se izobražujejo v gelščini, jeziku avtohtone manjšine na Škotskem), hkrati pa so aktivno vključevale tudi osebe zunaj ciljne skupine. Povezava med jezikovno identiteto in kulturo je bila vključena v zasnovo obeh sklopov dejavnosti pa tudi v kvalitativno vrednotenje. Zadnje obravnava, kako so udeleženci ocenjevali intervencije, ki so jih izvajali s pisanjem ali z risanjem na prazno razglednico, in kako so bili zasnovani za zagotavljanje nestrukturiranih odgovorov, ter raziskuje, kaj so pridobljeni podatki razkrili o učinku intervencij. Rezultati kažejo, da je bil sklop dejavnosti, ki je udeležence najmočneje pritegnil k razmišljanju o vrednosti raznolikosti pri ustvarjanju naravoslovnega znanja in povečal njihovo osredinjenost na posledice naravoslovne dejavnosti, tisti, ki je omogočal bolj raziskovalen pristop k predmetu. Nasprotno pa so dejavnosti, ki jih je bilo treba izvajati skladno s standardnim znanstvenim protokolom, povzročile rast znanja o posameznem predmetu. V tem prispevku so raziskana načela inkluzivne pedagogike, ki so bila podlaga za oblikovanje dejavnosti, v prispevku pa obravnavamo tudi, kako so se ta načela izvajala v dveh zelo kontrastnih kulturnih okoljih. Ključna ugotovitev je bila, da je za spodbujanje sodelovanja udeležencev ključnega pomena predstaviti naravoslovje kot družbeno in ne družbeno nevtralno prakso ter da je koristno izrecno prikazati pomen naravoslovja za vsakdanje življenje udeležencev.

Ključne besede: inkluzija; pravičnost; kultura; raznolikost; naravoslovje, ki temelji na kontekstu

Introduction

In Scotland, one of the four nations of the UK and the location of the reported study, the devolved government has had a strong focus on promoting STEM for all pupils. Despite this, concerns persist about recruitment to professional STEM pathways, overshadowing the importance of STEM for citizenship or socialisation (Scottish Government, 2017). The agenda to recruit professional scientists tends to understand science as a neutral and objective study of the natural world, set apart from the cultural environment in which it is practised. Paradoxically, while upholding the cultural neutrality of science, policy drivers may, unintentionally, prevent the equitable distribution of the benefits of STEM learning across the population. The present study considered whether presenting science as an activity intimately connected to its cultural context could enhance the engagement of groups who are currently under-represented in science. The intention was to achieve educational inclusion, as defined in the paper, as well as to meet the stated intention of Scottish education policy that every child should be 'present, participating and succeeding' (Scottish Government, 2019).

At present, there is a sad litany of groups who are under-represented in STEM or, more accurately, minoritised by the culture and practices of STEM (Campaign for Science and Education, 2016). Characteristics associated with disproportionately low uptake in STEM in the post-compulsory phases of education and in the STEM workplace provide the best indicator we currently have for those at risk of disaffection from science more generally. Evidence identifies that those with a below average engagement with STEM include those living in conditions of socioeconomic deprivation, those with disabilities, those whose first language is other than the dominant language of instruction, LGBTQ+ people, young carers, and those in remote geographical areas, as well as with intersecting combinations of such characteristics (All-Party Parliamentary Group, 2020). Other characteristics result in a more nuanced picture of exclusion, giving variable outcomes for people of colour depending on the precise ethnic identity, while gender is disadvantageous in different ways across different STEM disciplines (Campaign for Science and Education, 2016).One factor that recurs through studies of why these disparate groups are alienated from science and other STEM subjects is the discrepancy between their personal cultural identity and that which they associate with the pursuit of science (Archer et al., 2020; Asbacher et al., 2010; Vincent-Ruz & Schunn, 2018). The study that is reported here considers two interventions that sought to actively include participants who are culturally diverse: one case linked to ethnicity and the other to linguistic heterogeneity.

Inclusive education as aspiration and practice

Inclusion is commonly viewed in the UK as an approach to education that seeks to address the educational needs of children with disabilities within existing educational structures. This 'shorthand' view of diversity and inclusion may well arise from the fact that children with disabilities were legally excluded from standard state educational provision and educated in segregated settings (or not at all, in some cases) until well into the twentieth century in both Scotland and the rest of the UK. While disability may have been a proving ground for teachers' notions of differences and otherness, the list of characteristics set out in the introduction reminds us that difference takes many forms. Initially, as further diversity characteristics were understood to be associated with differing educational achievement, different pedagogical strategies were devised for the different categories of difference. The Swan Report (Committee of Enquiry into the Education of Children from Ethnic Minority Groups, 1985), for instance, was a response to the scholastic under-achievement of children of colour whose parents had arrived in the UK after World War Two. However, rather than a raft of different forms of inclusion, growing awareness of the complexities of educational identity has resulted in a more holistic notion of inclusion, as expressed in UNICEF's (n.d.) definition:

> Inclusive education allows students of all backgrounds to learn and grow side by side, to the benefit of all.

