Teacher experience of a pandemic science intervention rooted in epistemic insight

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Abstract The COVID-19 pandemic greatly reduced students' capacities to engage in hands-on 'enquiry' science. But even before the pandemic, teachers and researchers were questioning the value and purpose of practical science. This article describes a project that imagined and then tested two answers. It imagined that the answer is to give every child their own unique experience of working scientifically. And it imagined that the answer is to help students to understand the role of science in helping humanity to ask and explore 'big questions' that bridge science, religion and the wider humanities – and so stretch across more than one subject discipline in school. The data analysed focuses on teachers' accounts of their experiences co-creating and delivering the project.

The context for the study

Education during the COVID-19 pandemic was challenging for teachers, children and parents, with the LLAKES working paper (Green, 2020) indicating that around one-fifth of school students in the UK did not engage in formal education, with often the most disadvantaged having least opportunity to learn. This amplified the recognised inequalities in students' education and science capital identified by Canovan and Fallon (2020). Focusing on the transition from primary to secondary science education, this article reports on a study that examined a practical 'hands-on' science intervention developed to counter the impact of lockdowns on students' science learning experiences, and also to enhance their understanding of the nature of science. In particular, we look at the teacher experience of using the resources developed, and their views on the student experience. Teachers recruited to the project were based in primary and secondary schools in England, working with students aged 9–12.

The interventions considered here incorporated resources to facilitate discussions around 'science and big questions' that challenge students to think out of siloed notions of subject disciplines and to draw on knowledge and experience gained in many different ways. We believe that the guiding principles behind the approach not only made it appropriate for the particular challenges of teaching during COVID-19 but also present significant opportunities for development and application in the long term.

Accessibility

Numerous factors contribute to accessibility problems in science education, particularly for hands-on practical teaching, and these were exacerbated by COVID-19 restrictions requiring home teaching and different use of classroom space and equipment. These, of course, are not unique to pandemic conditions. For example, home schooling or support for those in specialist units is a longer-term reality for many and requires tailored approaches to ensure high-quality science education is maintained.

Another contributing factor to making practical science education less accessible is lack of resources. This is frequently due to the cost of apparatus, and results in the need for group working. Small, or indeed large, group working can lead to tasks being dominated by particular individuals because of their perceived ability or force of personality. Students who lack confidence, or initial interest, are frequently excluded or self-exclude from active participation in group activities that only have a limited number of active roles. Our belief is that, in this context, observers in group work are often passive, with less learning being achieved in the activity. This issue in particular is likely to be more marked in lower-income settings owing to resource availability. We do not argue that group working lacks value, but where the only rationale is lack of resources then disadvantages do exist.

In order to address these concerns on accessibility, the interventions described below are all rooted in real-world experience, rather than abstract theoretical notions, and use low-technology equipment that is likely to be available in all schools and even most homes (Figure 1). Its low cost also means each student can have their own set of equipment. This initially allowed hands-on science in a socially distanced or home setting, but also provides the opportunity to reduce group work where this is done solely because of lack of resources.

Co-creation

An important part of the design and implementation of the study was the use of co-creation, both at the level of the higher education institutions carrying out the project and in collaboration with teachers delivering the interventions. Teachers provided important experience that helped shape the nature of the study and of interventions. Some misconceptions about the nature of science are found in stories communicated by teachers from the classroom. In one example, year 6 students (ages 10–11) failed to recall a science lesson from the previous day and even countered the teacher by stating that no science had been studied at all on that day. When the teacher reminded them of a session outside in which they had engaged in various activities followed by measurement of physiological parameters, such as pulse rate, the students responded that they saw that as PE, not science, because it was done outside in PE kit. Similarly, during the pandemic a number of students reported that science was something 'you do online', meaning that scientific information was gathered through online search engines. Both of these anecdotes suggest that the nature of science is often misunderstood and that it is frequently those on the front line who have access to the true level of misunderstanding and input into interventions.

