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Participatory Inquiries That Promote Consideration of Socio-Scientific Issues Related to Sustainability within Three Different Contexts: Agriculture, Botany and Palaeontology

Debra McGregor [1,*], Sarah Frodsham [2] and Clarysly Deller [3]

[1] School of Education, Oxford-Brookes University, Oxford OX2 9AT, UK
[2] Department of Continuing Education, University of Oxford, Oxford OX1 2JA, UK; sarah.frodsham@conted.ox.ac.uk
[3] School of Teacher Education & Professional Development, Faculty of Health and Education, Manchester Metropolitan University, Manchester M15 6BH, UK; c.deller@mmu.ac.uk
* Correspondence: dmcgregor@brookes.ac.uk

Abstract: The involvement of students in dramatised inquiries, through participatory activity, offers opportunities to act in-role as scientists. The inquiries can 'set-the-scene', provide context and challenges for students to consider possibilities within and beyond everyday life. This approach can engage students in thinking about sustainability and developing citizenship competencies, such as thinking scientifically and critiquing ideas, interrogating evidence and assessing the validity of information, as well as decision making and problem solving. In this paper, adopting stories from the history of science is shown to provide rich, authentic contexts that engage students imaginatively and collaboratively in addressing past, present and future socio-scientific issues. To demonstrate how the approach can be adapted we drew on the work of three scientists: an agriculturalist; a botanist and a palaeontologist. Their scientific work informed the learning activities of several primary science lessons (with students aged 9–10). The agricultural activities were informed by the work of George Washington Carver and were related to improving soil quality through crop rotation as well as thinking about the diversity of food and other products that can be produced from plants. The botanically informed activities promoted understanding about processes linked to maintaining species diversity. These drew on the work of Marianne North, a Victorian botanical artist, noted for her detailed plant observations. The final socio-scientific context was related to the work of Mary Anning, a pioneering 19th century palaeontologist, who made significant fossil discoveries that contributed to the understanding of geology and evolution. Interactive and participatory activities, informed by the lives and work of these scientists, were designed to engage students in socio-scientific inquiry-based learning through a drama-based pedagogy. These dramatised inquiries promoted the development of scientific citizenship competencies. Scrutiny of data collected through multiple methods suggested that, by extending opportunities for learners to participate in these dramatised lessons, understanding sustainability became more salient for the students. Outcomes suggest several distinctive affordances offered by dramatisation when supporting understanding about sustainability and the development of scientific citizenship.

Keywords: scientific citizenship; sustainability across contexts; dramatised inquiries

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1. Introduction

On an almost daily basis we are confronted by headline news describing environmental concerns that the planet is in 'climate crisis' [1]. Scientists have presented ever-increasing evidence about rising global temperatures causing climatic disruption, reducing biodiversity and aggravating food shortages. Social issues related to, and caused by, climate changes have resulted in human displacement because of unsuitable living conditions. Resultantly, the associated pressures of millions of people having to relocate have prompted many international organisations to think anew about education. Many are generating new educational policies [1–3]. These policies promote a focus on socio-scientific issues (SSI) that aim to teach students not only about scientific 'content knowledge but also the nature of science' but also provide practice in considering the consequences of alternate perspectives [4] (p. 2209).

In order to understand more about SSIs, Amos and Levinson [5] (p. 29) suggest encouraging young people to 'ask real world questions', 'collect evidence to answer questions' and 'take action'. This, they state, can be achieved through socio-scientific inquiry-based learning (SSIBL). This approach recognises that students need space and time in order to generate 'authentic questions' (ibid, p. 11), consider evidence and decide whether subsequent actions are needed. Zeidler et al. [6] emphasize how the contextual nature of tasks is important. They elaborate that SSI education should include student dialogue, discussion, debate and argumentation, using ill-structured problems that lack teacher-prescribed methods to resolve them. SSI activities have a desired aim have a desired aim, outcome or solution but in SSIBL there exists no clear pre-determined method to reach a resolution [7]. The tasks are not 'well-structured problems' that Mayer [8] cited in Hambrick et al. [7] (p. 554) refers to. Real-world, ill-defined problems do not include optional solutions offered by the teacher. Tackling these kinds of unprescribed problems related to real world contexts are arguably more challenging and not simple low-level tasks.

Tasks contextualised within a real-world (practical) situation are more akin to SSIBLs. Problem-based tasks in which resolutions are not obvious, afford opportunities for students to figure out original solutions [7], employing both cognitive and pragmatic processes to reach a resolution.

Zeidler et al. [6] suggest how presenting SSIs in this more open way affords reasoning opportunities [9] associated with negotiation and resolution. Inherent in the processes of solving these 'open' challenges is the space for students to discuss and deliberate over alternate views about science and consider what actions are possible to carry out. As McGregor et al. [10] describe, a dramatised inquiry provides a structure that can be adapted for students to be agentive, make decisions and act upon those choices. Framing problems that can be resolved in multiple ways resonates with more authentic situations. Therefore, setting up opportunities to solve a variety of open tasks within agricultural, biodiversity and archaeological contexts, allows students to think about aspects of sustainability from distinct perspectives.