Accompanying this, a newer notion of inclusion has seen a shift away from deficit thinking about diversity towards asset-based practices and consideration of how we can make a shared learning environment conducive to optimal learning by all. Success with such an approach has previously been reported in careers guidance (Drobnič, 2023) and might be expected to have a comparable impact in orientating young people towards science. The transformation has wrought a reconsideration of how diversity can enrich learning, rather than presenting a barrier to curriculum delivery (Göransson & Nilholm, 2014). However, the reality in the UK differs markedly from this aspiration. In many places, provision is very granular, with different school types serving young people with different characteristics. Even in Scotland, where education in the neighbourhood school is the presumed option (Scottish Government web site), STEM subjects are not equally taken up, despite being universally available. This raises questions about the ways in which STEM is especially exclusionary. The answer may lie deep within the culture of STEM, much of which springs from historical legacies that are no longer visible but have conferred an enduring pattern of thinking, practices and values regarding STEM subjects. To render science education genuinely inclusive, current practices and assumptions need to be subject to critical scrutiny in such a way as to dismantle the barriers that are embedded within them. This includes the remoteness of science from everyday practices in the home and community, the paucity of diverse role models, the use of unfamiliar terms and apparatus, and the notion that only controlled experimentation can produce valid findings (Essex, 2023). The repositioning of science as social knowledge could, conversely, be expected to enhance its accessibility to learners from a wide range of cultures.

Cultural diversity in science

Science could justifiably be described as having its own distinctive culture if we adopt a sociological definition of culture. This describes culture as being the values, beliefs, practices, language and communication that people share as a result of learning. It also includes the artefacts associated with their shared ways of thinking (Hall et al., 2003). Science clearly meets this definition in that it shares beliefs, some of which are foundational, including the belief that natural phenomena are subject to verifiable physical laws. Scientists also generally share the belief that ideas should be verifiable by controlled experimentation, and they communicate their work using a shared technical vocabulary, formulae and diagrams. Their artefacts are the very similar scientific instruments they use to conduct their experiments. Furthermore, treating science as a culture has enabled researchers to explore how it confers 'capital' in the Bourdieusian sense, that is, the power to make choices and achieve self-advancement (Archer et al., 2020) in the way that Bourdieu described 'cultural capital' operating in wider society.

The agency that capital confers on its possessor is not, however, of universal value, but is dependent on the cultural environment in which the possessor finds themselves. This is the mechanism by which children who have had prior exposure to culture that is considered desirable at school find that they already have knowledge that is favoured in the school environment. Bourdieu considered this to be the mechanism whereby school sustains existing class inequalities (Bourdieu, 1984). The same mechanism is applicable when the impact of science capital is analysed. Children who come from home lives where science is used, talked about and valued, those who engage in scientific activities during their leisure time, are found to do well in science and to choose to pursue it after it ceases to be a compulsory school subject (Archer et al., 2020). One of the key recommendations to arise from Archer et al.'s work is that teachers need to portray science not as something separate from pupils' everyday life, but as something relevant to it. Such endeavours could be interpreted as a renewed attempt to bridge 'two cultures' (Snow, 1959). As Reingold and Zamir (2017) note, despite the pressing need for such cultural mediation, there is far more said in policy than is known about successful practical implementation.

