Examining the use of drama to develop epistemological understanding about the Nature of Science : A collective case from experience in New Zealand and England

Paper in preparation for the International Journal of Science Education (Part B)

McGregor, D[1]., Baskerville, D[2]., Anderson, D[2]. and Duggan, A[1].

Authors[1] from Oxford Brookes University, Oxford, UK
Authors[2] from Victoria University, Wellington, NZ

Abstract

Understanding the nature of science (NoS) is perplexing for young children because it is concerned with not only understanding how evidence is generated but also what kind of meanings can be made from information collected. However, acting as a scientist-in-role, making independent decisions about what information to collect and deciding how to go about it, can enable students to experience scientific practices that empower them to better appreciate and understand the NOS. This paper illustrates how drama processes, in two international settings in Wellington, New Zealand and Oxford, United Kingdom encouraged nine to ten year old children to engage in the scientific 'as-if' world. The data collected from these two locations was analysed deductively to illustrate how working-in-role can influence the nature of learning and shape the scientific practices experienced that consequently inform how the NoS is understood. The children in Wellington (New Zealand) worked in-role as atmospheric scientists to design a reduced-emissions race track. The class in Oxford (UK) adopted the role of technological scientists theorising about properties of materials to create and test original carriers designed to transport a range of everyday objects. How drama promoted working-in-role to experience scientific practices supporting the understanding of the NoS, are discussed. The findings suggest that being in-role as a scientist offered learners various opportunities to be agentive, to think and act scientifically, better appreciate the nature of work that scientists do and consequently appreciate the NoS.

Introduction

Understanding the Nature of Science (NoS) is challenging (Driver, Leach, Millar and Scott 1996; Lederman 2004; Lederman 2007; Lederman and Lederman 2014). There is still no clear and unequivocal definition that can be readily utilised and applied for teachers in science classrooms. However, there is collective agreement that it is of critical international concern (Lederman and Lederman 2014) and an important component of learning science, particularly for the purposes of citizenship (e.g., Abd_El-Khalick, 2012; Allchin 2014; Hodson and Wong 2014; Lederman and Lederman, 2014). As Duschl (2008) has suggested, to engage with science, students need to understand not only the relevant science concepts, but how they came to be, i.e., “how we know what we know” (Osborne, 2014 : 184). Exactly what students need to learn about the NoS has also been disputed. Much NoS-focused science education research has suggested that students should develop understanding of commonly agreed and generalised concepts or tenets abstracted from studies of the history, sociology and philosophy of science (Lederman, 2004; Lederman and Lederman, 2014). For example, Harlen (2011) suggests, that one of the big ideas students should learn about science is that “Scientific explanations, theories and models are those that best fit the facts known at a particular time” (p. 23). Such views of what should be learned about the NoS have been questioned. Hodson and Wong (2014) expressed concern that students could learn generalisations about the NoS without the depth of experience that would properly contextualise it. They suggest that learning about science itself is complex; the acceptance of a scientific claim is viewed in terms of its reliability and validity, which is inevitably interconnected with the scientific processes that developed it. Tala and Vesterinen (2015) envisaged the tenets of NoS as discussion starters. Abd-El-Khalick (2012) also suggested that the tenets represent a starting point for science teaching and learning rather than a final outcome, a view similar to that of Kampourakis (2016). Both Hodson (2009) and Allchin (2013; 2011) proposed that what students need to learn about NoS should be more functional than conceptual. A functional understanding of the NoS is reflected in the current United States National Research Council’s *Framework for K-12 science education* (2012) where students are expected to develop scientific practices as a goal for learning in science. A similar view of the NoS is expressed in both the New Zealand and English curricula as discussed in the methodology where the contexts for this study are outlined. Osborne (2014) argues that the idea of science as a set of practices (listed in Table 1) inform a more accurate representation of current understanding of the NoS as a social and cultural practice. The practices include: asking questions; developing and using models; constructing explanations; engaging in argument from evidence; planning and carrying out investigation; analysing and interpreting data; using mathematical and computational thinking; and obtaining, evaluating and communicating information (National Research Council, 2012). Osborne (2014) highlights the central role of critique in each of these practices.

Research into primary school students’ learning about the NoS provides a mixed picture. While it has been shown that young children are capable of developing useful ideas about the NoS (Akerson and Donnelly, 2010; Akerson and Hanuscin, 2007; Akerson and Volrich, 2006; Akerson, Weiland, Pongsanon, and Nargund, 2010), simply participating in a science investigation, even when the teacher has the intention of students learning about it, does not necessarily appear to result in improved understanding (Akerson and Abd-El-Khalick, 2005). The inclusion of explicit reflective instruction appears effective in furthering young students' appreciation of the NoS (Akerson, Weiland, Pongsanon, and Nargund, 2011; Khishfe and Abd-El-Khalick, 2002). A mix of both contextualised and decontextualised experiences of the NoS also appear productive (Akerson, Weiland, Pongsanon, and Nargund, 2010). Hodson (2009) suggests that instead of students developing a prescribed set of beliefs about the NoS, it may be more appropriate to engage them in critique and debate in science from which experiences they develop their own beliefs and understanding of the discipline. Osborne (2014) summarises the positive effect that participating in scientific critique and debate has on learning, of and about, science.

Participating in the practice of science relates strongly to sociocultural theories where learning is seen as participation in a community of practice (Wenger, 1991). Rogoff (2003), another sociocultural theorist, describes how offering children opportunities to take on a specified role is one means of guided participation that adults adopt to help children learn the practices of cultural communities. From an examination of the practice of science through a sociocultural lens, Ford and Forman (2006) proposed a framework for authentic disciplinary learning in science that involved students engaging in "practice as an interplay of roles" played by all scientists: "Constructor and Critiquer of claims" (pp. 4-5). When sixth grade students gained experience in these two roles they demonstrated a grasp of scientific practice that surpassed simply following procedures (Ford, 2008). Tucker-Raymond, Varelas, Pappas, Korzh, and Wentland (2007) highlighted the significance of children's experiences of science influencing development of their scientific identities and suggested that active participation is key in contributing to this.

To consider how drama can contribute to supporting and promoting scientific practices and actively coming to understanding the NoS it is therefore important to consider the kinds of learning opportunities afforded through the use of theatrical strategies.

Learning Science through Drama

Learning Science through Drama (LStD) is developing as a field of research. The range of approaches extend from Odegaard and Oiestad (2002) who report utilising the world of Ibsen, a playwright, to understand biotechnology; Craciun, (2010) who describes how the structure of matter and abstract physics phenomena can be explored through role-play. Ofsted (2011) even note how using props can more effectively convey and communicate scientific ideas. Warner and Anderson (2004) report on students being in-role as scientists designing snail care manuals and McGregor and Precious (2015) draw on stories about famous scientists to engage students enacting aspects of their life and work. The application of drama across a wide range of scientific contexts for secondary students is described by Abrahams and Braund (2012). Braund (2015) suggests how simulations where pupils portray scientific processes, for instance, 'acting out' being an X or Y chromosome within the process of fertilisation, fosters engagement and through the experience they develop conceptual science understanding. This kind of teacher-structured drama represents one of several ways that drama can be used to support learning science (Odegaard 2003). Odegaard also offers two other categories defining the extent to which teachers prescribe what learners should do, she suggests that 'semi-structured', (e.g., a framed role-play) provides some guidance and direction, whereas 'explorative' drama is that where children initiate the drama and are more spontaneous and self-directive in the way they engage with science. These three forms of drama (teacher-structured, semi-structured and explorative) suggest a progressive framework, whereby the less teacher direction and guidance the more autonomy and agency the children have that influences epistemologically what they learn through their drama experiences.

The use of drama to promote different kinds of learning

Structured drama : A choreographed approach

Theatrical conventions provide powerful frames (Neelands and Goode 2011 : 1) for learning through drama. The nature of action and language required to communicate to others, in small group collaborations or large class performances, is characterised and underpinned by discussion that is required for interpreting teacher directions and negotiating understandings about what is to be done. Directions that instruct students to 'mime' and represent as closely as possible how electrical circuits work (Tvieta 1996), kidneys function (Johnson 1999) or how photosynthesis works (Carlsson 2002) require transformation of concepts into a three-dimensional representational model. These kinds of tightly choreographed activities provide a 'concrete and personal experience' (Odegaard 2003 : 81) that improve student understanding and enable teachers to immediately 'see' and assess what has been understood. This is supported by Braund (1999 : 35) who also indicates how students modelling electrical circuits 'can understand a lot from other groups' presentations [….] you can see what they have gone through to explain the ideas because you have been there yourself'. Additionally, as Varelas *et al* (2010 : 302) suggests, even teacher-directed drama activities of this kind can offer students the opportunity to engage their bodies on multiple mediated levels, as 'material objects that move through space', as 'social objects that negotiate classroom relationships and rules' and as 'metaphorical entities' that represent particles in solid, liquid or gaseous substances or moving electrons in a circuit or the water moving through a tree'.