A series of five classroom sessions was designed in a collaborative exercise involving scientists, educationists and classroom teachers. Similarly, the design of the study itself, and its implementation in various locations, was also an act of co-creation in which sampling and analysis were adapted to the reality of local conditions, which were often shifting through illness and changing guidelines. An important part of the model was that teachers were provided with all five sessions as potential parts of the intervention but with no expectation that all five would be used. In fact, only one session was used in all settings and teachers were encouraged to co-create the overall intervention for their particular setting depending upon their own skill set, knowledge of their students, their local needs and environment.

Again, this was an important aspect of accessibility and also important for our vision of a sustainable model of intervention that could be used in the longer term for all schools. In allowing teachers to use their own strengths at a time when multiple demands were being placed upon them because of pandemic requirements, it was hoped that the co-created intervention would place a lower burden on them and also engender a greater sense of confidence in delivery.

Figure 1 Each student had their own 'discovery bag', containing equipment and instructions for a simple investigation

Epistemic insight

At the heart of epistemic insight is the concept of knowing about knowing: understanding how we gain knowledge and the diverse interactions between the different ways we have of seeking to understand the world. In the context of science education, this involves a broader understanding of science and its location within the wider curriculum. Seeking to explore how science is complemented by, and complements, other subject disciplines in our efforts to answer questions and understand the way the world works helps to broaden thinking and develop new approaches to problems. In order to encourage this, we used a number of 'big questions' within the five intervention activities provided to teachers, and sought to help teachers in encouraging thought in the broader context of epistemic insight. These big questions were not simply exciting topic areas with 'wow' moments designed to catch attention. They were real-world questions that could be readily grasped by students, but which led them to deeper thought and enquiry into underlying principles of how they were coming to understand the answers they were getting.

The activities

Recent studies have shown that many students learn and think in ways that are comparable to scientists in that they observe, hypothesise, experiment and evaluate during their daily lives (Gopnik, 2012). They often question why something occurs, similarly to those who lead scientific investigations. Students are also encouraged to examine scientific concepts as they engage with their surroundings and environments (Brenneman, Stevenson-Boyd and Frede, 2009). Throughout their explorations, students become creative as they are stimulated to develop ideas and methods, reason critically and generate explanations compatible with the available information (Rossi et al., 2014). The growing body of scientific research concerning students' ability to learn

Figure 2 Students were provided with investigation cards and worksheets that contained prompts for discussion

science has helped to accentuate the potential value of science education in pre-16 compulsory education (Metz, 2009).

The interventions used in this study consisted of 'Discovery Bags', which included resources for activities to provide opportunities to explore 'big questions' bridging science, religion and the wider humanities – and so stretch across more than one subject discipline in school. Each student had their own discovery bag containing pieces of science equipment, such as diffraction glasses and coloured cards, and instructions on how to conduct a simple investigation to explore how we make sense of the universe. The teachers and students were then provided with investigation cards and worksheets that contained prompts for discussion (Figure 2).

The five intervention sessions provided to teachers all focused on questions traditionally aligned to physics and considered the following big questions by using opening science investigations:

- **Why do spinners spin?** This practical activity on gravity and air resistance, leads into the consideration of the role of observation and experimentation in science. Students are asked to explore air resistance through comparing how fast paper falls when dropped as a flat sheet and a scrunched-up ball. They then make a 'spinner' out of paper, which slows the rate of fall, and are asked to measure the time it takes to fall compared with paper in other forms (Figure 3). After considering examples of this in nature and engineering (e.g. sycamore seeds) they are then encouraged to experiment by changing the design of the spinner.
- **How do clouds stay up?** This simple activity demonstrates surface tension in water and develops the theme to consider the broader scientific concepts in the water cycle. Students start by investigating the behaviour of water droplets by placing drops onto the surface of a penny and observing what happens as they join up. This forms the basis of a further discussion about the behaviour of water inside clouds and what leads to rain. Students are then encouraged to think about their observations of clouds and other meteorological phenomena.
- **Why is the sky blue?** This question is asked in relation to the nature and diffraction of light and then as an introduction to our planet as a host for life. Students are given easily available diffraction glasses, which scatter light. When observing white light they see rainbow effects, but when asked to look at a red card they see only one colour. This

enables a discussion of the way white light is made up of different colours and how the atmosphere acts like the diffraction glasses but only lets through blue light. The discussion then leads into a consideration of the very particular circumstances of the Earth's location and conditions and its status as a 'Goldilocks' planet capable of sustaining life.

