Towards truly inclusive science education: a case study of successful curriculum innovation in a special school

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The paper provides a first person account of participant evaluation research of curriculum innovation in a school serving students with profound learning difficulties. It describes how the aspirations of the school leadership team to introduce science, combined with advisory support, overcame the initial anxiety of teaching staff about teaching an unfamiliar subject. The staff position was transformed and they gave a very positive evaluation of their experiences of teaching science, due to the impact of the subject on their students. The introduction of a distinct and inclusive model of science into the curriculum was ultimately found to have significant benefits for both students and staff.

Key words: science, curriculum, inclusion.

Introduction

The study school was already known to the researcher in my role as a school governor. The study describes an evaluation of the introduction of regular science

lessons to a group of pupils who would not commonly be taught much, if any, science. The special school, in an outer London borough setting, serves around 70 students from the west side of London with severe learning difficulties (SLD), profound and multiple learning difficulties (PMLD) and autistic spectrum condition (ASC). Two school leaders decided to introduce regular science lessons to its timetable in September 2018. The change was from rare, episodic science activities to a weekly period of science, lasting an hour and, over the course of several weeks, addressing an agreed topic.

Science, elitism and special schools

The general assumption that science is an elite subject is deeply embedded in the educational psyche (Osborne and Wellington, 2001; Essex, 2018). However, the socio-political basis of the assumption remains largely uncritiqued by critical curriculum theorists, due to failures in critical curriculum studies in recent years (Apple, 2010) one of which is the absence of attention to the 'null curriculum' (Eisner, 1994). From its origins as natural philosophy, whose costly experiments limited its pursuit to the wealthy, to its role as a subject for landowners and industrial leaders in the 19th century, science has been primarily the prerogative of an elite. Its abstract nature and neo-classical vocabulary removed it from the realm of mass education (Jenkins, 1979). The late 20th century saw what might be termed the democratisation of science, along with other major educational reforms, in terms of the growth in forms of, and access to, science education. However, this was countered by the drive for science in pursuit of the so-called 'sputnik curriculum', the notion that science would underpin technological development that would underpin economic, military and political supremacy (Bybee, 1997). Neoliberal and neo-conservative education policies since the 1980s have resulted in the almost exclusive focus on pupils of average, and above average, levels of academic attainment in science and has spelled the end of post-war aspirations to 'science for all' (Fensham, 1985; Hill *et al*., 2015). This has privileged traditional subject knowledge, which treats a 'content-rich' science curriculum as 'powerful knowledge', in the tradition of the Sputnik curriculum (Wellington, 2001; Young, 2014; Hirsch, 2016).

The tradition of separate schools serving learners with the most exceptional learning needs, draws on a legacy of social support for those who could demonstrably not be expected to support themselves. (Pritchard, 1963) The demand for separate provision is now sustained by a desire by parents and staff to protect students,

who are 'different' (Essex, 2018). In special schools, teachers are commonly skilled in diverse pedagogic approaches and social support, but feel less skilled in 'specialist' areas of the curriculum (Swanson and Bianchini, 2015). This has become increasingly apparent since special schools in England and Wales underwent a 'mainstreaming' of curriculum expectations after the Education Reform Act (1988). In England and Wales, this entitlement was further signalled by the creation of P (Performance) Scales for assessment of pre-level students in subjects including Science. The impact of common expectation was, however, mitigated by the ability to exempt SEN students from the core curriculum. This left students and staff in a 'grey area' of curricular possibilities without any corresponding entitlement. In practice, the focus of many special schools remains on functional skills in order to equip students for adult life, including employability (Bobzien, 2014), and seems to derive from the intentions of the workhouse rather more than educational aims.

The staff working in special schools very rarely come from a scientific background and so frequently lack confidence in their own ability to teach science (Villanueva *et al*., 2012; Swanson and Bianchini, 2015). The dearth of expertise has resulted in very limited evidence being available on teaching science to very diverse populations of learners (Brooke and Solomon, 2001). Meanwhile, the absence of science educators in special schools means that staff lack role models or immediate sources of guidance on implementing science activities with learners with complex and profound learning difficulties.