Semi-Structured : Adopting Role Plays as drama

Odegaard (2003) describes how less teacher direction in drama can be defined as semi-structured. She offers role plays as an example that can extend the nature of interaction between the learners to develop ‘cognitive, affective and technical objectives, especially higher order thinking skills relating to analysis, synthesis and evaluation (Ellington *et al* 1981; Wagner 1998; cited in Dorion 2009 : 3). Perkins (2002) also highlights how role-play can render ‘thinking more visible’. McSharry and Jones (2000) illustrate how role-play can offer cognitive engagement with scientific ideas. They describe a range of ways that intellectual rigour can be facilitated by the teacher as the students progress from ‘play’, to ‘games’ and finally to ‘stimulation’. Aubusson and Fogwill (2006) also recognise the cognitive benefits of dialogically based interaction in role plays, but despite the elicitation of ideas and the elevated discussion McSharry and Jones and Dorion indicate concerns remain regarding scientific ‘inaccuracies’ that may not be resolved in this kind of learning situation where there is less teacher control.

Epistemologically, learning in these kinds of situations arises through social interactions of a verbal and actional kind, engaged in to agree or disagree about (teacher determined) cognitive outcomes.

More exploratory : Using drama to work in role

Odegaard (2003 : 81) describes how this is kind of drama, drawing on the Mantle of The Expert (MoE) can be highly explorative, where the students have the freedom to affect *both* the process and the outcome. The MoE is a well recognised dramatic interventional approach developed by Dorothy Heathcote (1985). It provides a structure that can be adapted to engage in an inquiry. This approach enables students to become immersed in a particular context, the ‘frame’ (Aitken 2013 : 43), that is the crucial aspects of the situation in which the drama will unfold. It also involves the teacher generating a task as a justification for taking on a particular role within a situation or frame. The ‘commission’ (Aitken 2013 : 44) is the task or enterprise that a team or group of students undertakes. Working in a particular frame or context, given a challenge, task or commission, the role or ‘client’ (Aitken 2013 : 45) characterises the nature of personnel the learners are ‘acting’ as or on behalf of. Adopting these key elements of the MoE approach (as outlined in Table 2), the students can ‘see’ themselves as someone else as they become immersed in the frame and engage on the commission to achieve an outcome for the client(s).

In both locations of this project, the drama approaches drew on the MOE approach. They each provided the students with the opportunity to work-in-role as a scientist, to be more agentive (make decisions and act upon them), in authentic (Hume and Coll 2010) situations. The drama activities were also interactive and offered open learning opportunities (such as the commission). These aspects are key features of contexts to ‘set-up’ inquiry opportunities in science (Minner *et al* 2009). This is in stark contrast to the more teacher directed approaches, often used straight forwardly in regular science lessons which Braund

(2015) highlights consolidate *known* concepts, but which can constrain inquiry opportunities (Rowell and Ebbers 2004). Therefore, acting-in-role as scientists solving a problem, offers real opportunities for pupils to jointly consider what matters in a situation and work collaboratively to act on decisions to reach a resolution. Open inquiries offering these kinds of agentive space affords learners opportunities (Minner *et al* 2009 : 3) to consider what is salient and develop courses of action that can echo scientists deliberating and deciding how to conduct an inquiry and work out what the evidence means to draw conclusions. Working as a scientist in-role, therefore, can enable leaners to experience and rehearse scientific practices (within the MoE frame) that begin to help them understand and appreciate the NOS. Working collaboratively with others (for a client) on a well designed authentic task (as the commission, designed within the frame) can naturalistically develop opportunities for learners to practice being scientific.

Relating Scientific Practices, Inquiry and Nature of Science

Learning about the Nature of Science [NoS] and developing scientific thinking and practice is now a common requirement in many curricula internationally, but supporting such learning has been shown to be difficult (e.g., Harlen 2012; Lederman and Lederman 2014; Crawford 2014). Particular application of drama conventions can offer a pedagogy that has the potential to be useful in addressing this problem. This kind of learning draws on pupils' affective and cognitive capabilities. They enter a constructed world of would-be-scientists with multiple possibilities for engaging in, and contributing to a collective outcome. Through the two international cases, described in this article, where the students work in-role as atmospheric or technological scientists there are scientific practices (and inquiry processes) that become evident through engaging in their commission.

In the NZ setting, the commission positions children as atmospheric scientists undertaking to solve a local environmental problem through collaboratively designing a reduced-emissions racetrack.

In the English setting, the commission positions children as technological scientists considering properties of materials to resolve a problem with grocery carriers of the nineteenth century. A summary of the two commissions, which frame the drama interventions is provided in Table 2. The object of this paper is to examine the use of dramatic techniques, through rehearsing and practicing working-in-role as scientists to understand the NoS.to develop learners' understanding of the NoS in two international locations. teaching in both locations was concerned with exploring how using drama could enable children to

Conceptualisation of the NoS as participation in scientific practices, together with ideas about the roles that scientists assume, prompted the exploration as to whether drama could assist children's learning. Transforming the classroom into a scientific workplace through drama, offers children explicit experiences of being a scientist (Tucker-Raymond et al., 2007). It provides an opportunity for them to participate in the scientific enterprise by creating a practice field (Barab and Duffy, 2000). Practice fields are contexts in which learners can practise the kinds of activities that legitimate participants such as scientists use. They are separated in time and setting from the real field and comprise authentic activities carried out in an environment and circumstance as close as possible to that of the legitimate practice. We wanted to explore whether supporting children to be in-role as scientists could provide experiences that would support them to develop scientific practices in a would-be real-world context. Aikenhead's (1996) view of learning science as an act of border crossing also informed our thinking. We considered how taking on the role of a scientist would make the nature of the border (or discipline) crossing into science explicit; we thought that children may associate with science the practices and ways of being that they undertook when working in-role as a scientist, and thereby experience and appreciate what it means to be scientific. Reflecting on the ways that working-in-role could support young people learning about science we framed the following research question :

How can drama approaches that place children in role as scientists participating in and undertaking scientific practices, promote understanding of the NOS?

Methodology

This section will firstly consider the curricular imperatives which informed the context of the two international locations in which the project took place. Secondly the interventions that were devised will be described and finally the research approach (of using combined methods and deductive analyses) to develop the collective case study will be discussed.

The New Zealand curricular context

The NZ Curriculum places the NoS strand in the Science Learning Area as overarching and compulsory so that children can participate as critical and informed citizens in a society where science plays a key role (Ministry of Education, 2007). However, generalist primary teachers have little experience or support to develop NoS-focussed teaching approaches (Bull, Gilbert, Barwick, Hipkins and Baker, 2010; Education Review Office, 2010). The most recent curriculum support material for teachers characterises the NoS strand objectives as the development of a specified set of science capabilities for citizenship such as gathering and interpreting data, using evidence, and critiquing evidence (http://scienceonline.tki.org.nz/Science-capabilities-for-citizenship). For primary aged children the curriculum suggests they should build their experience and understanding of science through play and exploration. The Drama Discipline of The Arts Learning Area in the

NZ Curriculum (Ministry of Education, 2007) similarly highlights the importance of both individual and 'purposeful play' (p. 21). In this way, children link thought, feeling and imagination. Through being in role, through action and tension played out in time and space, children are able to express human experiences.

A persistent governmental focus since 2002 on literacy and numeracy in NZ primary schools has resulted in reduced classroom time for other aspects of curriculum (Thrupp and White 2013), creating a need for ways to address the requirements of different learning areas simultaneously. Additionally, the NZ curriculum directs teachers to exploit connections between disciplines to support learning: "All learning should make use of the natural connections that exist between learning areas" (Ministry of Education 2007 :16). In this context, it seemed useful to investigate the potential of integrating drama and science. Wellington primary children were therefore provided with opportunities for purposeful play in-role using drama conventions in ways that provided opportunity to learn about the NoS. The students were supported to be in-role as environmental scientists working for a company commissioned to solve a community problem by investigating ways to design a 'reduced-emissions' race track.

The English, UK curricular context

The current English, UK curriculum for primary science highlights the importance of students appreciating the processes and methods of science through practical activities. More recent policy documents emphasize how understanding of the NoS should be underpinned by children "working scientifically" (Department for Education [DfE] 2013 :169). In England, the focus on core subjects and testing in English, Maths, Phonics, SPAG (Spelling Punctuation and Grammar) and the abolition of the Science SATS at KS2 has taken focus away from testing scientific knowledge but there are very clear guidelines on working scientifically that should be covered at each stage of the primary curriculum. In the English National Curriculum of 2014 (DfE 2013), it is advised that children at upper Key Stage 2 should find out about the work of eminent scientists and that different contexts will be used for scientific inquiry to maximise student engagement. As a response to this, the children were given the task of solving the problem of transporting different kinds of objects using materials and available resources available in the Victorian era of the technological scientist, Mattie Knight (who had designed the machine which made flat-bottomed paper-bags). In the Oxford setting, children in Year 5 (aged 9-10) were supported through a scientific inquiry lasting two hours using a range of drama conventions. It was in this 'as if' Victorian context that the children worked in-role as technological scientists themselves.