- **How do we make sense of the weather?** In this activity, measuring wind using analogues such as the movement of paper in draughts develops into how we think about the control of the weather. Students carry out an investigation in which they use a piece of tissue paper to show the movement of air from a cold room to a warm room through a small space such as a door that is slightly open. This is then discussed in a scaled-up way to think about wind and other weather phenomena of which the students have direct experience. A discussion is then encouraged on the subject of science and religion and the nature of a scientific question, initiated by the prompt question '*Does God control the weather?*'
- **In the future will people travel and live in space?** An initial consideration of the scale of the solar system expands to consider the science, politics, economics, ethics, and so on, involved in colonising space (Figure 4). Students map out the relative positions of the planets of our solar system using measurements that are given on the work card. This is used to consider the potential benefits and weaknesses of scientific models by encouraging comparison with pictures that show the planets evenly arranged in order. The students are then encouraged to think through the challenges and benefits of humans living in space in the future, firstly through the scientific and technical perspective and then through drawing on different disciplines such as economics, psychology and ethics.

A link to the resources used for all of the sessions is given at the end of this article.

Some of these questions, such as *Why is the sky blue?*, are fundamental childhood questions asked by many students as they begin to observe the world; they have ready analogues in other subject areas – such as *Why is the grass green?* for biology. Also contained within these questions are further questions about the nature of human experience and observation of the world. To continue with the example of why the sky is blue we provided information about light, the atmosphere, diffraction, and so on, but discussions on this question can easily move on to the question of our perception of colour and thus how psychology, art and other disciplines help us to understand the world and what it is to be human. We also used the opportunity of this question to consider the unique nature of the Earth's atmosphere and its location as a 'Goldilocks' planet to think about how the Earth's position enables the development of life, including human life. It is this perfect set of conditions that not only results in the sky being blue but in the existence of conscious life to ask the question of why it is blue.

Figure 3 Hands on science and agency through making paper 'spinners'

The example of the sky being blue illustrates how the entry-level questions posed in the activities were designed to engender deeper and broader exploration of subjects beyond the traditional boundaries and be a launchpad for a discussion about how we know what we know. Thus, *Why is the sky blue?* is a question appropriate not only to atmospheric science but also to psychology, art, astronomy, history, philosophy and, indeed, any number of subject disciplines, each able to provide a different aspect of the answer.

Teacher experience

In the first instance, teachers delivering the sessions received continuing professional development (CPD) training from members of the academic institutions carrying out the study. This included training on how to use the investigation cards, key learning points, the teaching notes, links to the science National Curriculum content, and how best to utilise the discussion guides. As part of this, 'style guides' were offered, which helped to provide vocabulary and grammar when talking about the nature of science, big questions and the relationship between science and real-world problems. Thus, the notion of '*observation of the natural world*' as foundational to science was reinforced as a key stage 2 (ages 7–11) objective and built on with key stage 3 (ages 11–14) objectives '*Science informs our thinking about every aspect of our lives*' and '*Some questions are more amenable to science*'.

The practical activities were designed to be used both at school and at home in the event of local lockdowns in line with contemporary COVID-19 pandemic regulations, thereby increasing the resilience of provision. Teachers were given the freedom to select which of the activities and resources they wished to use with their classes and asked to administer survey questionnaires to help assess the impacts of the interventions. In addition, teachers were asked to provide feedback on the process, content of materials and any impacts the sessions had on their own teaching and plans. Below is a summary of feedback from key stage 2 and 3 teachers, which has been grouped into three categories: confidence, big questions and learning points. All feedback was anonymous and in the form of open answers provided on questionnaires or through interviews.