The need for conscious mediation between the culture of science and the 'popular' cultures of pupils' everyday lives is important for its uptake. School science has a history as an elitist subject, available only to people attending schools that were selective based on academic attainment and, very frequently, based on coming from a family that could pay large fees for school attendance (Jenkins, 1979). The fees enabled the provision of specialist laboratory facilities for science and the recruitment of highly educated teachers, who presented a curriculum that was abstract and very intellectually demanding. The same teachers were over-represented in organisations that have come to define what science education ought to be (Jenkins, 2013), such as the Association for Science Education. Ultimately, an elite minority have made their own, very particular version of science synonymous with the entire subject. Their legacy is a subject that is commonly perceived as 'hard' and 'male, pale and stale' (Chambers, 1983; Finson et al., 1995), and that has not responded in a timely manner to the ever more diverse nature of learners in science classrooms (All-Party Parliamentary Group, 2020). 'Draw-a-scientist' methodologies show repeatedly that young people see scientists as someone not like them, in that they are older, only one gender and only one ethnicity. They are also commonly depicted as 'mad', secretive, engaging in dangerous activities and exceptionally clever (Chambers 1983; Finson et al., 1995). Other researchers describe the frequency with which scientists are perceived as different, often cleverer than them (Osborne et al., 2010). Children's notions of scientists as people very different from themselves are accompanied by ideas about the strangeness of what they do, how they do it and the objects they use. This contrasts sharply with 'folk science' or 'naïve science', which relates to familiar, everyday objects and phenomena (Champagne et al., 1983). The combination of these factors makes formal science seem culturally alien to many young people.

Inclusive science pedagogy

Attempts to enact inclusion in pedagogy quicky become mired in conflicting performativity pressures to which science, as a 'gatekeeper' subject, is especially prone. Such efforts are also hampered by the tendency of school systems to view diversity as an administrative challenge and a drain on resources

(Essex et al., 2019). The fear of diminishing attainment by promoting inclusion is a common fallacy, despite evidence to the contrary (Palid et al., 2023). The common result is a tokenistic reference to different cultures, which may succeed only in 'othering' minority groups (Alexiadou & Essex, 2015). Gibson (2015, p. 2) notes that this leads to a situation in which "[i]nclusion becomes about attempts to induct that which is 'different' into already established forms and dominant institutional cultures". However, full inclusion would seek not to subsume a minority culture into the hegemonic culture, but to actively incorporate diverse positions as valuable assets for everyone.

Mensah and Larson (2017) posit six approaches to (culturally) inclusive pedagogy. They call for culturally relevant, culturally responsive, culturally congruent and culturally sustaining science education for both teachers and students. They also advocate the intentional deployment of the 'funds of knowledge' that students bring in from beyond the classroom and, aligned to this, they encourage the use of the 'third space', that is, places that are neither school nor home, for the elicitation of such knowledge. These approaches all affirm cultural identities and draw upon them in the creation of scientific knowledge, emphatically rejecting any notions of inadequacy amongst the marginalised. Similarly, Cobian et al. (2024) advocate the centring of cultural identity in STEM undergraduate programmes. Evidence of the practical difficulties in implementing these changes in practice is provided by Underwood and Mensah (2018), whose interviews with science teacher educators indicate a recognition of the imperative to enact culturally responsive pedagogies, but, at the same time, reveal a lack of knowledge of how this might be carried out in practice. The strategies are intended to show science education to be much more than the transmission of objective facts and to include the development of critical insights into how science has been practised and used. However, Cobian et al. (2024) caution that systematic changes in the support and climate in educational spaces are needed alongside curriculum and pedagogic reform if uptake is to be diversified. One under-acknowledged source of support for minoritised students who persevere with science is their community, and initiatives that enable community members to contribute to teaching are a powerful source of affirmation (Aschbacher et al., 2010).

The characteristics of inclusive pedagogy can be summarised in the following framework, based on work by Pomeroy (1994) and updated in the light of evidence that has been published since its inception (Essex, 2023). Note that this framework is designed to ensure optimal learning by all pupils, irrespective of individual characteristics, but it is certainly applicable to culturally diversity populations.

1. Relevant

The importance of showing science as something that impacts upon learners' daily lives has been established by various context-based science courses. Although the academic gains are commonly not large, there are marked improvements in attitudes towards science and there is evidence of a reduction in the gap between groups in this regard by enhancing the positive views of the group that had been previously less enthusiastic about science (Bennett et al., 2007). It is important, however, that the contexts and applications of science are shown in a diverse way, so that a 'male, stale and pale' image of people to whom science matters is not perpetuated. Another aspect of making science relevant is the deployment of multi-modal resources, including hands-on and sensory exploration, different types of images, speech, written texts and a range of digital media. A further pedagogic consideration is the deployment of a range of teaching and learning strategies, including group work. This enables pupils to draw on their personal knowledge and to have it validated.

2. Free from prejudice and respectful of diverse responses

Inclusive pedagogy must, of necessity, start from the position that everyone has both the capacity to learn and the capacity to contribute. This requires teachers to challenge any barriers created by low expectations and negative stereotyping. In this environment, diversity is seen as a resource to be valued, rather than a problem to be corrected (Rapp & Corral-Granados, 2021). Critically challenging structural barriers to the fair treatment of everyone is an important aspect of actively countering prejudice. By showing how inequalities in power have enabled science to become a exclusionary undertaking, we equip our young people to re-evaluate their ideas about what science is and who has made valuable but unacknowledged contributions.