The three foci for SSI activities are each discussed as cases in this paper. Each case is described in more detail in the Section 2, highlighting how students can be offered SSIBL opportunities to think scientifically, critique ideas, interrogate evidence, assess the validity of evidence, make decisions informed by evidence and collaborate to problem-solve. For each case, the sustainability topic and the relative strength of evidence reflecting various scientific citizenship capabilities are presented in Table 1.

Table 1. Features of scientific citizenship developed from [11] and practices integral to SSIBL [5] supported across the three cases, with the relative strength of evidence reflected by X or x.

Sustainability Topic of Each SSI Case	Thinking Scientifically	Thinking Critically	Interrogating Evidence	Assessing Validity of Evidence	Making Decisions [Informed by Evidence]	Collaborating to Problem-Solve
Case 1: Soil quality	X	X	X	X	X	x
Case 2: Species preservation	X	X	x	x	x	x
Case 3: Understanding the historical natural world	X	X	X	x	X	X

The affordances extended to the students to actively participate in solving ill-structured problems were not the same in each of these cases, but they collectively [10] suggest how students can practise the competencies of acting and thinking as scientists within contrasting contexts related to sustainability. Table 1 also summarises how the tasks can provide rich educational affordances enabling learners to think in different ways about soil quality affecting crop growth and food production (Case 1), to study wildlife without endangering species and therefore protect the local biodiversity (Case 2) and to critique evidence to hypothesize about the way the natural world works in terms of predator/prey interactions in real pre-historic habitats (Case 3).

This paper collates evidence from these three illustrative cases to indicate how active and participatory inquiries [10,12–14] afford opportunities for students to consider, discuss, deliberate and act with purpose to resolve authentic socio-scientific issues. As such, this article offers an original contribution that demonstrates how innovative practice can successfully support young students in rehearsing how to think and act in ways that promote understanding about different aspects of sustainability across three distinct scientific contexts.

2. Methodology

The approach taken in this paper is that of a collective case [15]. This has involved combining the evidence across three case study lessons from the classes of the same teacher. Each of the cases involve active, participatory science inquiries framed around three different science contexts. The impact of thinking and acting as scientists and learning about sustainability has been 'analysed across the cases' [16] (p. 10). This enables the systematic collation of practices concerned with SSIs, and the subsequent impact on learning to be coalesced in one place (Table 1), beyond one specific context, to enable 'synthesis' [17] (p. 42). Thus, a collective case comprising three individual case lessons is presented here. Each SSI addressed in Cases 1–3 is described in more detail below.

These three cases can be understood as 'bounded systems' [18] (p. 19), in the sense that they were each a singular primary science lesson. The dramatised participatory inquiries were all supported by the same teacher, so the cases resonated in time (the duration of the learning episodes), place (the environment, both real and imaginary), and participants (the teacher and her 9 and 10-year-old students). The collective analysis, therefore, illustrates how, across distinct dramatised inquiries designed to immerse and support learners engaging with and in scientific practices, students can come to understand and appreciate 'real world' socio-scientific issues. A variety of research methods were applied (Table 2) to explore this 'contemporary phenomenon' of students thinking scientifically and acting within relatable 'real-life contexts', where 'the boundaries between phenomenon and context' were considered [18] (p. 18). The three SSI cases within the collective case are further considered in turn below.

i. SSI—Soil quality

Case 1 is related to agriculture and involves investigating the impact of soil quality by examining what happens to radish seeds sown three times in the same compost (demonstrating a decline in quality of root vegetable and foliage) as well as the ways that plants grown for a wide variety of foods can be thought about in multiple ways. This relates to maximising vegetable food production to sustain human population growth.

ii. SSI—Species preservation

Case 2 re-orientates thinking about sustainability from a conservation perspective. The students are encouraged to consider the implications of Victorian scientists who investigated the natural world by digging up specimens (even those found overseas) and transporting them to museums (in England) for scientific scrutiny. This inquiry also highlights the development of scientific literacy, not only enhancing students' use of vocabulary but also illustrating how species can be studied in their natural habitat and remain undisturbed.

iii. SSI—Understanding the historical natural world.

Case 3 offers opportunities for students to think about scientific evidence represented as a series of three diagrams depicting where different fossilised footprints were found in the rocks uncovered in an old quarry. The dramatised inquiry involves the students thinking about fossils, fossilisation and Mary Anning's work as a fossil hunter. The inquiry also includes opportunities for the students to consider and act-out possibilities of the ways that dinosaurs might have lived in pre-historic times.

Across the three different socio-scientific contexts described above, participatory drama conventions were adapted to immerse the students in thinking scientifically about soil fertility and the impact on plant growth and species preservation, as well as understanding aspects of the historic natural world of dinosaurs.

Table 2. Summary of methods evidencing scientific citizenship.