Methodology

The study was undertaken from an evaluative position, in which all those involved were given a chance to contribute. The intention was address three objectives:

1. To understand the reasons behind the introduction of science to the curriculum
2. To document the nature of the science being taught to pupils at the study school.
3. To explore the impact of the introduction of science upon learners with SLD and school staff.

The study was undertaken as participant evaluative research, because of my existing relationship of the researcher with the school. This position was further consolidated when the staff asked me, very early on in the study, to provide

curriculum advice as well as an evaluator. This participant position raises potential issues of reflexivity for myself as the researcher, in requiring that I be not only mindful of my own position in the school where I am researching but also having to consider which of the two roles I was fulfilling at the point of each observation or interaction (Finlay, 2002).

The ethical considerations for the study were sensitive, since they related to the protection of participants who are recognised as being triply vulnerable by virtue of their age, their being questioned in an institutional setting and their intellectual disability. Participation was voluntary at all stages. The work complied with current guidelines for educational research (British Educational Research Association, 2018) and the work was approved by the University of Strathclyde's University Ethics Committee. Informed consent for participation in the study was obtained from staff and, on behalf of the students, their parents. The agency of those students who were judged to have the intellectual capacity to understand the request was upheld by being asked directly for their verbal or written permission for video recording. Their wishes were respected if they chose not to be recorded, regardless of whether their parent or carer had consented. Openness and transparency was maintained by regularly reporting observations back to staff and at twice yearly parent/ carer meetings at the school. Finally, data gathering was never allowed to interfere with teaching or learning, and at some points recording was halted to ensure that it did not disrupt classroom routines.

Fourteen full-day visits, augmented by video conferencing on four occasions at staff meetings over the course of a school year, provided substantial and sustained contact and enabled me to become very familiar with the day-to-day life of the school in a way that I had not been when working simply as a governor. Participant research seeks to create pluralistic accounts of phenomena and this was achieved, by the gathering of multiple data sets (in this case interview transcripts, documentation, field notes, photos, video clips) through which a holistic account of the phenomenon could be constructed (Dick, 1979).

This methodology for the study was ethnography, which is compatible with the participant stance that my circumstances required. Ethnography generates rich description arising out of extensive interaction and multiple data sets (Delamont, 2004). It was considered especially suitable for getting to know the non-verbal

students who form the majority of the school population. The approach also left me open to the new understandings that arose from the data (Shweder, 1997).

The diverse data were analysed by thematic analysis. Previous experience suggested that this would be a suitable way of finding the meaning in a range of data types, collected over an extended period (Essex *et al*., 2019). The data were repeatedly scrutinised, preliminary codes assigned to the material's themes, and the recurrent topics and concepts (such as expressions of staff anxiety, accounts of successful teaching episodes) were identified and then collated into clusters of related meaning. These clusters, along with the supporting evidence, constitute the overall findings from the original data (Guest *et al*., 2012).

The data gathered during the study comprised:

1. Field notes were kept upon each visit to the school. These included details of interviews and recordings captured during the day, observations made in lessons and around the school, notes on incidental interactions with staff and students and reflections on the observations.
2. Interviews with staff at regular intervals through the academic year 2018–2019. All interviews were audio recorded, with the consent of the interviewee, and subsequently transcribed.
3. Observations of pupils. The observation of behaviours as an indirect indicator of learning had previously been undertaken (Essex and Haxton, 2017) and was judged to be especially suitable for subjects many of whom were non-verbal. Videos of staff-student interactions during science lessons were recorded, with prior informed consent, in the classes summarised in Figure 1. The video clips were closely observed at least four times, and nine distinctive types of teacher behaviours were identified that were intended to elicit a response during a teaching episode. The number of times that a student responded within 10 seconds of a teacher intervention was also recorded. The teaching staff's actions were then collated into in three main groups, shown in Figure 2. A tally was created of the number of times the teacher showed one of the three categories of intervention, and the corresponding number of student responses, either verbal or physically, such as moving their eyes towards the teacher, pointing, or smiling.