The interventions in the two settings

The interventions carried out in the two international locations were influenced by their curricular contexts in their respective countries. However, the common characteristics of these two interventions, for the purpose of demonstrating how dramatization of the inquiries was enacted for the collective case study, is summarised in Table 2 and 3.

The NZ Intervention

In the NZ setting, the students invested in being in-role as atmospheric scientists. Students worked together to plan investigations, interpret data and graphs; make, critique and justify claims using evidence (Baskerville and Anderson 2015; Anderson and Baskerville 2016). As summarised in Table 2 and 3, the adapted MoE approach was a current science context developed into a fictitious narrative where students acted in-role as atmospheric scientists working collaboratively for a company solving a local environmental problem, boy-racers impacting on a local community. The commission required them to work in teams to design investigations to gather data on greenhouse gas emissions and use it to design a new race track. The client was a town councillor responsible for the funding of the track. Students, in-role as atmospheric scientists, were required to defend and justify their design choices. A range of drama conventions scaffolded learning, over four successive sessions. Various drama conventions (e.g.: role-on-the-wall and hot seating) were used to enable the students to become familiar with the skills an environmental scientist might need to solve problems, as well as the context within which they worked.

The role-on-the–wall convention involved an adult-sized outline drawn on a large sheet of paper that provided the space to collectively record what the students knew about nature of the work (i.e.: the environment in which the scientist worked) and capabilities this kind of scientist would need. Used as a diagnostic activity, this convention captured the students' prior understandings about the scientific context they were about to engage with.

The hot seating convention was used to provide additional information, ideas, and attitudes about an environmental scientist and what she did. Students, not in-role, questioned a Teacher-in-Role (TiR) who was 'playing' the scientist. The TiR, as scientist, recounted aspects of her time spent in a science organisation with atmospheric scientists: collecting and analysing samples, working together, using specialist equipment. The TiR was used to enter, authenticate and grow the "as-if" world, model scientists' behaviour and answer children's questions. The use of name badges also provided more specific opportunity for students to playfully engage students with the context of working as scientists. Children put on scientist name badges to signal that they were entering the "as-if" world. These experiences were planned to support them to take on a role, focus, use their imagination, play purposefully, and work as scientists.

The pretext was a noticeboard. It was a mechanism that activated the drama and provided opportunities to begin to learn about the NoS. The intention was that children perceived scientists as real people, involved in social and family activities when they recorded their birth dates on the birthday list and looked at photos of social club activities. On the noticeboard, they observed photos of scientists in the field to see the kind of work environmental scientists do. Recommendations from previous clients, company values, and health and safety posters depicted scientists as responsible for working safely, valuing sound evidence and collaboration with other scientists. Conference advertisements and company policy statements explained that the company expected its scientists to share their work and seek peer review. The words and images were provided so the children could understand who worked in this place and what their company valued. A close examination of this noticeboard, as well as drawing a picture of an object to represent what they needed in their staffroom, provided opportunity to invest in the drama, become part of the "as-if" world, see scientists as humans with needs and wants, and belong to this company. This experience at the same time provided information about scientists' practices and their work. This convention foreshadowed the commission. The commission letter arrived in the classroom immediately after the noticeboard activity. Scientists in this reputable company were invited to solve the problem of boy racers in a community by designing a reduced-emissions racetrack. Children accepted the commission. They proceeded to work in-role as scientists, planning fair tests to check aspects that would inform their track design, and interpreting graphs of data that corresponded to their design to make conclusions. They used the collective map-making convention to draw a map of the new track together and illustrate the ideas they developed. Dramatic tension, an element of drama in the NZ curriculum (Ministry of Education 2007), was introduced when the principal entered the classroom in-role as a city councillor. The principal managed the class from within the drama. He took on a city councillor role to explain that the council wanted justification to continue funding the commission, providing opportunity to deepen and extend children' inquiry and learning. The aim was to add mental pressure and emotional intensity to provoke a response, focus attention, and heighten children's involvement in the drama by justifying the commission to decide if it should continue. It was also a planned opportunity for children to use the evidence from their designed investigation to support their arguments and their track designs. The children participated in the whole-group role play in order to be present in the "as-if" world, investing in the discussion together, shaping the drama, using evidence to defend and justify claims, and taking a stance on a scientific issue.

The English, UK Intervention

In the UK setting, the teacher begins in-role as Mattie Knight, to model and introduce the technological scientist and provide background context to the drama inquiry. The teacher later works in a variety of ways, as an enabler or facilitator of the drama rather than continuing to act as (a TiR as) Mattie Knight. This is so that gradually the learners are re-positioned (McGregor and Duggan 2016) to become the scientist-in-role. Neelands and Goode (2000) describe the TiR as 'adopting a suitable role' (p. 40) to invite involvement and generate choices through the teacher moving in and out of role. The teacher is able to ask questions of the children, not to which s/he presumes to know answers, but through which s/he 'excites interest' or 'challenges' thinking (Neelands and Goode, 2000 : 40). Bolton (1984) sees the TiR as a dramatist; someone who controls the action from within and without, stepping in and out as the drama develops. They make decisions as to what is done next, based on what has gone before. It is an organic process, not a predetermined script, as outlined earlier. The teacher enables the children to share and develop their dialogue as they work collaboratively on their commission. The TiR is not the solo performer throughout the lesson, the class is not continually an audience although they might shift in and out of that role at points (Fleming, 1997). In the English classroom, the strategy of TiR was used to transport children into the imagined nineteenth century factory setting. The TiR as Mattie Knight introduced the Victorian factory by inviting students in groups to mime the specific workings of cutting, rolling and gluing (or fixing) machines. There was a pause in the action whilst the TiR, as Mattie, relayed witnessing an accident in the factory which inspired her design of an automatic catch mechanism to stop the machines working. The TiR relates how a problem like a machine not pausing if something (or someone) is trapped in it acts as a stimulus for Mattie Knight to think creatively to develop an original solution to a problem. This was related directly through a 'narrative link' (Neelands and Goode 2001 : 85), to the framed inquiry, to explain how they would then enter Mattie Knight's 'as-if' world again. The framed inquiry (as explained in Table 2 and 3) positions the students as technological scientists collaboratively solving a real-life issue of the nineteenth century, where coned shaped carriers used to transport groceries, spill out their contents as soon as they are placed on a table top. The majority of the session was focussed on the commission, working on designing, testing authentic materials (as listed in Table 3) and devising a 'fit-for-purpose' carrier. Towards the end of the 2-hour session, each group of 3 or 4 children, were invited in turn, as technological scientists, like Mattie Knight, to present their original blue-print design; describing why the proto-type carrier was constructed as it was and then, finally demonstrating how (using fair testing) it worked reliably and consistently to transport various objects. The remainder of the 'listening' class were in-role as members of the Patent Committee judging the originality and 'fit-for-purpose' design, insisted on a demonstration that showed fair-testing of each unique carrier produced. The teacher worked in-role as the Chair of the Patent Committee (the client) steering the class to a collective meeting decision (Neelands and Goode 2000 : 35) to determine whether or not the commission (of a useful, workable and original carrier) had been achieved. In so doing they applied the 'working scientifically' criteria laid down by the UK curriculum (DfE 2014 : 190).

In the UK setting (described in further detail in McGregor 2017), the students work in role as Mattie Knight, a technological scientist, working toward a better resolution than the cone shaped carrier used to transport goods from the grocery store to home. The commission was to devise, produce, justify and evaluate an original solution to the problem of transporting fragile or extremely heavy objects that had to be presented to the patent committee.

The school contexts

In the Wellington research, all participants, including children, their parents and caregivers, scientists, principal, and teacher, were well informed about the nature of the project prior to giving consent. Participation in this research project was voluntary, school and student identity were protected, and participants were offered the right to withdraw. The NZ case was situated in a multicultural school. Twenty-seven Year Five and Six children, aged between nine and eleven years, were involved in LStD; data collected through audio recordings of all four lessons, student artefacts (e.g., maps and investigation designs), ten student and three teacher individual interviews (before, during and post-process), and field notes from the teacher's and teacher educator/researchers' observations of the process is summarised in Table 4.

In the Oxford setting, the project school was a larger than average, mixed gender, primary school for children aged 5 to 11 years on the outskirts of Oxford. There were 22 mixed ability children aged 9-10 years old, who took part in the study for a half day (2 hours). The group of children involved a balanced number of boys and girls. At the end of the drama session, immediate feedback regarding the children's perceptions of the learning experience was elicited. Subsequently, a questionnaire was also completed by all children which aimed to ascertain their reflections of the session and the extent to which the drama enhanced development of their scientific skills and understanding. A few days after the drama intervention several children were interviewed. This focus group interview was structured to elicit their lasting reflections on the learning process and outcomes. The multiple sources of data from the two cases provides provided triangulation, enhancing the reliability of the data.