Sustainability Topic of Each SSI Case	Thinking Scientifically	Thinking Critically	Interrogating Evidence	Assessing Validity of Evidence	Making Decisions [Informed by Evidence]	Collaborating to Problem-Solve
Case 1: Soil quality	Transcript of dialogue: students questioning teacher-in-role as agricultural scientist.	Photographs and transcript of discussion while students enact process of plant growth in nutrient-rich and nutrient-depleted soil.	Photographs and teacher recollections of student responses to the results of radish growth in various types of soil.	Photographs and teacher recollections of student responses to the results of radish growth in the same soil three times.	Photographs and teacher recollections about student decisions relating to the nature of vegetative material and its many potential uses.	Photographs and teacher recollections regarding student discussion about divergent uses of different crops.
Case 2: Species preservation	Transcript of dialogue: students questioning teacher-in-role as Victorian botanist.	Photographs, transcripts of discussions and students' hand-drawn pictures of a pitcher plant.	Students' hand-drawn images and photographs from activity discussing the morphology of a pitcher plant.	Transcript of dialogue: discussion about walking through an imagined forest floor.	Transcript of dialogue: students questioning how to minimize damage when walking through a rainforest.	Photographs and transcript of discussion while modelling the morphology of buttress roots.
Case 3: Understanding the historical natural world	Photographs [from video] of students modelling morphology and movement of ammonites/fossilised animals.	Teacher recollections and video of student's discussions interpreting what the fosslised footprints might mean.	Teacher recollections and moments from video relating to possible movement of dinosaurs represented by the fosslised footprints.	Teacher recollections and moments from video relating to student interpretations of movement patterns of dinosaurs represented by the fosslised footprints.	Photographs of hand-made clay models and dialogic excerpts where students created their own imagined fossilised creature.	Teacher recollections and photographs of students expressing and exchanging ideas.

Methods of Data Collection

Data collection was multifarious. Observation data from these cases, for example, comprised audio recordings, video, photographs, teacher notes as well as enactments and artefacts produced by the students themselves. Data were collected from both teacher and student perspectives, which enabled researcher insight into the teaching and learning processes involved in each SSI. Dialogic exchanges and visual data (from teacher and learner interactions) demonstrated how the activities, physical movements and enactments within the three science lessons emphasized different aspects of scientific citizenship. As such the methodological approach could be defined as a multi-method convergent approach [19]. Table 2 outlines the types of dataset collected, per case, and cross-references this with the ways the six facets of scientific citizenship were evidenced.

Combining the data from the three cases to construct the collective case study, reifies the nature of each of the bounded systems in different ways [20] (p. 4). For example, teacher notes taken during and after the lesson (as presented in Cases 1 and 3) provide evidence of the reflective construal of discussions in key activities. Photographs (from all three cases) and video screen shots (Case 3 only) present visual evidence of enactments.

Student-produced artefacts included, for example, clay models and hand drawn pictures. Interviews (Case 1) also elicited student recollections and recounted understandings of learning activities. Additionally, transcribed dialogue (Cases 1 and 2) provided clarity about discussion and utterances that emerged during the inquiry activities.

3. Findings

Each case has evidenced understanding about sustainability and the development of citizenship competencies in various ways, but the data quality varies in strength (Table 1). A cross-cases analysis of these various datasets illustrates how dramatised inquiries that consider distinct SSIs contexts can immerse and support learners engaging in, and with, scientific practices as they come to understand and appreciate 'real world' scientific issues. Each of the six facets of scientific citizenship are reflected on below, in pairs, as matched dichotomies: Thinking Scientifically and Critically; Interrogating and Assessing Validity of Evidence; and Making Decisions and Collaborating. This is not because they are natural pairings. Indeed, the dichotomies are false, but all six contribute, in reality, to a complex tapestry of related planes. However, combined and converged [19], together they suggest what it is to think and enact scientific practices as a citizen. These demonstrable couplings of scientific citizenship competencies are considered in turn, as they are presented in Table 1.

3.1. Thinking Scientifically and Critically

Students in Case 1 were invited to interrogate the teacher-in-role as George Washington Carver (GWC). GWC was a black, African-American scientist, born into slavery, best known for his experimentation in crop rotation to mitigate against nitrogen depletion in the soil. He also invented numerous unique products from the alternative crops which he encouraged local farmers to cultivate. Once the students had been orientated to his historical, lived context, they considered ways of physically modelling GWC's explanation of nutrient depletion in the soil. The enacted their interpretations of the various ways plant growth could be affected if nutrients, such as nitrogen, as well as sunlight or water, were not available (Figure 1).