Class	Key stage, chronological age range in years	Characteristics of students	Class staff who provided data
a)	Key Stage 4, 14-16	Majority of students were verbal, literate and numerate	Class teacher M, learning support assistant O
b)	Key Stage 3, 11-13	Majority non-verbal, moderate use of Makaton signing and symbols.	Class teacher K, learning support assistant N
c)	Key Stage 3, 11-13	All non-verbal with autistic spectrum condition (ASC)	Class teacher R
d)	Key Stage 4,14-16	All non-verbal students with ASC	Class teacher G
e)	Key Stage 4, 14-16	All non-verbal students with ASC	Class teacher R

Figure 1. Profile of the classes observed

Findings

In total, 20 short video recordings were made, totalling just over an hour of footage, while nine individual interviews with staff were audio recorded.

Category of input	Staff action and example from video footage
Verbal inputs	Makaton signing/ gesticulating e.g. putting finger over lips to denote a request for quiet
	Asking a direct question of a student e.g. 'Do you think the liquid chocolate or solid chocolate is better to make a chocolate biscuit, H.?'
	Giving verbal encouragement e.g. 'You're nearly there.', 'You're doing really well!'
	Giving verbal confirmation e.g. 'That's right!'
	Speaking in an extra enthusiastic tone, 'We really want to test the jelly, don't we?'
Physical	Physical encouragement e.g. giving a thumbs up or applauding a student response
	Physical intervention in a task e.g. holding a student's hand to guide them with putting seeds into the compost
Sensory	Providing physical stimuli e.g. holding scented oils under students' noses, encouraging students to touch the cornflour and water mix, letting them taste melted chocolate
	Digital stimuli e.g. video clips, audio clips, a light ball

Figure 2. Different types of intervention by staff

Teaching staff are gatekeepers to the implementation of curriculum innovation

At the beginning of the year, school management saw strategic benefits to introducing a science focus, whereas classroom staff were anxious. Both the leaders responsible for the innovation spoke of previous positive experiences of science along with strategic pressures, to improve student attainment and to provide additional breadth of curriculum. As the year progressed, they expressed satisfaction that their intentions had been realised.

> *So I think that I'm glad that we took that decision because I think that developing the breadth of the curriculum is the future* (Head teacher, July 2019).

By contrast, classroom-based staff were initially very uncertain about their ability to teach science. They felt insufficiently knowledgeable, and were concerned that it is a 'difficult' subject, requiring very specialist expertise to deliver, echoing previous studies (Swanson and Bianchini, 2015; Essex, 2018).The lack of confidence was described by one teacher,

> *I did hear some Key Stage 4 teachers saying that they struggled to deliver with electricity, and how can they deliver the same topics over 6-7 weeks, what else you can do with it. Not only their knowledge, I would put it down to lack of resources. They were struggling with what they could do* (Teacher N, October 2018).

However, the position of the classroom staff underwent a massive change as the year progressed and they grew more experienced in teaching science. There was a seismic shift in the staff attitude to science,

> *For me it was really surprising that all the students enjoyed it so much and they had so much fun, and I never thought about science like that before. We can do it this way, and for our students you can make it very exciting and something they didn't see before* (Teacher A, July 2019).

> *Staff were very honest with me about being anxious about asking for help. I said to each of them, "If the head and deputy head said at the end of term that they can't fit science into the timetable next year", there was universal fighting to save it! I thought that was really interesting; there were lots of*

accounts of "I wasn't sure but I had a go ... The kids loved it, so I loved it!" (Field notes, July 2019).