Research Approach

This study is not about a single 'case' in the traditional sense that Thomas (2016 : 12) suggests, or an event or even an instance. It is more about a set of circumstances, that relate to, and are concerned with, setting up opportunities for pupils to engage in scientific practices, by working in-role as scientists, and thereby develop an understanding of the NoS. The two enactments in different international settings are presented in this paper to explore what the use of drama pedagogy, adapted from the MoE approach (Heathcote 1984), might reveal collectively about teaching in this way to promote understanding of the NoS. In so doing, the analysis is framed to explore 'happenings' (Stake 2006 : 29) that emerge from the pedagogic approaches that have immersed learners in two novel situations and afforded them the opportunity to work-in-role as scientists. The phenomena, therefore, under scrutiny is the way the teachers illustrate (through their enactments) how to use dramatic techniques, informed by the MoE principles to develop learners' understanding of the NoS. Stake (2006 : 10) describes how a 'multi-case assertion' is possible by 'interpreting patterns of data' and focusing on 'issue-related observations'. This paper, then reports on the ways that across two settings, the teachers generate situations for children to learn about the nature of science through employing drama techniques. The influence of the pedagogic approaches is detailed in the analysis and the outcomes from these two class cases are 'studied jointly' in order to investigate the phenomena. The collective case (Thomas 2011 : 141) design involves combining the evidence from the two settings and 'analysing across the cases' (Stake 2006 : 10) using different methods (Table 4) to gather data (Table 5, 6 and 7) and subsequently enable 'synthesis' (Gorard and Taylor 2004 : 42). In the two different social situations (Mitchell 2006 : 27) drama conventions were adapted to construe a frame, commission and client (Table 2). So the 'intensive descriptions' of two 'bounded systems' (Merriam 2001 : 19) illustrate how the two cases resonated in time (the duration of the learning episodes), place (the environment; both real and imaginary), and the participants (the teachers and their 9 – 10 year old students). The analysis therefore, illustrates how drama approaches that immerse and support learners engaging in, and with, scientific practices might learn to be scientific and understand the NOS. Yin (2009 : 13) suggests that in 'some situations' all kinds of 'research methods might be relevant (such as exploratory research)'. In this paper a variety of methods are applied (see Table 4) to explore the 'contemporary phenomenon' within its 'real-life context' where 'the boundaries between phenomenon and context' have been considered (*ibid* : 18). The LStD approaches in two international settings, are intended to reveal an in-depth understanding of the consequences of inviting learners to take up alternate roles, i.e.: as scientists in contrast to their everyday life positions in school (as pupils) might recognise and understand the NoS. More specifically by combining the use of data, gathered through different means (or methods, as indicated in Table 4) an interpretative 'story' (Simons 2009 : 138) has been construed through a mixed-mode analysis.

Verifying the drama approach within the two settings

The teacher educators involved in the two international interventions had at least 15 years-experience in Higher Education, preparing teachers to teach 9 – 10 year old children. Each interventional episode was taught by both a science and drama teacher educator. All four educators had previously worked together. They agreed the 'pupil-in-role' approach within an MoE framework and planned their teaching accordingly. This was an innovative LStD approach (not carried out previously), but experientially each teacher educator was well informed about the NoS and the ways that scientific practices could be 'set-up' in a classroom situation. The approach drew on the adapted MoE framework (as detailed earlier, outlined in Table 2, summarised in Table 4 and implied in Table 5 and 6).

Findings

The Framework for K-12 Standards (National Research Council 2012), expresses an active goal for learning how science works. These standards emphasise teaching about investigations as scientific practices, which are perceived as essential for learning in science that contributes to citizenship. As described earlier, these practices include: asking questions; developing and using models; constructing explanations; engaging in argument from evidence; planning and carrying out investigation; analysing and interpreting data; using mathematical and computational thinking; and obtaining, evaluating and communicating information. They resonate quite overtly with both the English curricular requirements for *Working Scientifically* and the *Science Capabilities for Citizenship developed to support implementation of the New Zealand curriculum (Http://scienceonline.tki.org.nz/science -capabilities-for-citizenship).* These science practices (Table 1) provided a framework, alongside the combined data (Table 4, 5, 6 and 7) to inform the deductive analysis gauging the impact of LstD in the two different settings. The discussion that follows illuminates how the students responded to their experiences in-role of scientific practices.

We present the findings in two parts: Firstly we present these aspects in relation to the specific practices (Osborne, 2014) that formed part of the drama processes, that is engaging in argument from evidence, developing and using models, constructing explanations, planning and carrying out investigation, analysing and interpreting data, and obtaining, evaluating and communicating information (see Table 5). Secondly the ways that being-in-role supports the identification of scientists' dispositions, the nature of their work and the NoS is also evidenced (see Table 6 and 7).

Scientific practices that emerged from being in-role as scientists

The processes of comparing the two cases did not always provide the opportunity to develop and illustrate *all* practices. However, Table 5 summarises the practices engaged in and illustrates how engaging with (and in) scientific practices promoted understanding of the NOS.

From the NZ setting :

In-role as atmospheric scientists, the practice of engaging in arguments from evidence was apparent in the following excerpt from the interview transcripts, “I thought about all the data, is it going to be wrong, or is it going to be right because if it’s wrong, that means we have to go test it again and we have to do the exact same stuff and see what went wrong” (Eli interview). This student in class, also shared “I reckon if we wanted to keep less CO2 on the earth and for the environment, 50 is the best speed because 50’s our normal speed and it was the lowest CO2 (points to graph), I reckon we should keep that speed (Eli, defending his team’s track design to the rest of the class). The researchers also noted that the group leaders each referred to their data when defending their designs because they referred to the graphs of their findings to inform and defend their decisions (Researcher field notes). These responses illustrated that they were thinking about and demonstrating understanding of the way that scientists process information in order to make decisions and explain their findings from data in an evidence-based way. The students recognised the nature of, and work involved in, gathering scientific evidence; the data needed to be both reliable and to be collected in a consistent manner in order to develop the most effective design for meeting their commission. As they progressed they appeared to be learning to develop explanations, pursue the best explanation and apply how changes in car speed can affect emissions that impact on climate change. The designing-a-race-track commission found that *being scientific* involved these children using evidence to support claims and assessing the relevance of data in order to understand the impact of carbon emissions on climate change. The practice of engaging in arguments from evidence as part of the drama, supported the students experiencing the kinds of uncertainty scientists’ face when gathering knowledge and applying it to real world problems.

At the beginning of the drama inquiry, observational data gathered by the researchers included how the students engaged in the practice of planning and carrying out investigations. In groups the students designed investigations to measure emissions and gather evidence to inform their track design. They were also given an opportunity to critique the experimental designs of another team. Initially students’ responses showed no understanding of what to look for or how to offer scientific critique. This was not surprising, because whilst students are often engaged in developing a scientific inquiry, they are hardly ever encouraged to justify or critique their research deign or that of others (Anderson, 2014; Osborne, 2014; Watson, Swain, and McRobbie, 2004). A TiR strategy was included whereby two teachers in-role as scientists from the company evaluated a research design that was used to provide an example of scientific critique. Students were then given an opportunity to critique an investigational report from an alternate company for a project similar to that of their own commission. This time, the student responses showed a great improvement in their ability to offer scientific critique, “There are two concerns I have about your data: first you are using three different types of car so you may not know if they affect the results. Also you are using different amounts of fuel and the engines are different, so this may change your results as well” (Zoe). Another student offered a constructive suggestion that, “You should have done an equal amount of tests to be more accurate. Make the amount of petrol the same in each car” (Ephraim). In the documented research designs, most students (15 out of 17 student artefacts) were able to identify problems in the design of fair tests. Some students (6 of the 17 student artefacts) were able to suggest improvements to the design of a fair test. They carried out their scientific investigations in-role as scientists in an “as-if” world. This illustrated most could identify problems in the design of a fair test, and some were able to suggest improvements to the design, there was also evidence to suggest that many of the students engaged in the critical evaluation of the report from another company. They identified variables (car type, petrol quantity and engine size) and the ways in which these variables needed to be controlled in order to carry out a more methodical investigation. Akerson and Donnelly’s (2010) research in the USA aimed at investigating the impact of an extra-curricular science one-day programme on student views of NoS, provides further insight. In their study, when students drew connections across NoS elements they were working beyond teachers’ questioning, internalising their ideas, and even in some instances, applying their ideas to their everyday lives. Important to note here, too, is Ford’s (2008) claim that critique is vital to constructing accurate scientific knowledge and that students need to learn to critique in scientific ways (Ford and Forman, 2006). Zoe understood that the claim or inference drawn from the data was flawed; that this other company had not developed reliable knowledge as well as being able to identify ways to reduce error. Being in-role as scientists then, supported the students to think as scientists, and identify and test design problems. They experienced how scientists tested and evaluated problems and developed the practice of scientists by learning how to be critical in a scientific way. Students were developing their ability to assess what data is reliable and realistic, evident in the National Research Council (2012) dimension, which suggests that “scientists defend their explanations, formulating evidence based on a solid foundation of data” (p. 52).

There were also times during this drama-science learning inquiry process that students experienced the practice of analysing and interpreting data, for example, “Multiple hills produced less CO2 than a very high steep hill so we’ve got multiple hills” (Matthew, interpreting data from graph) and “We tested the straight section of the track and we decided to go 80 kilometres per hour because that was our lowest CO2 out of 50, 80 and 100. We did not use the lowest speed because it produced more CO2 than at 80 kilometres per hour.