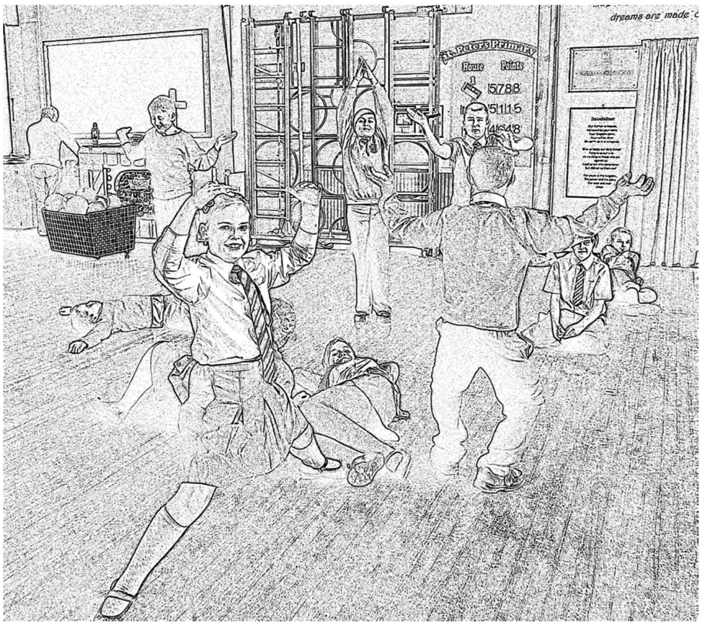


Figure 1. Students modelling the impact of nutrient depletion on plant growth. Image from observation depicting nutrient depletion (students lying on the floor), irregular and misshapen plants (girl standing with her feet wide apart and a boy standing with his knees bent; both pupils in the center of Figure 1) [21].

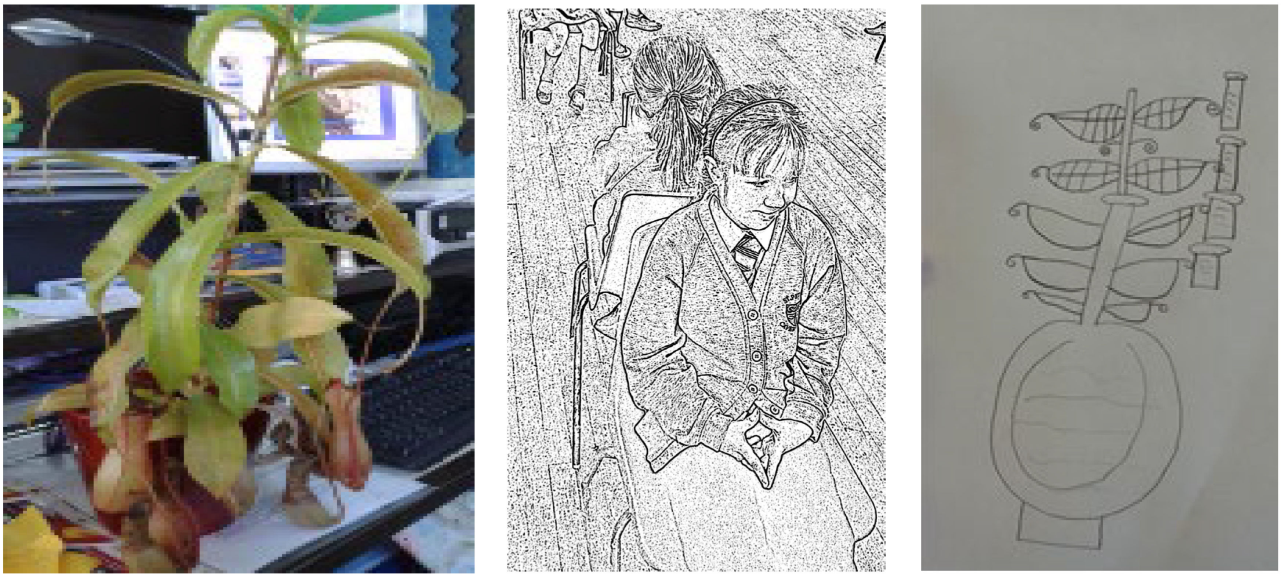
Modelling plant growth, as in Figure 1, offers a physical affordance beyond simply observing a botanical specimen growing. Through enactment of growth in alternate soils, the students are afforded an opportunity to critique the impact of nutrient depletion on vegetable growth. Working with others also afforded the students opportunities to assess the validity of their modelling (discussed further in the section below).

The students in Case 2, interrogated an adult, the teaching assistant (TA), acting in-role [22] as Marianne North (a 19th Century English Victorian biologist and botanical artist). Here, the teacher (or in this case the TA) assumes an 'expert' role and students pose inquiring questions after they have listened to her monologue about her life and work (ibid: 57). In excerpt 1 below, the TA is in-role as Marianne North and the students are asking questions.

> Student 1: Why (are you painting). Why are you doing it?
>
> TA: Why am I painting? Because I want people to see things what I can see when I go on my travels. I want to show people parts of the world and what I can see there.
>
> Student 2: You travel around the world?
>
> TA: Yes, I've travelled to lots of places.
>
> [. . . several ask how she got to the rainforest . . .]
>
> Student 3: Why are you going to different places?
>
> TA: Why am I going to different places? Because of the things I see far, far away in my travels; we don't see the beauties, the colours, the plants.
>
> Student 4: Everything you see, do you draw?
>
> TA: Not everything I see do I draw, but I draw a lot of what I see.
>
> Excerpt 1, transcript from observation

The original monologue, spoken by the TA in-role, described her international travels, by sea and land, and the numerous paintings she created of the flora she observed. In excerpt 1, the students are reflecting what had previously been orally presented by the TA. That is, they appear to be thinking critically about how and why she travelled a long way to reach the exotic plant life. They also appear to be considering why she (as Marianne North) had painted a range of plants in different habitats.