Staff were initially reluctant to talk to me, or to let me into their lessons. This seems to have reflected their anxiety about not being competent to teach science; the latter explanation was evident in this comment,

Before I was like, if someone came up to me and said "I am going to observe your (science) lesson", I would be very stressed and feeling like, "What can I do?" I wouldn't feel confident, now I would like to do science ... Now, no problem, go for it (Teacher A, June 2019).

The pressure to succeed in an area where staff lacked confidence was also evident in a massive shift in staff attitude to the researcher after a critical incident (Frankrijker, 1998). The transformation of the staff was immediate. On my next visit, and all subsequent visits, they came to seek me out when I was in school, to talk about ideas and check resources that they had found on-line.

Teacher K came in to the staff area and said that he had forgotten to prepare for the afternoon's science lesson. He is a music specialist and didn't have anything up his sleeve for the science topic, 'Explosions'. I asked him whether he had tried the Mentos fizz with his class; he hadn't heard of it. I offered to go over to the shops and buy the necessary materials (sweets and fizzy drinks) and explained how it could be used to demonstrate the two key features of explosions ('big' and 'fast' change.) He accepted the offer and invited me into his class to run the activity. I did this and he was clearly pleased with how it went. At the end of the afternoon, he went down to the staff room and told colleagues that I was amazing, knew a lot of science, I had great ideas and that they should ask me for help. We then co-planned his next week's lesson (Field notes, October 2019).

As the year progressed, the role of science as a synoptic area of study, though which a range of subjects and transferable thinking skills could be taught, was understood to be a benefit. This has previously been recorded as an important rationale for SEN students learning science (Essex, 2018).

You're actually doing some Maths and English in the science ... While we're waiting, we can count how many seconds we're going to wait. ...... It's introducing the language of science there, and the skills we tried to teach

them are all integrated into science. … I had C observe our science lesson just last week, and she said to me, "Oh maths is well integrated …" Yes, we were putting the Vitamin C tablet into the bottle, then we counted up to 10. … By delivering science, you've crossed off English, Maths … (Teacher N, July 2019).

Not all of them get the concept of process and that "I will get some outcome if I do this." So exploring all of this (Electricity), I can see the results now in class, now the students who would never tell me that the iPad needs to me charged, will now ask me to go and charge it (Teacher A, July 2019).

A very different type of science facilitates full inclusion

The linking of conceptual development to practical exploration is a distinctive feature of Science (Jenkins, 1979). Moreover, the twinning of conceptual development with tangible phenomena appeals to staff working with students with special educational needs (Essex, 2018). Strong coupling of carefully selected and clearly communicated concepts and reinforcement, through haptic and other sensory stimuli, points to a powerful pedagogic model that might equally be used in other curriculum areas. Although teaching was based on conceptual frameworks, such as solids, liquids and gases, the science foregrounded sensory engagement by students. The approach also used much repetition of a few key ideas and terms, which has been found previously to be an effective intervention (Therrien *et al.*, 2011).

Numerous references were made to the key and very positive role of experiential learning, such as,

Before, science lessons were more paper-based activities, and for me it didn't really make sense. Our students did not understand what we were talking about and I never felt that passion to do the science lesson. … but the experiments we did, they were all amazing, I never did other activities like the science activities where we all were sitting round the big table, calmly watching … That was something unfamiliar, and the effect which it has … It's not the same as other subjects, I think that now from what I can see, across the school we are trying to use more practical things in all areas (Teacher A, July, 2019).

Proportional response to stimulus/ class	Verbal	Physical	Multisensory
Class a)	35/44	1/1	0/0
Class b)	59/64	24/24	7/7
Class c)	14/20	16/18	6/7
Class d)	12/15	12/14	15/20
Class e)	10/11	13/17	16/20

Figure 3. Proportion of student responses to staff interventions

Sensory inputs were not used indiscriminately, however, but according to the capacity of students to engage with a range of range of stumli. There was a trend towards using fewer verbal inputs and, correspondingly, more sensory input when the number of verbal students in the class is lower, as shown by Figure 3.

The numerator is the number of responses by student and the denominator is the number of times staff demonstrated a stimulus in that category.