3. The three R's: reflective, reflexive and responsive

Teacher disposition is at the heart of inclusive teaching, although many teachers continue to see inclusion as a question of resourcing or the acquisition of specialist techniques (Alexiadou & Essex, 2015). The tendency to locate difficulties associated with inclusion in the diverse pupil perpetuates a deficiency model of diversity. The most effective teachers have been found to be those who take responsibility for the learning in their classrooms and demonstrate reflexion, that is, they recognise their role in the events that unfold. They incorporate this awareness of their own impact in an ongoing cycle of observation of pupils during lessons, reflection on the outcomes of lessons and, in response to the insights derived from this, revise future teaching as indicated (European Agency for Development in Special Needs Education, 2012).

4. **Constructed to offer diverse pathways to success**

One of the fundamental pedagogic shifts that has taken place in response to the increasingly diverse pupil population is the shift away from a single learning pathway that all pupils will follow in an identical manner. It is now expected that there will be multiple ways to undertake an expected piece of learning, providing challenge alongside support, as needed. Support may be required with language, whether this is because pupils customarily use other languages than the one of school instruction, or whether it is due to unfamiliarity with technical vocabulary and unfamiliar apparatus. Ensuring that all learners can both understand and contribute to the learning constitutes testimonial epistemic justice (Fricker, 2007), which must be a primary aim of inclusive education. Another crucial consideration is the need to allow sufficient time for the repetition and reflection that give rise to deep learning (Bruner, 1966). In the case of science, which is commonly presented as a content-rich subject (Hirsch, 1996) that requires children to learn facts, emphasising science as an approach may be a helpful way to reconceptualise success. This provides the learner with the chance to tackle problems in a scientific manner and removes anxiety about knowing the right answer.

Research aims

The present study was constructed to evaluate the impact of intentionally culturally inclusive science activities on young people's responses to such activities. The work was designed to answer the following research questions:

1. To what extent do intentionally inclusive science activities successfully convey the intended scientific concepts?
2. Do intentionally inclusive science activities alter young people's ideas about science?

Method

Participants

Three plant science activities were run in two Scottish botanic gardens and at two science festivals, where participants included families and social groups as well as school groups of pupils and their teachers. The venues were selected because of their location and because the places where the activities were being conducted could reasonably be expected to attract culturally diverse visitors. The sampling was random, as it depended on the decision of adults to visit the gardens or festivals. The participants chose how long they wished to spend on the activities and the time spent varied from a few minutes to half an hour.

The second set of activities comprised forensic science tests devised to appeal to schools educating children through the medium of Gaelic, the majority of which are based in the rural northwest of Scotland and islands to the west of that. Gaelic is commonly presented in popular media as a language linked to a historic past, but not as a modern language of the twenty-first century (Dumore, 2017). For this reason, the research team was interested to know whether that stereotype could be challenged by the presentation of modern analytical techniques and materials in the medium of Gaelic. Sampling was purposive, in that all of the schools in the target area were contacted. However, access to the young people was by the agreement of the teachers in the schools.

Instruments

The evaluation process was approved by the University of Strathclyde's School of Education Ethics Committee before data gathering began. In order to be as inclusive as possible, designing evaluation tools that were equally inclusive was integral to the design of the activities. The same format of data gathering instrument was used in both sets of activities, with appropriate minor modifications to make it relevant to the set of activities to which it related. To that end, postcards were used that asked the young people who took part in the interventions to write or draw their ideas about plant science or forensic science before doing the activities, and then again afterwards (Ross et al., 2023; Ross, 2023). The question at the top of the postcard was 'What do you think about when you hear the words plant science/forensic science?'. On the back of the postcard, to be filled in after doing the activities, was the question, 'What do you <u>now</u> think about when you hear the word plant science (or forensic science)?' The postcards were available in English and the sixteen community languages in use in Scotland: Arabic, French, Finnish, Gaelic, German, Greek, Italian, Malay, Maltese, Polish, Romanian, Russian, Urdu, Pashto, Sinhalese and Welsh. Translations into all of these languages had been obtained by asking members of a public engagement group who knew languages other than English, and participants could choose to use whichever version of the evaluation card they wanted. Skin-tone crayons were provided to enable participants to represent people of diverse ethnicities in their drawings. In addition, a ten-item questionnaire was created on a secure web area and a QR code to access this was shared with participating adult members of the public and teachers accompanying the young people, based on the Dimensions of Attitudes towards Science survey instrument (Wendt & Rockinson-Szapkiw, 2018). Finally, field notes were written at the end of each session and noteworthy comments made by the participants were recorded in the notes.