Marianne North chose to paint what she observed in-situ, for others to appreciate the natural morphology of unusual plants beyond the UK, demonstrating the extent of biodiversity elsewhere. Her actions prevented the need to up-root specimens from their natural environment for others to appreciate. Alongside this activity, in Case 2, half of the class remained with the teacher to look at and discuss the features of an unusual pitcher plant (Figure 2i). Echoing Marianne North's detailed observations of the natural world [23], some of the students were tasked with accurately reproducing the plant as a hand-drawn image. To further connect with preserving biodiversity, as Marianne North did, those students who had not observed the pitcher plant paired up, back-to-back, with a child who had (Figure 2ii). The child who had not seen the plant was then challenged to draw the plant using only their peer's verbal descriptions (Figure 2iii). This required the students (who had examined the pitcher plant) to carefully think about what they had seen to accurately recollect and describe its features. This then meant the paired student could create a hand-drawn image of the plant from the description they were given (Figure 2iii).



(i) (ii) (iii)

Figure 2. (**i**) An unusual plant used for close observation (photograph from lesson observation). (**ii**) Pupil drawing the unusual plant using verbal directions only. Image from lesson observation of two pupils sitting down, back-to-back. The child facing the camera had observed the unusual plant. The other is drawing the plant using verbal descriptions only. (**iii**) Drawing of unusual plant. (Drawing created by the pupil sitting behind the foregrounded pupil in (**ii**)).

3.2. Interrogating and Assessing Validity of Evidence

Interrogating and validating evidence was particularly noteworthy in Case 1 when radishes were grown multiple times in the same soil without replenishing the nutrients [24]. Here the students noted that the first crop was the healthiest, whereas the third was very small and misshapen (ibid). Indeed, a student remarked that watching seeds grow and making observations, as the scientist would have, helped them understand the decisions a scientist, such as GWC, makes when analysing the data they collect.

> "I guess if you understand where the original scientists happened upon it, I guess it helps you recreate that he saw what they went through and then if you do a similar technique, you kind of figure out it's like. If you don't know how they found out, there's no way that you're going to. Maybe the way they came across it is the best way to learn it."
>
> (Excerpt 2, from post-lesson interview, originally from McGregor et al., 2022 [24].)

This scientific way of thinking was also noted in Case 3 when examining a diagrammatic representation of fossilised animal footprints found imprinted in plates of rock in a quarry (Figure 3).

During this activity the teacher revealed the footprints in three stages (from Line 1 to Line 2) until the diagram was completely uncovered. After each reveal she invited the students to explain what they thought might have happened and/or generate a hypothesis about the pre-historic organisms and what might have happened. She noted down their answers as they articulated their ideas, suggestions and plausible explanations (see Table 3 for example responses).

To check the validity of one hypothesis, that a dinosaur had started running towards or chasing the other, the student who suggested it modelled how the creature might move. She modelled how it would move if it were walking (Figure 4i) as opposed to running after potential prey (Figure 4ii).