Despite the strong emphasis placed on sensory learning, staff were universally clear that Science represented something far more than a pretext to do sensory activities. This echoes earlier findings that students with learning difficulties are much more capable of being 'active participants' than they are commonly credited with (Brooke and Solomon, 2001). This is illustrated by comments such as,

Today I videoed Class e) studying solids and liquids. Teacher G touched their hands and lips with solid chocolate, then melted chocolate, each time repeating the words and signing 'solid' or 'liquid'. The assessment was to show them a plain biscuit, and ask them whether he should use liquid or solid chocolate, if he wanted to make a chocolate biscuit. Every student pointed or eye gazed to the sign for liquid. It was amazing to see that they had understood the

properties and were then able to apply their insight to the task (Field notes, May 2019).

It was observed that pairs of concepts, and the associated words and Makaton signs, were commonly taught in science, quite often opposites. Examples observed included 'change' and no change', 'big' and 'fast' change (during the Explosions topic), and 'solid' or 'liquid'. However, the relationship between the concepts and the sensory experiences did not, however, follow the Baconian model of science, in which experimental data is used to drive forward conceptualisation. Instead, an alternative model of science was frequently used, that might be termed 'thinking by doing', reminiscent of reminiscent of Shulman's (1986) 'knowledge in action'. Students commonly started an activity without a clear plan or purpose and then made adjustments as they proceeded, as illustrated by the following incident, observed in Class c).

The activity involved classifying materials (water, cornflour) as liquid or solid. Students then had to mix a small amount of each and decide whether the mixture was a liquid or solid. Learning support assistant N was seated between C. and another student and was guiding the other student on how to put cornflour on to a laminated sheet, and, separately a spoonful of water. The student was guided to use a small wooden spoon to mix the two and to try pushing it. C. observed this and, when the pot of water was put on the table, reached over and looked at it. He then looked over again at his neighbour, and appeared slightly puzzled. When the packet of cornflour was put back on the table, he reached for it and shook some into the pot of water. He glanced over at his neighbour again, then started to look across the table and under the table. He then bent to retrieve a twig that he had brought in after break time and put under the table. He then used the twig in place of the spoon, to stir the water and cornflour together and make the 'gloop', as his neighbour had (Field notes, April 2019).

Today, as part of the 'Explosions' topic, class a) made 'fizzy rockets', using effervescent Vitamin C tablets in the pots for blood sugar testing strips. I videoed them trying to get their pot to fly the furthest. I was interested to see that, even though they are the highest attaining group of students, they didn't plan their rockets, but set them off and then afterwards analysed the results to reach their conclusion. They discovered, by trial and error that there is a maximum number of tablets, after which the rocket won't fly any further (Field notes, November 2018).

Science stimulated pedagogic risk taking and enhanced collaboration

The shared lack of confidence that staff felt was associated with a willingness to collaborate more with colleagues than would usually have happened,

> *In quite a few experiments, because the practicality of it and because it was shared ideas, the teachers would plan an activity and all the classes would join this particular class, so that it was really a good sharing of ideas. It's not just what you are thinking about your students, it is how it can be planned and how your pupils respond to other people's experiments* (Deputy head teacher, interview, July 2019).

> *, …… after a little while people asked me to download the folders with the video so they could all access it. We had a transition morning and I was asked to lead a session* (Teacher N, interview, July 2019).

The introduction of a new, and relatively unfamiliar, subject also encouraged staff to try new teaching approaches. Examples of these included borrowing circuit board equipment from a neighbouring education establishment, to do activities that were unfamiliar but suggested by the researcher, also field trips. In one case, concern over class management had deterred the teacher from taking students out previously, but she had changed her mind after it was recommended in the scheme of work on 'Living and non-living things'.