Figure 4 Example of an investigation card on space

Impacts on teacher confidence

One feature of the feedback from teachers was an enhanced sense of confidence in teaching. This seemed to be, in part, associated with a sense of 'expert' support and endorsement of materials being used. As one teacher explained:

> *I found it useful to have lessons planned by someone who understands the subject at a much deeper level than me. This made it so much easier to engage the students as the teachers were so much more confident delivering the lesson.*

This, of course, points to the ongoing value of CPD, but also suggests that active interactions between classroom teachers and academic specialists have the potential to support teachers, particularly those who are less experienced or feel less 'in touch' with subject developments. This appears to be supported by teacher responses to the pre-intervention CPD, for example:

> *I learned how to explain everyday phenomena in a clear and easily understandable style.*

This was central for the purposes of this study, in which such everyday phenomena were the launching point into both understanding the scientific principles and engaging with epistemic insight aims. It is important that teachers delivering resources are confident with using them if outcomes are to be good for students, particularly in circumstances that provide additional challenges such as pandemic restrictions or isolation from mainstream classrooms. Thus, as well as providing resources and guidance notes it would seem that more active support provides enhanced outcomes. Here, this was provided through CPD sessions but was also embedded within the co-creation model in which teachers could select material they felt most confident with and could interact with investigators from the higher education institutions. While this last element will not be possible in most circumstances, the co-creation model and well-developed support materials are feasible options, provided adequate support and guidance is put in place.

Big questions

The use of 'big questions' as opposed to simply using eye-catching examples in science was an important part of the approach in this study and appears to have been a highly engaging aspect for teachers. When asked what had engaged them regarding big questions one teacher responded:

> *Finding out the answers together as a class. Encouraging students to ask the big questions, even if you do not know the answer. Fixing misconceptions to the answers to some big questions.*

This appears to show learning as a collaborative process between teacher and student, with the teacher feeling confident to explore questions without knowing the answer themselves and providing the opportunity to explore the current level of knowledge and understanding of students. When asked what had struck them most about the experience of using the resources in the classroom, another teacher replied:

Learning opportunities from big questions. Some may not be answered but can link to other areas, such as RE. Reinforced that sometimes we find questions difficult to answer and we may not have a definitive answer.

Big questions, then, seemed to meet our objectives of empowering teachers to explore subject matter in a way that complemented their own strengths. Similarly, another teacher reported:

Great to have the big questions for a starting point and the teacher guides are helpful as give some ideas but room also to interpret to suit students.

Here, then, the teacher highlights the aims of co-creation alongside the materials supplied. All teachers quoted here point to the value of big questions and collaborative working. Thus it would seem that it is valuable to work in a co-creative way but it is also important to formulate questions carefully to enable this to flourish; the big questions seem to have achieved this. We also deemed it important to provide clarity around what we mean by 'big questions'. This is important so that teachers can identify and work with other examples, beyond those we provided in this resource. As we learned from some of our participants and advisers, the phrase 'big questions' is widely used and with many different meanings. We therefore updated our teacher notes for future use to say, '*Big questions that bridge science, religion and the wider humanities*'.

Most important learning points

Perhaps the most important question for any intervention-based study of this nature is about transferability and sustainability. In other words, was this simply a one-off event or have any of the elements made any significant difference to teachers' understanding and plans for the future? For some teachers, there may have been little shift but for those who responded to our questions there appears to have been a range of insights and developments:

I will spend more time in class getting the students to think about their initial thoughts.

I will frame experiments as a question to answer more often.

Observation is a great way of addressing misconceptions and learning.

It changed the way I taught science, to make it more hands on.

The resources have encouraged me to go beyond what the age expectations are and to go more with where the students' learning is and where it can be expanded following their interests and ideas.

It's great to see this link [between science and other disciplines] and it's one I intend to pursue where possible.

I will use this one in class as part of our learning. I can see that some of the others would work well in after-school clubs too.

It has allowed to me to use resources effectively and know even little resources can go a long way. I will allow the children more independent time to research moving forward.