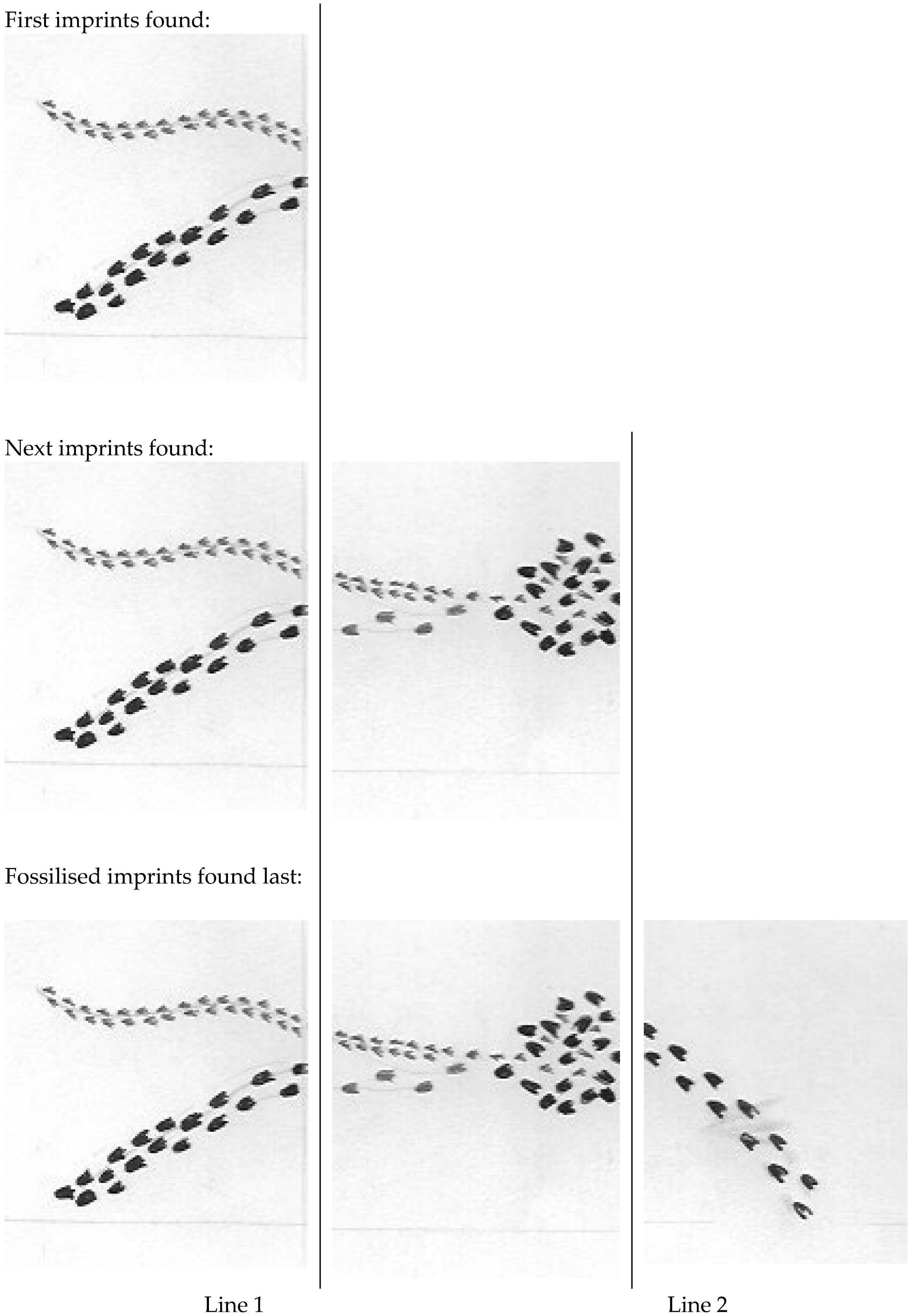
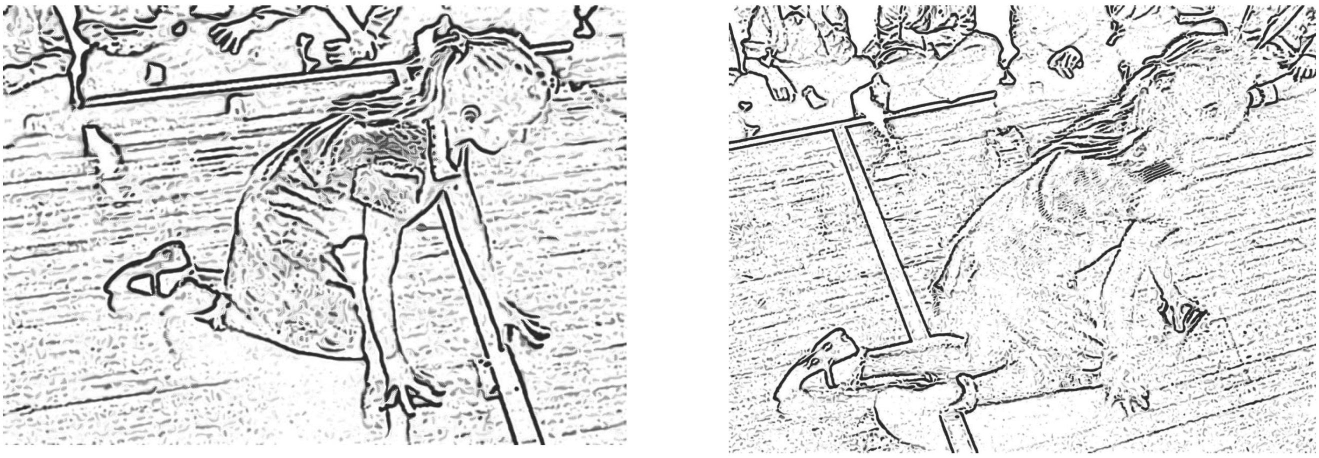


Figure 3. Fossilised animal footprints revealed in 3 phases, as inspired by the findings of King [25] and informed by American Natural History Museum [26].

Table 3. A range of students' interpretations and hypotheses regarding the fossilised footprints.

Students' Comments about the Fossilised Footprints Found First	Students' Comments about the Further Fossilised Footprints	Students' Comments Relating to All the Fossilised Footprints
The second dinosaur is different to the other—it has smaller and different feet.	The two dinosaurs are fighting.	The smaller dinosaur has been eaten!
The two dinosaurs look like they are going to meet up. Perhaps they are making friends?	The dinosaurs could be mating or making friends.	If one eats the other, where are the fossilised bones of the little one?
One dinosaur is chasing the other.	The big one will grab the little one and carry it off in its mouth to eat. There will only be the big footprints left.	The smaller dinosaur might have flown off.
You might be able to tell the type of dinosaur by their fossilised footprints.	One dinosaur is trying to get away.	If the footprints are deeper, maybe it is carrying the other one in its mouth to eat?



(**i**) (**ii**)

Figure 4. (**i**) Modelling a dinosaur moving at a slower pace. A screenshot from an observational video. A pupil is on all fours and moving very slowly. (**ii**) Modelling a dinosaur moving more quickly. This is a screenshot from the same video as (**i**). The pupil is still on all fours but is moving rapidly towards their prey (another pupil).