We think we got a higher result for 50 because the engine had to work harder at that speed" (Tina, justifying the track design). Students communicated their results to others. They were able to interpret data presented to them in graphs when justifying their track design to other group members. They were able to summarise the main features of the data (Osborne, 2014), and suggest correlations (CO_2 emissions varied with speed, engine size and the nature of the road travelled). This evidence suggests that they were able to be scientific in their thinking: they examined data, considered possibilities, made inferences, and used evidence to justify their judgements. This aligns with Osborne's (2014) discussion of the K-12 framework of standards including that learning about science requires children to communicate with others about the relevance of the data so it can be used in evidence, to recognise when data is in conflict with expectations and when revision is required. When children talked about the impact of car speed, engine size and the nature of the terrain driven on in relation to CO_2 emissions, they were able to relate their ideas to their track design. They were developing an understanding of how scientists think about their work. Working in-role as scientists supported the students to think and behave as scientists. Another aspect of scientific practice, obtaining, evaluating and communicating information, was also illustrated in transcription excerpts, "Not everyone wants this track, but we need this track. This will help global warming…CO_2 will go down. We need this track" (Barrie explaining to others about his group's track design). Another student, also noted that "Trees are helpful. More small cars. We need to keep finding out about gas and air" (Noah reflecting on what influenced CO_2).

The students were able to talk about science, using scientific language. They communicated socially relevant scientific ideas as part of their defence of their decisions. Some children understood the importance and need for scientific work as well as the need for change because of their understanding of the work of scientists. These are interesting findings given that the Framework for K-12 standards (as referred to by Osborne 2014) claim that the scientific practice of obtaining, evaluating and communicating information, requires scientists to practice good communication skills. They need to not only read, interpret and produce text; they also need to be competent in oral communication. Mastery of these skills is evident in scientists' ability to precisely describe observations, clarify thinking, justify claims and clearly and persuasively communicate findings. Barrie communicates his ideas competently; he is persuasive in justifying his argument for change. Noah not only identifies findings but also implies potential future research. Working in-role as scientists supported these children to practice obtaining, evaluating and communicating information. Therefore, it is suggested that because students were able to communicate ideas about science articulately and present and justify arguments about their investigation, these students were demonstrating the acquisition of scientific practices. According to Osborne (2014) spoken communication is a fundamental practice of science, as children are required to exercise precision when describing observations, clarify their thinking and justify their arguments. Therefore, it appears that the work of students in the LStD processes described in this paper provides the opportunity to develop their scientific practices, supporting them to be scientific.

From the UK setting :

In the UK context there are also excerpts from discussions that illustrate how the students demonstrate a range of the scientific practices (listed in Table 2 and 5). Where the students are planning which materials are more or less appropriate to use to generate a unique carrier (see Figure 1) there are utterances (Table 5 and 6) that illustrate how they are imagining the materials might be used, reasoning what is the best to adopt for the base, handles, fasteners etc, as well as calculating how the objects (strawberries in one case, wet clothes in another) could be transported and then predicting what size holes (or waterproofed material) might be useful in different parts of the container (to ensure there is no escaping fruit, in the case of carrying strawberries, that could be washed in situ but the water drain away). Discussions during the lesson indicated how they have thought about, asked questions and offered suggestions to each other of a scientific and technological nature (this is also corroborated by their responses to the reflective questionnaire presented in Table 7). Some students stitched together hessian and created flaps of material to prevent loose items falling out; others generated padded bottoms and even separate compartments to their carriers so that eggs, for example, would be individually protected. Others generated shoulder straps or short handles. Some created fasteners from buttons and string or even brass spilt pins. Each solution produced by the groups, whilst they were in role as technological scientists illustrated empirical practices like engineers who need to appreciate the properties of materials they are using to develop a new structure and test the prototype under a range of simulated conditions.

Each of the groups successfully completed their commissions, and developed a strong feeling of achievement and felt a sense of their original work being the beginning of a bigger developing project that could impact on future inventions of carriers (see quotations in Table 6 particularly).

In front of the Patent Committee (just like Mattie Knight had to in 1871 when registering her new bag making invention) each group in-role as technological scientists had to describe, explain and justify how they constructed their carriers, why they used the materials they did as well as respond to questions (from students in-role as Patent Committee members) about how they overcame problems or challenges that confronted them. Constructing explanations and arguing originality was practiced by all the children in the Oxford classroom. Their authentic experience of designing, constructing and testing something made from resources available in Victorian times (Figure 2) enabled them to consider what was a real challenge (at that time) in their endeavours to achieving a successful outcome, as indicated by one student who said “It helped you imagine what it would look like if these things happen” (Sue, in an interview after the lesson).

The quality, variety and successful application of the carriers was such that several children felt like Stephen, who stated, “It felt like one day [the carrier] could be all over the world and everyone could be using it” (Stephen, in an interview after the lesson).

Recognition of scientists’ dispositions and the nature of their work that emerged from being in-role as scientists

Evidence from observations and elicitation of children’s views provided further insights beyond the development of scientific practices. Discussed below are episodes where they seemed also to have learnt something of the dispositions required of scientists and the nature of their work (see Table 3).

Combining the evidence from the two settings

The way that the evidence from the two cases can be combined to illustrate how the adaptation of MoE can enable young people to rehearse scientific practices and better come to understand the NoS is demonstrated in Table 5. Evidence in Table 6 also indicates how the nature of scientists work was illustrated through the students working in role in these two studies. As Ephraim stated in the NZ study, “being a scientist is hard work”. Seven other students shared his perspective when reflecting in class on the process. Eli’s comment earlier concerning the need for reliability of data also suggests an understanding that perseverance and resilience are characteristic of scientists’ dispositions, “…that means we have to go test it again and we have to do the exact same stuff and see what went wrong” (Eli interview, NZ) and “…If the stuff is wrong you need to rethink it” (Zoe, NZ).

The children were observed to collaborate in their teams as they worked on their commission, as exemplified in a conversation from the English case when children worked to complete a task under pressure:

Sarah : Shall we have these at the top?...

Marion : Yes, we need to decide…

Leyla : I can put buttons on, I am good at buttons”

Phillipa : Do you have any ideas?

This kind of dialogue illustrates teamwork and collaboration, students asking for ideas and volunteering to complete aspects of the tasks they are good at. The excerpt suggests how working collaboratively and sharing ideas through collective endeavours can be effective where there is a clear, common and attainable goal. Working as a team is not only preferable but almost essential for a scientist to be successful in today's world. This way of working appears to have supported the students identify collaboration as a feature of scientists' work, indicated by the comment, "I learnt that scientists have to share ideas (Wendy, England in interview). As corroborated by another student, "All scientists have to share ideas and work as a group because if a scientist tried to make something by themselves, it would probably just end up failing or it wouldn't be that good" (Nile, England in interview). Students from the NZ study, also highlight how, "… you have to work together" (Zoe, NZ), "… you have to work together as a team to get it happening" (Barrie, NZ) and "… having lots of scientists gets the work done faster" (Tina, NZ).

These children understood that when they shared ideas, worked collaboratively and took notes, they were behaving like scientists. All the children were observed to engage in the science learning through being in-role. Many recognised the value of drama for engaging them in learning about science; the props appear to have helped them believe in their role, and support learning in an alternate context, develop their sense of inclusion, commitment and confidence in tackling their 'commissions', "You're being like, being included, like having a badge on and having the books to write in and all the data and like when we had to design a track, it made you feel like you were actually doing it and you were actually in the proper meeting room" (Mathew, NZ). Being a particular character in-role, helped too, "Just having a character helped me be more confident, I liked being a character and I liked sticking to that character, making everything how it should be" (Tina, NZ) and this focused their endeavours, "You are concentrating more because you have to put yourself in the person's shoes…you listen more" (Wendy, England).

Even though some students felt that "Drama means you can pretend" (Christian, England), several also communicated that "I was actually a real scientist, I was in my lab, out in the field, testing the pacman [gas sampling] machine and [investigating] how CO2 pollutes the air" (Eli, NZ).

In the Oxford classroom, after the lesson the students completed a reflective questionnaire that explored their personal views of the drama inquiry. They were asked whether they increased the number of questions they personally posed; thought of new ideas; tested ideas; observed things changing; compared things; used evidence to make conclusions; used scientific words; made decisions like scientists, thought like a scientist, acted like a scientist and, indeed, thought they were being a scientist. The ways they thought they were being scientific when in role is summarised in Table 7 (which was analysed using the chi-squared test and found to indicate significant impact at the 0.05% level).

These varied forms of evidence indicate how drama used in this way really does succeed in supporting children to feel they can be someone else. In-role, they each took on the identity of a scientist, working hard to complete what they perceived as important tasks.

By working in imagined as-if worlds, the children engaged in scientific practices, discourses and inquiry experiences all associated with being-in-role as a problem-solving scientist.

This pedagogical methodology of introducing an ‘as if’ context, ensuring pupils work with materials associated within that imagined world to respond to an invitation to solve a credible issue (the resolution of which is not pre-determined) within that context, offers an approach that overcomes many issues recognised as barriers to learning through inquiry (Minner *et al* 2009; Harlen 2012) to develop scientific literacy (Taber 2012) that contributes to understanding the NoS (Lederman 2014).