The questionnaire administered to teachers and accompanying adults at both sets of activities contained the following questions and statements:

Q1 I think that science education is essential for helping children and young people become more involved with society's problems.

Q2 I enjoy teaching science

Q3 Which subjects do you think that your children and young people like best?

Q4 In what ways or contexts do you think they recognise the importance of science in their daily lives?

Q5 What jobs do you think your children and young people aspire to do?

Q6 How many people do your children and young people know who use science in their job? Who are they and what jobs do they do?

Q7 Do your children and young people find science interesting?

Q8 Do your children and young people find science hard?

Q9 Do you think that the sort of science you teach in school/youth group is the same as what real scientists do?

Q10 Do your children and young people think they could make a new scientific discovery?

Science activities

Two sets of science activities were devised, informed by the principles of inclusive pedagogy, especially those of Menson and Larson (2017). The activities were intended to model culturally responsive approaches relevant to two cultural groups who appear to be under-represented in the media of science education, and who may therefore feel alienated from science.

The first set of activities related to the interconnections between Scottish plant scientists and those of South Asia, with the intention of engaging people who had links to, or were interested in, South Asia. The activities were informed by ideas of 'decolonising the curriculum' and considering the power imbalances that made it possible for northern hemisphere travellers to exploit the people and natural resources of the southern hemisphere, including its plants (Begum & Saini, 2019). Most importantly, however, there was no suggestion that the activities were only for those of South Asian heritage. This suite contained three activities:

1. A sniff and match activity, in which visitors were asked to match whole spices to processed spice; for example, matching whole cloves to clove oil by smell. This activity was accompanied by conversations about the parts of the plants that gave us spices, the evolutionary origin of spices and the biological activity as well as chemical composition.
2. A 'junk modelling' activity in which visitors were asked to build a plant carrying case suitable for carrying specimens (a piece of sprouting ginger rhizome, coriander seeds and saffron crocus bulb) on a ship for six months, as the eighteenth-century explorers had to. The activity was accompanied by a discussion about the impact of advances in technology to transport plants on local and global economies and a conversation about the lives of some Scottish and South Asian plant scientists, for whom an accompanying set of short biographies were provided.
3. A cyanotype (blue printing) activity in which visitors were asked to use letters, negative images of plant scientists from Scotland and South Asia, and pressed South Asian plant specimens to create an image showing what they had learned.

The second suite of four activities comprised a set of forensic activities designed to enable participants to deduce who had dumped litter, resulting in the death of a rare seabird that had ingested the litter. The context was chosen to be of relevance to children in places where ecotourism involving observing wildlife is essential to the local economy. The associated worksheets, casts of shoe prints, photographs of evidence, labels on experimental apparatus and reagents used by the pupils were written in Gaelic and a supporting vocabulary list was provided for teachers with Gaelic-English translations of all of the technical terms to assist its use with pupils who were not proficient Gaelic speakers. The context of the analysis concerned a puffin that had been found dead, with the death being attributable to the bird having eaten plastic items among litter that had been illegally dumped on a beach. The importance of ecotourism in rural parts of Scotland was intended to make the problem relevant to the young people.

The evidence that was presented were footprints from the crime scene, fingerprints and a (synthetic) blood sample recovered from items in the bag of rubbish, as well as DNA profiles from blood and hairs found at the crime scene. These were compared to those of three suspects, whose data was provided. The activities followed on sequentially, although they were not all offered to all participants, depending on the ages of the children. The sequential nature of the activities required them to be carried out in an ordered way. This contrasted with the first suite of activities, each of which was 'standalone' and so permitted participants to do the activities in any order they chose or to omit activities completely if they wished to. The forensic science activities were run in schools in the northwest of Scotland, where teachers were able to observe the resources being used with their pupils. The sessions lasted between 40 and 60 minutes. In addition, three professional development sessions were run online for teachers to support them in the use of the forensic kits. Although the activities were different in the second group, basic demographic data captured on the evaluation cards indicated that the age profiles of the participants were similar to those who engaged with the first set of activities.

Research Design

The data processing took the form of a compilation of the quantitative data generated by Likert scales associated with some of the questions and statements in the questionnaire given to teachers and other adults. The answers to the open-ended questions on both the questionnaire and the postcards were subject to thematic analysis in the following stages. Firstly, the two sets of data were coded separately, that is, terms, phrases or images with shared meaning (though not necessarily the same words) were assigned a common code (Braun & Clarke, 2006).