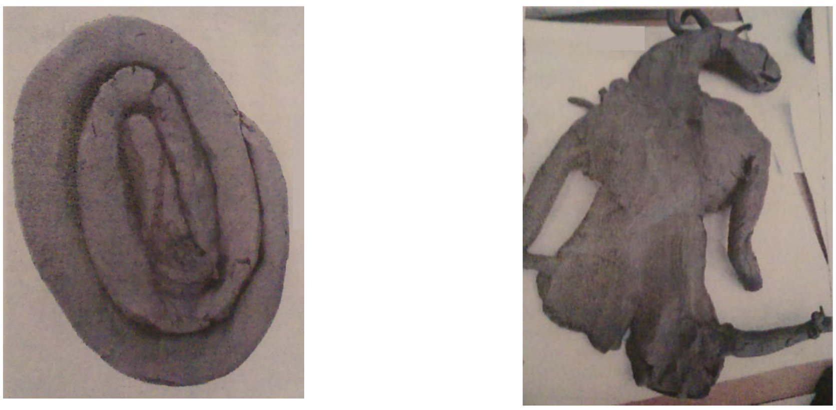
3.3. Making Decisions and Collaborating

Modelling or enacting ideas was also adopted during Case 2 when the students collaborated to think about how the roots of a tree support its mass. The teacher invited them to think further about the way they positioned themselves when she asked, 'Do you think you are big enough yet?' Some students decided to lie on the floor whilst others supported the mass of the tree by reaching into the centre of imagined tree trunk (Figure 5). To facilitate scientific thinking the teacher also asked, 'Why do you think the trees have all these extra bits?' and 'What do you think the job of buttress roots is?'

In Case 3, decision-making moments were demonstrated through verbal utterances as the students crafted their imagined clay models of fossilised prehistoric creatures (Figure 6i,ii with accompanying dialogue).

Further decision making and demonstrable collaboration in Case 1 was evident when students were invited, in groups, to think about ways that parts of a melon could be used in multiple, divergent ways so that nothing was wasted. This echoed GWC's scientific work when he devised over 300+ applications for the peanut [26]. Figure 7i,ii shows two of the students' products (jewellery and bowls).

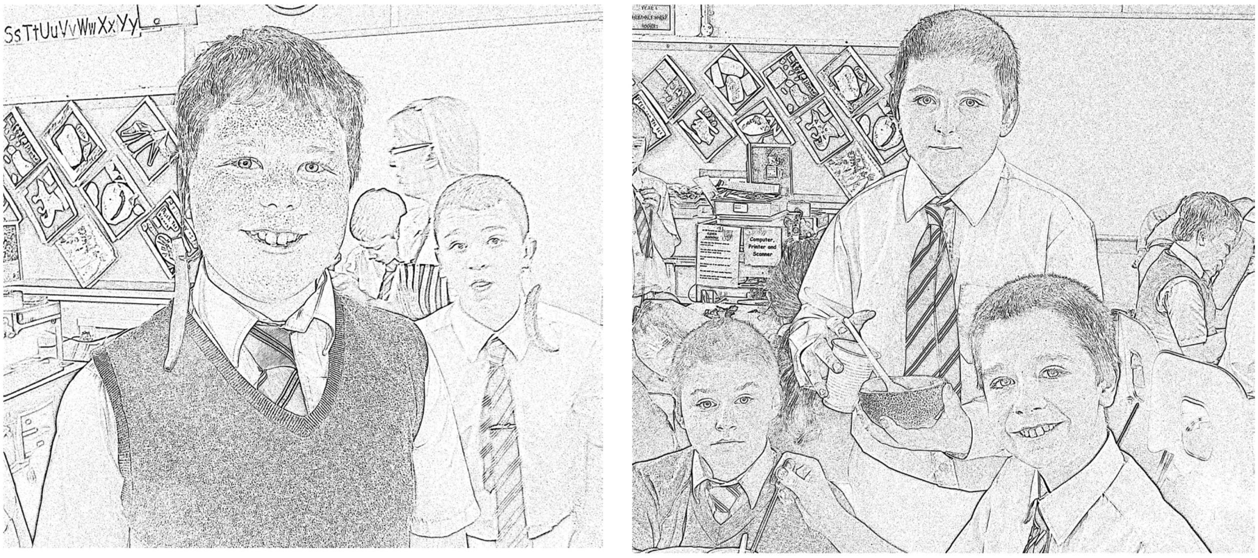
Figure 5. Modelling the base of a tree trunk. A photograph taken during lesson observation. One pupil is seen lying on the floor modelling being a tree root whilst others reach into the centre to support the height and mass of the tree.



(**i**) (**ii**)

Figure 6. (**i**) Clay model of an ammonite. 'I'm making an Ammonite and I'm just about to put the details on it'. (**ii**) Clay model of an imagined prehistoric creature 'I've done the end of the tail of my made-up creature called the Plasus . . . It's a long line with spikes like a Stegosaurus'.