One teacher in particular indicated that this way of teaching was more akin to what she had been trained, and hoped, to do but had not been able to for various reasons:

On my PGCE course it was promoted, this way of learning, it really was and we were all ready to do this when I came into the job but then it was, 'you have to make sure the children have this recorded into their book' and 'you have to make sure they have done this'. I think we still want to teach this way and I think we are aware that children want to learn in this way, to direct their own learning. I think I have learnt more about the big questions – I think what we do want to do is to let children explore the ideas. I think we are aware of this and do value this and to have the opportunity to do this in the classroom.

In several ways, then, teachers appear to have shifted their approach to teaching science or their expectations of their students. This includes:

- the use of questions rather than simply formulaic experiment-based teaching;
- the key role of observation in science;
- an enhanced role for hands-on science;
- using the model of learning to stretch expectations of students;
- using the co-creation model to align teaching outcomes with students' own interests, questions and ideas;
- applying the model beyond typical classroom situations.

Each of these provides valuable shifts and realistic expectations of change with little need for major investment or resources by individual teachers or schools.

Conclusions

While the outcomes of these interventions on student learning will be reported elsewhere, we can perhaps conclude here that for teachers there were a number of positive outcomes to using both these interventions specifically and the general model in a broader sense. Gaining confidence in subject matter for teachers is important and well recognised. In this study, we saw teachers able to use the flexibility of the materials supplied, alongside provision of guidance in vocabulary and grammar, to adapt to their own strengths and engage in bigger questions beyond immediate science content. The full co-creation model as used here may well not be practicable in all circumstances because of the scale of the study, but elements such as flexible resources, underpinning CPD and some form of mentoring may well be achievable. The ability to teach science in a research-engaged manner does not require the full resources of a university, only the correct language, frame of mind and resources. We believe that the approach of 'science and big questions' goes a long way towards the language and frame of mind. The resources produced for this study are relatively straightforward to replicate in other settings and with other questions; beginning any lesson with the question '*Why does…?*' immediately opens up possibilities for engagement and development of themes through research-based learning.

In the responses of teachers considered in this study, we find use of key terms for the nature of science, such as 'observation', but also use of interdisciplinary concepts and language to frame their experience. In this one experience, then, it is possible to see some fundamental shifts in their approach to science teaching. We do not profess that this is a complete change in approach, nor perhaps should it be, but that an intervention rooted in the co-created model and offering challenging and engaging materials, alongside formative support, can begin a process of thinking epistemologically when teaching science. Further research and longer engagement would seem necessary in order to evaluate the efficacy for students and teachers as they progress through school, but these initial results seem to show some important outcomes for teachers.

The *Investigating Big Questions* resources referred to in this article can be accessed at: https://zenodo.org/record/6556690.

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References

Brenneman, K., Stevenson-Boyd, J. and Frede, E. (2009) Math and science in preschool: policies and practice. *NIEER Policy Brief*, 19, 1–12.

Canovan, C. and Fallon, N. (2021) Widening the divide: the impact of school closures on primary science learning. *SN Social Sciences*, **1**(5), 1–22.

Gopnik, A. (2012) Scientific thinking in young children: theoretical advances, empirical research, and policy implications. *Science*, **337**(6102), 1623–1627.

Green, F. (2020) *Schoolwork in lockdown: new evidence on the epidemic of educational poverty*. LLAKES Research Paper 67. www.llakes.ac.uk

Metz, K. (2009) Rethinking what is 'developmentally appropriate' from a learning progression perspective: the power and the challenge. *Review of Science, Mathematics & ICT Education*, **3**(1), 5–22.

Rossi, D., Glauert, E., Stylianidou, F., Compton, A., Craft, A., Cremin, T. and Havu-Nuutinen, S. (2014) *Creative Little Scientists: Enabling Creativity Through Science and Mathematics in Preschool and First Years of Primary Education*. www.creative-little-scientists.eu/sites/default/files/Recommendations_to_Policy_Makers_and_Stakeholders.pdf

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