The use of the postcards is illustrated by the following example. One completed postcard depicted the outline of a body on the floor, a microscope and the phrase 'DNA'. The outline of the body and the microscope were judged to be about the scientific process specific to the context of forensic science, while the DNA was judged to be factual knowledge specific to the activity. Afterwards, the same participant provided a bullet point list setting out materials relevant to the activities they had done. The list comprised blood, hair, DNA and fingerprint. Initially reflecting repeatedly upon the very disparate data gave rise to lower order codes, such as forensic science process and forensic science reagents. Further reflection gave rise to three high order themes that overarched all of the meanings conveyed by the raw data, of which the lower order themes formed sub-themes. The themes were general epistemology, topic-specific content and the impact of scientific knowledge. The resultant sub-themes and derived themes are shown in the columns headed 'sub-themes' and 'themes' respectively in Table 2.

After analysis of the raw data, the two sets of data were observed to give equivalent sub-themes, which made it possible to compare how they had been received by the participants. Finally, the analysis was compared with field notes and feedback from colleagues who had been present to ensure that the themes fairly represented the reactions of the participants (King, 2004). Once the themes and sub-themes had been agreed, the four data sets (plant science, forensic science; before intervention and after intervention) were analysed separately. A tally was made of the incidence with which the different sub-themes were expressed in the raw data, expressed as a proportion of the total responses, using the formula:

$$\frac{\text{number of responses corresponding to the sub-theme}}{\text{total number of responses}} = \text{proportion of answers referring to the sub-theme}$$

The descriptive statistical approach enabled a comparison to be made of the frequency with which different ideas were expressed before carrying out the activities and identified any shift in thinking due to the intervention.

Results

The data gathered are summarised below.

Table 1

Responses to the questionnaires administered to adults.

Q1 I think that science education is essential for helping children and young people become more involved with society's problems.

Response	Tally
Strongly agree	9
Agree	6
Neutral	
Total	15

Q2 I enjoy teaching science

Response	Tally
Strongly agree	4
Agree	8
Neutral	3

Q3 Which subjects do you think that your children and young people like best?

Subject	Category/number of responses	Number of responses
Practical science	STEM 11	2
Science		4
STEM		3
Mathematics		2
Active learning	Experiential learning 18	4
Practical science		2
PE		5
Art		6
Music		1
Ones that connect to their context	Other 4	1
Health and well-being		1
Reading/literacy		2
Total		**33**

Q4 In what ways or contexts do you think they recognise the importance of science in their daily lives?

Response	Location	Number
Few or none	Not applicable	**4**
Teaching/class discussion	School input	3
Science teaching		2
Hands on experiences		2
	Total	**8**
News	Out of school experience	1
Technology around them		1
Natural world		1
Climate change		1
Media		1
	Total	**5**
	All responses	**17**

Q5 What jobs do you think your children and young people aspire to do?

Job	Category	Responses
Mechanic	STEM related	2
Engineer		1
Builder		1
Distillery work		1
Farming/crofting		2
Engineering		1
Game keeper		1
Work in renewable energy sector		1
Work at NASA		1
Digital media (gamer/You Tuber/influencer/games designer)		5
	Total	**16**
Nurse/doctor	Public sector	5
Teacher		3
Police		1
Firefighter		1
Soldier		1
	Total	**11**
Journalist	Service sector	1
Footballer		3
Hairdresser		1
Young parent		1
Shop assistant		1
Artist		1
	Total	**8**
	All responses	**35**

Table 2

Summary of responses to online questionnaires

		Plant science activities				Forensic science activities			
Theme	**Subtheme**	**Before**	**Proportion of answers**	**After**	**Proportion of answers**	**Before**	**Proportion of answers**	**After**	**Proportion of answers**
Epistemology	Scientific knowledge	17	.18	8	.10	1	.02	0	0
	Scientific process or activities	11	.12	15	.19	15	.30	30	.41
Topic-specific	Location/habitat/ context of science	7	.08	12	.15	9	.18	2	.03
	Factual knowledge, e.g., names of plants or tests and reagents	37	.40	17	.21	11	.22	30	.41
	People who do science	3	.03	6	.08	6	.12	4	.05
	Diversity	0	0	3	.04	0	0	0	0
Impact of knowledge	Utilitarian outcomes	6	.06	17	.21	6	.12	7	.09
	Affective response	11	.12	9	.11	0	0	1	.01
	Total	**92**	**1.00**	**80**	**1.00**	**50**	**1.00**	**74**	**100**

Only eight participants provided drawings as part of their response and those made at the plant science activities were considerably more detailed.