By ‘setting-up’ situations in which children could think and behave with purpose, teachers promoted ways of pupils working as scientists-in-role (e.g., describing observations, clarifying thinking, justify claims, and clearly and persuasively using evidence), so that they were developing their understanding of the nature of the work that (atmospheric and technological) scientists do.

These findings suggest that being in-role as a scientist afforded children various opportunities to be agentive, to think and work scientifically, consider and argue about meanings and relevancy of data which honed their scientific literacy to better appreciate the NoS.

Discussion

Lederman and Lederman (2011) argue how NoS can simply be seen as the critical component of scientific literacy. Straight forwardly, from a young child’s perspective, it could be summarised as being able to appreciate how they did something (in a logical and robust way) that provided information (or evidence) that helped them come to know something new. In this article the ways that a dramatic inquiry has been set-up in two international settings to support this kind of learning is discussed. Both settings adopted and adapted the MoE and provided a Frame, a Commission and a Client to develop the purpose and justification and context for learners to work in-role and practiced scientific ways of working. The UK intervention was also informed by a particular character from history, and was more technologically based than the NZ inquiry. However, it possible to consider bounded (Stenhouse 1999) and fuzzy (Bassey 1999) generalisations that emerge from these two settings combining to develop a collective case of the particularity and complexity of coming to understand how adopting principles from an MoE approach can position children in-role as scientists participating in, and undertaking scientific practices that resonate with the nature of scientists’ work, to promote understanding the NoS.

Conclusion

This paper presents two quite different situations in which the LStD approach adopted for this study has drawn from an adaptation of the MoE. Within both settings the authors have explored the impact of drama applied to support children to work scientifically, engage in inquiry practices and participate in associated discussions to achieve the tasks posed and thereby develop their understanding of the NoS.

According to the K-12 Framework, scientific investigations may be carried out in a laboratory, or in the field. However, this study suggests a third kind of location, that of the "as-if" dramatized world. Meaningful learning activities that invite pupils to work in-role as scientists, within an 'as if' scientific situation and face an appropriate, contextualised challenge can provide a learning experience that enables children to appreciate what it is (or was) to be a scientist and to think and act in scientific ways. In both the NZ and UK settings, the key three features of an adapted MoE appeared to be a 'frame' providing a scientific context, the 'client' for whom learners adopt an appropriate role and the 'commission' or task, which offers a clear and purposeful opportunity to solve a problem identified in the framing of the drama (as outlined in Table 2). Through the opportunities afforded the children adopted high levels of responsibility, worked in-role as problem solvers, investigated and resolved issues that existed in the chosen expert occupation (Heathcote, 1984), in this collective case that of a scientist. Being in-role as scientists supported children to think, create, collaborate, behave scientifically and undertake scientific tasks. In both countries, the key pedagogic features to nurture scientific practices, literacy and an understanding of the NoS have become more apparent. Further work is now needed to extend and evidence the ways that 'frame', 'commission' and 'client' can be successfully adapted for inquiry learning (Crawford 2014 : 516) across the science curriculum for students of all ages. Crawford (2014) explains why inquiry learning in the science classroom is 'surprisingly rare' and Harlen (2012 : 99) summaries why is it challenging for young learners to develop the skills of 'observing, collecting evidence, making predictions, testing possible explanations and interpreting findings'. However, this collective case illustrates how teachers can pedagogically adapt and support an 'as-if' world approach, through drawing on the MoE framing, that can successfully engage learners to think critically, ask questions, design and carry out investigations, interpret data as evidence, generate arguments, build models, and communicate findings (Crawford 2014 : 515). In the two international settings, each of these constituent activities listed above contributed to inquiry processes and some kind of resolution.

Characterising LStD this way to promote inquiry could provide a pedagogic tool that addresses the challenges Harlen (2012) and Lederman and Lederman (2014) indicate faces teachers. It appears to enhance their scientific literacy (Taber 2012) including recognising societal influences of the work of scientists.

In summary, there are three important implications of this collective case. The findings contribute to informing the nature of pedagogy that can offer genuine inquiry opportunities for learners and alongside this illustrate how scientific practices can be engaged in to support the development of both scientific literacy and understanding of the NoS.

References

Abd-El-Khalick, F. (2012) Examining the Sources for our Understandings about Science: Enduring conflations and critical issues in research on nature of science in science education. *International Journal of Science Education, 34(3)* 53-374.

Abrahams, I. and Braund, M. (2012) *Performing Science. Teaching Chemistry, Physics and Biology through Drama*. London : Continuum.

Ackroyd-Pilkington, J. (2010). Acting Role and Representation. *Research in Drama Education: The Journal of Applied Theatre and Performance, 6*(1).

Aitken, V. (2013). Dorothy Heathcote's Mantle of the Expert approach to teaching and learning: A brief introduction. In D. Fraser, V. Aitken, and B. Whyte (Eds.) *Connecting curriculum, linking learning* (pp. 34-56). Wellington: NZCER Press.

Akerson, V. L., and Abd-El Khalick, F. (2013) How Should I Know What Scientists Do?—I Am Just a Kid": Fourth-Grade Students' Conceptions of Nature of Science. *Journal of Elementary Science Education, 82* 1-11.

Akerson, V.L., and Donnelly, L.A. (2010). Teaching nature of science to K - 2 students: What understandings can they attain? *International Journal of Science Education, 32*(1) 97-124.

Akerson, V.L., and Hanuscin, D.L. (2007). Teaching nature of science through inquiry: Results of a 3-year professional development program. *Journal of Research in Science Teaching,44*(5) 653-680.

Akerson, V. L., and Volrich, M.L. (2006). Teaching nature of science explicitly in a first-grade internship setting. *Journal of Research in Science Teaching, 43* (4) 377-394.

Akerson, V. L, Weiland, I., Pongsanon, K., and Nargund-Joshi, V. (2010). Evidence-based strategies for teaching nature of science to young children. *Journal of Kirsehir Education, 11*(4) 61–78.

Allchin, D. (2014). From science studies to scientific literacy: A view from the classroom. Science and Education, 23(9) 1911-1932.Allchin, D. (2013). Teaching the nature of science: Perspectives and resources. Saint Paul: Ships Education Press.

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. Science Education, 95(3), 518–542.

Anderson, C. (2004) Learning in 'as if' worlds : Cognition in drama in education. Theory into practice. 43 (4) 281 – 286

Anderson, D. (2014). What makes it Science? Primary teacher practices that support learning about science. *set: Research Information for Teachers;* 2014(2) 9-17.

Anderson, D. and Baskerville, D. (2016). Developing science capabilities through drama: Learning about the nature of science through a guided drama–science inquiry process. *set: Research Information for Teachers*; 2016(1) 17-23.

Aspires – Young people's science and Career aspirations, age 10-14 www.kcl.ac.uk accessed August 2015.

Baskerville, D. and Anderson, D. (2015). Investing in the pretend: A drama inquiry process to support learning about the nature of science. *set: Research Information for Teachers*; 2015(1) 50-57.

Bassey, M. (1999) Case study research in Educational Settings. Buckingham, MK : Open University Press

Bolton, G. (1998) *Teacher in Role- acting behaviour (*from Ackroyd- Pilkington, J 2010 *Acting, Representation and Role'* Research in Drama Education: The Journal of Applied Theatre and Performance,

Bolton, G. (1984). *Drama as education: an argument for placing drama the centre of the curriculum.* London: Longman.

Bowell, P., and Heap, B.S. (2013). *Planning process drama: Enriching teaching and learning.* Abingdon: Routledge.

Bull, A., Gilbert, J., Barwick, H., Hipkins, R., and Baker, R. (2010). Inspired by science. A paper commissioned by the Royal Society and the Prime Minister's Chief Science Advisor. Wellington. New Zealand Council for Educational Research. Accessed 21 July 2015.

Braund, M. (1999) Electric drama in science *School Science Review* 81 (294)

Braund, M. (2015) Drama and learning science : An empty space? *British Educational Research Journal* 41 (1) 102 - 121

Crawford, B. (2014) From Inquiry to Scientific Practices in the Science Classroom. In N.G. Lederman and S. K. Abell (Eds) Handbook of Research on Science Education. Vol II.

Cowley, S. (2007). Getting the buggers into drama. London: Continuum.

Craciun, D. (2010). Role-playing as a creative method in science education. *Journal of Science and Arts, 1*(10), 175-182.

Dorion, K. (2009) Science through drama : a multiple case exploration of the characterististcs of drama activities in secondary science lessons. *International Journal of Science Education 31 (16) 2247 - 2270*

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of Research in Education, 32,* 268-291.

Department for Education (2014). *The national curriculum in England. Framework document.* London: Crown Copyright

Education Review Office. (2010). *Science in Years 5 to 8: Capable and competent teaching.* http://www.ero.govt.nz/National-Reports/ Science-in-Years-5-to-8-Capable-and-Competent-Teaching-May-2010/Overview. Accessed 6 June 2010.