> *We went twice to the park, once we went to B., where we were looking at the lake, and the ducks, and there were swans and there were birds, and there were dogs walking as well on leads. We were saying, "Look, they're flying, so they are moving, swimming, walking, running …" So there were different movements and they also looked at because there is a playground area we also looked at how the swing is, which we said was non-living. The other park was similar, we went there as well, we were also looking at the trees and the lake, and there were ducks as well. The students threw pebbles into the lake and we noticed that they were being very careful not to hit ducks or fish or passing dogs. So they knew that these things have feeling* (Teacher A, interview, July 2019).

Conclusion

Although Science is commonly perceived as a 'difficult' subject, the study shows very positive outcomes associated with its study by learners with PMLD. In the study school, the decision to introduce science as a regular, timetabled subject delivered a number of important benefits, some of them intended by the senior leadership team and others that had not been foreseen The positive outcomes occurred despite initial staff trepidation about the introduction of an unfamiliar subject, in which they didn't feel themselves to be competent. The more mutual relationship between myself, in my capacity as a specialist science educator, and the special school staff than those documented previously (Swanson and Bianchini, 2015), facilitated a marked growth on competence and confidence. Unfortunately, collaborations between science educators and special educators remain very rare, due to the widespread assumption that science is unsuitable for such learners (Essex, 2018). The study reported here is unusual, though not unique, in providing firm evidence that actively counters such pre-conceptions (Brooke and Solomon, 2001). Further studies of how future collaborations could be promoted between disciplinary experts and teachers with pedagogic expertise in working with individual SEND students would be valuable in developing a wider range of differentiated teaching strategies for specialist subject areas. It is interesting to speculate whether the same benefits would have been seen if the innovation was with a different, possibly less high status, curriculum subject. Beyond that, the success of introducing a subject that would not be expected to be a major presence in the school's curriculum, raises questions about the extent to which other subjects that are viewed as 'academic' and 'difficult', such as foreign languages, could be introduced with similar success. What the study highlights above all is the need to re-evaluate, and question, the values and assumptions that are embedded within the construction of curriculum for PMLD students.

Paradoxically, the staff's lack of familiarity with the subject provided them with the impetus for pedagogical innovation which, in turn, revealed previously unknown student capabilities. Their low level of confidence in the teaching material made them very open to trying out unfamiliar activities suggested by sources of support, including my suggestions. The challenge of the curriculum innovation appeared to be to move staff beyond the *'cognitively restricting rituals'* that greater familiarity with the subject matter engenders (Alexander, 2006, p. 14). While this level of innovation would doubtless be exhausting if teachers were perpetually teaching unfamiliar subjects, the study provided clear indications that

the level of challenge inherent in the curriculum innovation was stimulating for staff and, over the course of a year, invigorated both their work in the classroom and their relationship with the students.

The students themselves enjoyed the modified Science curriculum and there was ample evidence of learning in the behaviours and verbal responses of students. Beyond their gains in scientific knowledge and understanding, the lessons also offered an excellent opportunity for development in other curriculum areas and instilled a range of transferable skills. The sustained focus on a limited number of clearly articulated concepts, supported by sensory exemplification, was a highly successful teaching approach, especially with non-verbal students. Inclusive science pedagogy appears to offer a valuable classroom strategy that could be advantageously deployed in other curriculum areas with the learners observed.

Crucially, there was no evidence at all to suggest that science, presented in a suitably modified format, is unsuitable for any learner. Indeed, the study underlines the value of science for all learners and challenges assumptions that is 'too difficult' for some. Students learnt especially well by being allowed to explore activities in an open-ended way, rather than having a clearly structured plan at the start. This finding challenges the orthodoxy of the so-called hypethetico-deductive model of science that currently permeates the science curriculum (Osborne and Dillon, 2010). The study resurrects important questions about the extent to which such a singular notion of what science is constitutes a major exclusionary factor in school science more widely. The science education community still struggles, possibly due to curriculum and external assessment pressures, to accept that very different models of science are both needed and valid. If they can re-conceptualise the nature of the science in the curriculum, however, they will discover that an untapped reservoir of enthusiastic science students and science teachers await them.

Acknowledgement

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