Changes in the participants' thinking were indicated by the changing proportion with which different sub-themes featured in their answers before or after the intervention. The most noticeable shift – brought about by carrying out some or all of the plant science activities – was away from emphasising scientific knowledge towards engaging further with the scientific process. This shift was also reflected in what the participants communicated about the topic under study, with fewer factual comments about plants and more said about the people creating the scientific knowledge. The emphasis on science as a process, rather than a static and unquestionable body of knowledge, enhances accessibility and is a powerful tool for engaging a wider audience (McComas, 1996). There were also increased references to habitat and the interactions between plants and animals. For an intervention designed to explore cultural diversity in science, it was surprising to find only three pieces of data referring explicitly to diversity in the post-intervention data. One possible explanation for this is that asking about what they knew about science signalled that the responses expected would resemble those required for a school science test. The other change shown by the data is a proportionately large increase in awareness of the usefulness of scientific knowledge. This would have been predicted given that the activities focused on food products from plants. Anecdotal evidence recorded in the field notes suggest that the everyday nature of the plant science activities made them accessible. One child exclaimed, 'It smells like Christmas' while sniffing the whole cloves, and many of the participants talked about the dishes they associated with the different spices. There was, however, only one explicit comment on the multilingual postcards, when a primary aged child observed, 'My granny uses this', when they saw the card in Urdu.

The forensic science activities brought about a doubling in focus on the scientific process. Responses regarding the science underpinning the activities showed a large drop in focus on context, a near trebling of the proportion of answers providing factual knowledge, such as the names of tests or reagents, and a reduction in references to the people who do the science. This content-rich form of forensic science may align with pupils' perceptions of school science. There was no reference to linguistic diversity or culture in the feedback. The most common reference to the context of the activities was several comments by teachers about their appreciation that the researchers had visited them in their very rural location, rather than asking them to travel to a centre of population. There was also satisfaction at being given previously translated material, as many Gaelic medium teachers find translating English language resources into

Gaelic very time-consuming. Disappointingly, given that the activity had been chosen as one of direct relevance, by the time the interventions ended there was no change in the participants' recognition of the impact of the knowledge generated by the activities. This was surprising given the literature, which advocates for culturally relevant pedagogy (Aschbacher et al., 2010; Cobian et al., 2024; Mensah & Moore, 2017).

A comparison of the differences between the two sets of activities showed that they both brought about a change in people's thinking about science in general and about the area of science under study. The forensic science activities were especially successful at increasing the participants' awareness of the processes associated with science, but there was also a marked increase in focus on the factual aspects of the activity and a correspondingly reduced focus on the context in which the science was situated.

Discussion

The major factor limiting the gathering of data on impact seems to have been time constraints and the inevitable tension between taking time from science communication activities to leave sufficient time for feedback. The relatively short duration of the interventions also limited the level of impact that the activities could be expected to exert. There was greater detail in the drawings arising from the plant science activities, which were gathered at a public event, where participants were able to take as much time they wanted over the activities and evaluation. Conversely, delivering the forensic science activities in a school setting inevitably meant that the participants had limited time, dictated by their timetable. As described previously, external factors create time pressures that mitigate the desire for truly inclusive pedagogy, which raises major questions about our beliefs regarding what the most important outcomes from education should be.

Similarly, time pressures limited the response rates to the questionnaires. Nevertheless, some trends do appear within the data. As might be expected of staff who volunteered to engage with an additional science activity, they expressed positive views about science in school and their teaching of it (Q1, Q2 and Q7). They also believe that their pupils enjoy science, with both STEM subjects and 'hands on' subjects being considered popular; science has the considerable advantage of occupying both categories. This popularity sits alongside a view of science as only 'sometimes hard' (Q8). The teachers appear to see themselves as the main source of awareness about the role of science in the wider world (Q4). They also identify, whether consciously or not, a disconnect between school science and professional science (Q9), but nevertheless believe in the scientific capacity of their pupils and entertain positive views regarding whether their pupils could make a scientific discovery (Q10). Allied to this, many jobs that use STEM subjects were identified as career aspirations, although whether this factor contributed to the choices cannot be known. Familiarity with people who do STEM-related jobs doubtless plays a part in this, since it raises 'science capital', although the disconnect between aspiration and future realisation remains a major barrier (De Witt et al., 2013).