Fleming, M. (1997). *The art of drama teaching.* London: David Fulton Publishers.

Flyvberg, B. (2011) Case study. In N. K. Denzin and Y. S. Lincoln (Eds) The SAGE Handbook of Qualitative Research. London : SAGE Publications Ltd.

Ford, M. J., (2008). `Grasp of practice' as a reasoning resource for inquiry and nature of science understanding. *Science and Education, 17*(2-3) 147-177.

Ford, M. J., and Forman, E. A. (2006). Redefining disciplinary learning in classroom contexts. *Review of Research in Education, 30*(1), 1-32.

Harlen, W. (2011) Why is learning science important in primary schools? In W. Harlen (Ed) ASE Guide to Primary Science Education. Hatfield : Association of Science Education

Harlen, W. (2012) Scientific Inquiry. In J. Oversby (Ed) ASE Guide to Research in Science Education. Hatfield : Association of Science Education

Heathcote, D (1984). *Collected Writings on Education and Drama edited by Johnson and O'Neill*. London: Hutchinson.

Heathcote, D., and Herbert, P. (1985). A drama of learning: Mantle of the Expert. *Theory into Practice, 24*(3), 173-180.

Heathcote, D., and Bolton, G. (1985). *Drama for learning: Dorothy Heathcote's mantle of the expert approach to education.* Portsmouth: Heinemann

Hodson, D. (2009). *Teaching and learning about science. Language, theories, methods, history, traditions and values*. Rotterdam: Sense.

Hodson, D., and Wong, S.L. (2014). From the horse's mouth: Why scientists' views are crucial to nature of science understanding. *International Journal of Science Education 36(16)* 2639-2665.

Jackson, A 2013 *Education or Theatre? 'Learning through Theatre'* ed Jackson and Vine Routledge 2013Kampourakis, K. (2016) The "general aspects" conceptualization as a pragmatic and effective means to introducing students to nature of science. *Journal of Research in Science Teach*ing, 53(5), 667-682.

Johnson, G. (1999) Kidney role-plays. *School Science Review* 80 (292) 93 – 97

Khishfe, R., and Abd-El-Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. Journal of Research in Science Teaching,39(7) 551-578.

Lederman, N. G. (2004). Syntax of nature of science within inquiry and science instruction. In L. B. Flick and N. G. Lederman (Eds.), *Scientific inquiry and nature of science* (pp. 301-317). Dordrecht: Kluwer Academic.

Lederman, N. (2007) Nature of Science : Past, present and future. In S. K. Abell and N. G. Lederman (Eds) Handbook of research on Science Education. p.831 – 880) Mahwah, NJ; Lawrence Erlbaumn Associates

Lederman, N. G., and Lederman, J. S. (2014). Research on teaching and learning of nature of science. In N. G. Lederman and S. K. Abell (Eds.), *Handbook of research on science education (Volume II)* pp. 600-620. Abingdon: Routledge.

Lement, W 2013 *TIE as a Catalyst for Civic Dialogue 'Learning through Theatre'* ibid.

McGregor, D. (2017) Using drama within a STEM based context : Developing inquiry skills and appreciating what it is to become a scientist. *Journal of Emergent Science.* 12 p.16 - 24

McGregor, D. (2016) Using drama pedagogies to develop children's understanding : reflections on learning in science contexts. Cambridge Primary Review Trust conference, UCL, London. 'Primary education: what is and what might be' on 18 November, 2016.

McGregor, D. and Duggan, A. (2016) *Empowering learners through a dramatic enquiry.* Paper presented at British Educational Research Association Annual Conference. September 14th 2016. Leeds University, UK.

McGregor, D. and Precious, W. (2015) *Dramatic Science. Inspiring ideas for (5 - 11 year olds) learning science.* London : Routledge

McGregor, D., Anderson, D., Baskerville, D., and Gain, P. (2014). How does drama support learning about the nature of science: Contrasting narratives from the UK and NZ. In C. P. Constantinou, N. Papadouris and A. Hadjigeorgiou (Eds.), E-Book Proceedings of the ESERA 2013 Conference: Science education research for evidence-based teaching and coherence in learning: Part 6: Nature of science: History, philosophy and sociology of science (pp. 22-33), Nicosia, Cyprus: European Science Education Research Association. Accessed 16 February 2014 from http://www.esera.org/media/esera2013/Debra_McGregor.pdf

Merriam, S. B. (2001). *Qualitative research and case study applications in education.* San Francisco: Jossey-Bass.

Ministry of Education. (2007). *The New Zealand curriculum*. Wellington, NZ: Learning Media.

Morgan, N., and Saxon, J. (1987). Teaching Drama: A Mind of Many Wonders

Morris, G. (2005). Practicing role play: learning through experience. *South African Theatre Journal*. 19(1), 58-71.

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165.

Neelands, J. and Goode,T. (2000). *Structuring drama work: A handbook of available forms in theatre and drama.* Cambridge: University Press.

Ofsted (2011). *Successful Science. An evaluation of science education in England 2007-2010.* Manchester: Crown Copyright.

Ofsted (2015) Key Stage 3 : The wasted years. Available at www.gove.uk/government/organisations/ofsted. Accessed 23.6.18

Ødegaard, M. (2003). Dramatic science. A critical review of drama in science education. *Studies in Science Education, 39*(1), 75-101.

Ødegaard, M., and Oiestad, P. A. (2002). 'Gen-gangere' : exploring the borderland of knowledge, biotechnology and Henrik Ibsen's dramatic world. NJ (Drama Australia Journal); v.26 n.1 p.91-101; 2002.

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education*, *25*(2), 177-196.

Ozbek, Gokzen. (2014). Drama in education: Key conceptual features. Journal of Contempoary Studies, 1, 46-61.

Perkins, D. (2002) Making thinking visible. Available at http://www.pz.harvard.edu/resources/making-thinking-visible-article-0. Accessed 16.5.18

Rogoff, B. (2003). *The cultural nature of human development.* New York: Oxford University Press.

Roth, W. M. (1995) Authentic School Science. Knowing and learning in open-enquiry science laboratories

Simons, H. (2009) Case Study Research in Practice. London : Sage

Somers, J. (1995). Drama in the curriculum. London: Casell Educational.

Stake, R. E. (2006). *Multiple case study analysis.* New York: The Guildford Press.

Taber, K. (2012) Teaching and learning about the nature of science. In J. Oversby (Ed) ASE Guide to Research in Science Education. Hatfield : Association of Science Education

Tala, S., and Vesterinen, V. (2015). Nature of Science contextualized: Studying Nature of Science with scientists. *Science and Education, 24,* 435-457.

Tvieta, J. (1996) The drama model of electricity. Paper delivered to the 8th Symposium of the International Organisation of Science and Technology Education, Edmonton. University of Alberta.

Tucker-Raymond,E., Varelas, M., Pappas,C.C, with Korzh,A., and Wentland, A. (2007). “They probably aren’t named Rachel”: Young children’s scientist identities as emergent multimodal narratives. *Cultural Studies of Science Education1*(3) 559–592.

Thomas, G. (2011) *How to do your Case Study. A Guide for students and researchers.* London : Sage

Thrupp, M., and White, M. (2013). Research, analysis and insight into National Standards (RAINS) project final report: National standards and the damage done. Accessed 8 May 2017 from http://researchcommons.waikato.ac.nz/handle/10289/8394

Warner, C.C., and Anderson, C. (2004). ‘Snails are science’: creating context for science inquiry and writing through process Drama. *Youth Theatre Journal, 18*(1), 68-86.

Watson, R., Swain, J., and McRobbie, C. (2004). Students’ discussions in practical scientific enquiries. *International Journal of Science Education, 26*(1), 25–46.

Wenger, E. (1998). *Communities of practice: Learning, meaning and identity.* Cambridge: Cambridge University Press.