With the conundrum of what to do with all the component parts of the melon (including those parts that are often thrown away, such as the skin and seeds) one trio of pupils reportedly devised '20 ways to use a melon' (teacher's recollections). The generation of multiple ways each part of the fruit could be adapted and used was akin to the way GWC explored how the peanut could be mashed, ground, dissolved, sieved, mixed and heated [27] to create different products. Indeed, in a similar way to the famous agriculturalist, the students reported that the products they were devising could 'help people use all parts of the melon', and 'especially when there when there is a glut' (teacher's recollections).



(i) **(ii)**

Figure 7. (**i**) Making and selling jewellery. In this photograph, taken during lesson observation, a pupil is demonstrating how to wear the earring he has fashioned out of a melon skin. (**ii**) Making bowls and dishes. A group of three pupils are demonstrating the bowls they have fashioned in this photograph. This picture was taken during lesson observation and the pupil in the middle is holding one of the bowls.

4. Discussion

It appears that, within a single inquiry with young students, is difficult to design activities which afford opportunities for them to practise all six scientific citizenship capabilities considered in this paper. However, taken collectively, a series of dramatised inquires, engaged in sequentially, can offer learning opportunities that can promote understanding and appreciation of sustainability across a range of real-life and everyday contexts.

The cross-case analysis suggests how participatory inquiry [10] can support students' scientific thinking, critiquing, consideration of the validity of evidence, informed decision-making and problem solving, all of which comprise aspects of scientific citizenship.

In devising opportunities for students to rehearse what scientific citizenship involves the nature of learning activities requires careful framing. In many other participatory inquiry activities included in other projects [10,24,28], the sequence, focus, citizenship competencies and/or scientific subject matter, including sustainability, for example, need to be clearly communicated with the students. With older students, more specific kinds of curricular materials or approaches may need to be adapted for their benefit [5].

However, providing distinct opportunities for students to practise 'being scientists' by drawing on authentic contexts can afford inclusive opportunities for all. As can be seen, they can afford opportunities to think scientifically and critically about evidence, assess and validate evidence and engage in decision-making to solve problems. Each task within each case, as indicated in this paper, does not equitably offer all those opportunities. Using different contexts and adopting the dramatisation of inquiries will inevitably offer differentiated opportunities to engage with scientific practices. Adopted appropriately they can provide a range of inclusive and effective opportunities for learners.

Theoretically, then, the findings from this study suggest that the design of an effective dramatised inquiry that addresses an SSI can relate to a real-world context. A successful participatory inquiry also requires context-related challenges. There should not be a clearly defined approach or strategy to resolve the problem or challenge so that learners can jointly (as participants in-role) seek to resolve the scientific issue.

Pedagogically, teachers designing immersive and participatory learning opportunities for students need to heed particular experiential characteristics. Where they wish students to seek resolution to an authentic scientific issue they should ensure learners are positioned to work together (in-role as scientists). Presenting learners with real-world observations and data is key, and engagement with the task/s should afford differentiated opportunities for resolution rather than direct them toward a specific or particular outcome. Participation in task resolution should also involve resonant objects that serve to mediate or catalyse students' thinking. Working towards a solution should inherently involve scientific practices (Thinking Scientifically and Critically; Interrogating and Assessing Validity of Evidence; and Making Decisions and Collaborating) that can be regularly rehearsed and are, indeed, highly relevant to the problem context.

5. Conclusions

The collective features (from a cross-case analysis as indicated in Tables 1 and 2) illustrate how dramatising an inquiry appears to be a successful approach for teaching aspects of sustainability and scientific citizenship [28] through emphasizing SSIs. The immersive and participatory learning approach [10,29] effectively positions the students to engage with 'citizenship as a set of critical practices', as also highlighted by others [30] (p. 476). Inherent within the approach are opportunities for students to practise negotiating meaning through discussion, to collectively address misunderstandings (often referred to as misconceptions), to consider alternate perspectives and co-construct forms of knowledge informing what each group produced. The adoption of dramatisation techniques [10,29] to support learning, enriches dialogic exchange [10] through rehearsing actions [24,28,29] and practising processes inherent to scientific inquiry [31].

The approach adopted in this paper promotes discussion and rehearsal of sustainable practice rather than 'taking' community action [32] in outside-school contexts [33,34]. Although the tasks within these cases were not designed to contribute to the civic community, findings from them have shown that dramatised or active participatory inquiries can successfully engage students in practising citizen science capabilities and thinking scientifically, including gathering and interpreting data, using evidence, critiquing evidence, interpreting representations and engaging with science [10,24].

This approach to promoting sustainable education focussed on three distinct areas of science. Not only was scientific understanding that related to three distinct contexts promoted, but consideration of the wider impact in society and natural habitats extended beyond the scientific facts presented. The case activities impacted on the ways that the students thought and acted. The evidence from the collective case study of participatory inquiries considered in this paper indicates how learning [35] about, and engaging in, scientific practices [10,21,22] involves the students discussing, thinking and deliberating over dilemmas, alongside acting (with the intention of being scientific) in ways that resonate with scientists concerned with solving problems [10,21,22,33]. As such, this article offers an original contribution that demonstrates how teachers' innovative practice can successfully support young students in rehearsing how to think and act in ways that promote understanding about different aspects of sustainability across three distinct scientific contexts. This dramatisation approach may well prove to be a substantial introduction for would-be science citizens of the future.

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