The two sets of activities were quite distinctive in their design and execution. The two participating populations were very different in a number of important ways, so it is difficult to make a direct comparison. Despite this, the plant science activities were more closely related to everyday life and were designed to allow participants a high level of choice about how they tackled the activities they undertook. Although the activities could be linked to formal scientific theories, the explanations offered were determined by the aspects in which the participants expressed interest; for example, based on the questions they asked or the observations they made. In this respect, the activities could be considered to be complex, context-based science and were not driven by any single element of the school curriculum. The decrease in factual knowledge relating to the topic may reflect the fact that the activities were very different to those that the participants would associate with formal science instruction. On the other hand, the forensic activities were far more structured, with each activity illustrating one technique and one scientific concept, such as the way everyone has unique fingerprints and why. In this way, the delivery was much more akin to a standard school science lesson. Both the singularity of content and the predetermined outcome of the forensic science activities more closely resembled the format of formal science lessons. The approach may be reflected in the increased focus on topic-specific content shown on the postcards.

The participants' responses raise some interesting points about how science educators might set about working most effectively with culturally diverse audiences in future. Both sets of activities were designed and delivered in keeping with the criteria for generally inclusive science teaching (or knowledge exchange) and, additionally, to exhibit diversity identifiers. However, there was very little acknowledgement of the impact of the overt message about diversity in science. This raises important questions about whether such diversity markers may be viewed as superficial or tokenistic and disregarded (Alexiadou & Essex, 2015). Alternatively, they may serve as a general signal of intentional cultural pluralism, which, in turn, is associated with an improved diversity climate, in which both psycho-social impacts and academic outcomes are enhanced

(Schachner, 2019). This impact extends beyond those to whom any specific diversity signifier has personal meaning, as was shown in some of the anecdotal evidence. The implication of the latter explanation is that every science activity, whether formal or informal, would need to be matched very precisely to the cultural profile of the intended audience. It also treats diversity as a series of discrete categories rather than a complex and fluid aspect of society (Kraus, 2012). Such an approach would be both practically challenging and directly counter to the notion that education should broaden young people's understanding of their world and the different people in it (Biesta, 2010).

The generation of the sub-themes and themes suggests that the participants' notions about science fell into two categories: those relating to science in general and those relating to the specific topic being studied. There was a corresponding dichotomy of focus on the processes of science and the knowledge that arises from them, with a shift in the proportion of responses in the sub-themes from content, both general and topic-specific, towards the processes by which the knowledge is generated. Similarly, there was an increase in focus on the people who do science, which would facilitate further discussions about the ways in which science and culture are inter-related. Both groups showed an awareness of the consequences of scientific activities, but an increase in awareness of the impacts of science was only observed in response to the plant science activities. Interestingly, the forensic science activities did not provide evidence of an increased knowledge of social impact, despite their intended relevance to the young people's social and cultural context.

Conclusion

Efforts to explicitly involve diverse cultural groups via multilingual resources and the selection of culturally relevant topics resulted in slight changes in the participants' views of science, but did not result in an explicit articulation of the place of diverse knowledge in the pursuit of science. Nevertheless, there was evidence that these signifiers of diversity were noted and appreciated by a few participants and were not a deterrent to others. More significantly for future efforts to enhance social inclusion, the two sets of activities provide some evidence of how to bring about changes in thinking about what science actually is. Some of these changes could be expected to enhance engagement in science by those who are currently under-engaged. Noticeably, the set of activities that differed most from the format typically taken by school science brought about more changes in viewpoint that would be expected to mitigate the deterrent features of science. The study provides evidence of the benefits of a less content-driven approach to science, one that presents alternative ways of being scientific and presents science as body of knowledge to which very diverse people have contributed (and will continue to contribute). The findings suggest that easily assessed scientific knowledge is not the most inclusive version of science, nor is it ultimately the most socially sustainable. The implication of these findings for future practice is that the nature of science in the curriculum, and its associated assessment, may need radical review.

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Kirsty Ross, PhD, is a microbiologist by training and has extensive experience working across three of Scotland's Higher Education Institutions (St Andrews, Strathclyde and Edinburgh) in the field of public engagement with research. Equity has always been a key driver in her approach to engagement. Her engagement strategy focuses on industrial and third sector organisations, as well as under-represented groups and audiences with low STEM capital, who would otherwise be overlooked, such as Early Years settings and young people with additional support needs. She is currently employed as Industrial Liaison in the School of Computer Science at the University of St Andrews, with research interests in making Wikipedia and her sister projects more inclusive, diverse, equitable and accessible spaces for open knowledge.

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