Figures and tables

Figure 1 : Examples of carrier plans under construction

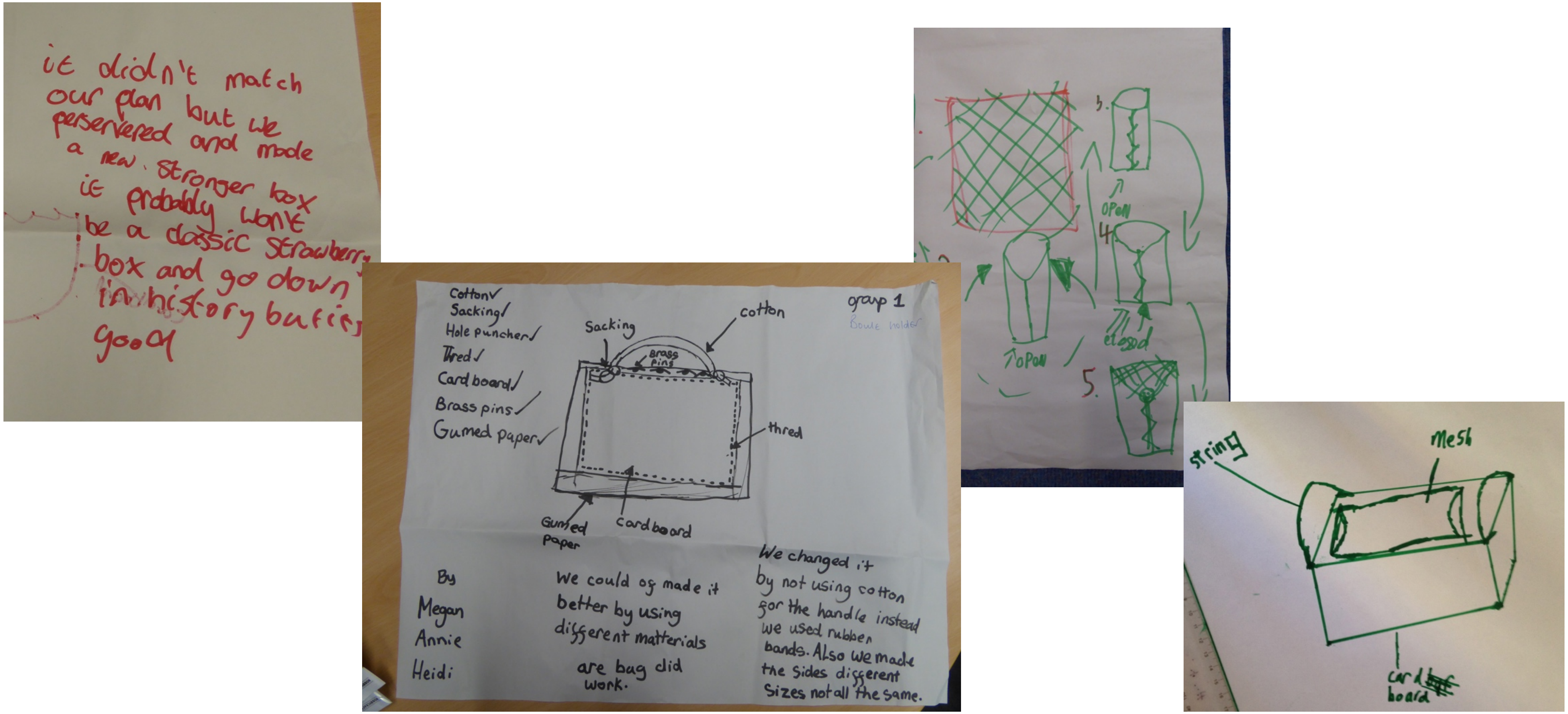

Figure 2 : Examples of artefacts produced when in-role as Mattie Knight.

Scientific practices	Key opportunities to develop scientific practices whilst working-in-role during the different drama approaches	
	NZ setting	UK setting
Asking questions	In this case the major inquiry was part of the commission and teams investigated the impact of a variable identified by the researchers. Students asked questions in their teams to clarify their choice and control of variables and in interpreting their data	Students querying how their work-in-role could impact on future scientific (or societal) developments.
Developing and using models	This practice was not a focus in this study.	The act of being-in-role enabled the students to test the strengths and limitations of different materials for specific functions.
Constructing explanations	Teams discussed and suggested possible explanations for their results in making choices about their design of the racetrack.	Students prepare in groups a justification *and* explanation of their carrier designs. These are captured in diagrammatic forms and explained to the patent committee.
Engaging in argument from evidence	Students used evidence from graphs to inform and defend their decisions about their racetrack designs in presenting to the councillor.	Question and answer (interrogation) between the members (in role) of the patent committee and each group of technological scientists required evidenced and substantive arguments to explain the process and outcome of their work.
Planning and carrying out investigations	Students in groups collaborated to design an investigation to measure emissions and gather evidence to inform their track design. Each team was given a variable to test and a team investigation sheet scaffolded them to decide on the ranges to be tested.	Students planned together in groups what their design would be. They also investigated which materials worked effectively for different components (handles, base, fasteners) of their carriers.

Analysing and interpreting data	Students analysed genuine data on emissions in graphical form. They interpreted bar graphs for their own investigations, summarised and suggested correlations between CO2 emissions and speed, engine size and the nature of the road travelled to inform their designs and in defending their track design to the councillor.	Students devised tests that involved using their original carriers to transport particular objects for a standard length of time and a standard distance without breaking or spilling contents.
Using mathematical and computational thinking	Students in groups interpreted graphical representations of their data, as above, in order to make choices for their track design.	Students in groups collaboratively design (and plan diagrammatically) what their carrier will look like on paper before being allowed access to the materials. They mathematically considered how properties of different materials (like strength and flexibility) determined how they were used.
Obtaining, evaluating and communicating information	After TiR modelling, most students were able to evaluate a report of a fair test in a similar context and identify problems in its design.	Students engaged in the processes (of obtaining, evaluating and communicating information) during their presentations (and justifications regarding their designs) to the patent committee. They also made systematic judgements of other groups' solutions as members of the patent committee.

Table 1 : Descriptions of the ways that Osborne's (2014) scientific practices were enacted in the two drama settings.

Key Features adapted from MoE	Atmospheric scientists to design a reduced-emissions race track (Author & Author, 2015; Author & Author, 2016)	Technological scientist creating original carriers to transport a range of everyday objects, e.g. : Mattie Knight (Author & Author, 2016)
Frame (Frames the context within which the pupils take on various roles)	Developed from a real and current science context as a fictitious narrative. Pupils in-role as teams of atmospheric scientists in a company investigating ways to reduce greenhouse emissions for a new race track designed to solve the problem of boy racers in a local community	Developed from a real context of an historical narrative. Pupils in-role as Mattie Knight (located in C19th with only materials available at that time) to solve carrying issue of different kinds of objects.
Commission (Provides the justification for taking on a role)	Develop investigations to gather evidence that informs the design of a race track with reduced greenhouse gas emissions.	Design and create a carrier specifically for transporting different objects (that are heavy, voluminous, small, sodden etc).
Client (Provides specific purpose and reason(s) to provide evidence to solve a problem identified in the framing of the drama.	To secure funding for the race track, the scientists (students in-role) need to persuade a town councillor of its worth, using evidence from their investigations.	Nineteenth century patent committee judging the quality of carrier design, the appropriate use of different materials and usefulness (whether it is fit for purpose).

Table 2 : Descriptions of three key features adapted from Mantle of the Expert (Aitken 2013 : 43 - 45) in the two settings carrying out dramatized inquiries.

Nature of scientists work	**Interpretation of the way that working-in-role can provide a real scientific experience**	
	NZ setting	UK setting
Real world context for the scientific work	The commission provided students with an opportunity to consider that car use contributes to greenhouse gas emissions that lead to global warming.	Issue with nineteenth century cone shaped carrier that is not appropriate for i. placing on counter top without spilling contents and ii. inappropriate carrier for eggs, strawberries, books etc
Problems to solve	Designing investigations to gather data in order to identify ways to reduce car emissions.	Devising an appropriate carrier from authentic C19th materials
Equipment used : Using materials or resources directed related to the commission (or task to be undertaken).	Putting on badges to signify when students were moving into role as scientists. Recording observations and thoughts in notebooks. Planning to use authentic scientific equipment (gas sampling) when designing investigations. Working with graphical data.	To generate a real solution (for the commission), the following were available to choose from : Hessian, brown (parcel) paper, cotton cloth, brass split pins, needle and thread, string, gummed paper (and damp sponge).
Scientists' dispositions		
Perseverance	Although students experienced frustrations collectively through role plays and in team decision-making, they overcame these because there was contextual justification for persevering to reach a solution, i.e., gathering reliable data and presenting evidence to defend their designs for a reduced emission race track to the councillor.	Time was extremely tight in two hours to design, produce, rigorously test carrier and present justification for materials used to patent committee. However, every child engaged with the task(s) and was a member of a group producing an original artefact *and* scientifically judging whether the quality of such.

Collaboration	This was evidenced through the ways that the students engaged in constructive verbal exchanges, teamwork and joint problem solving. Asking each other for suggestions, volunteering to complete tasks where they have expertise, such as in the map making, or taking leadership in presenting to the councillor, and working together toward a shared goal.	Each child was a member of a team producing their own unique carrier and devising ways of arguing and justifying how the properties of a particular materials were appropriate for their use.
Childrens' perceptions of scientists' work through being-in-role.	Reflective discussions and post-lesson interviews illustrated how students understood the ways that teams of scientists share resources and work collaboratively. Some students related to taking notes that assisted scientists in their work.	Being-in-role the students could become someone else and explain how they felt working like a technological scientist, producing something that could really be used by other people.

Table 3 : Relating the 'frame' to the nature of working as a scientist in two international settings.

Methods of data collection	NZ setting	UK setting
	Nature of data gathered	**Nature of data gathered**
Audio recordings	Student discussions as they worked in teams Class reflection circle on the completed process	Teacher and pupil verbal exchanges during the intervention
Photographs	Pictures of process and students engaging with the drama conventions used during the process	Photographic records of the students in-role and on-task (including the written plans; students actively collaborating to construct their solutions; final artefacts produced etc.).
Video recordings	Team discussions and presentations that were transcribed.	Not utilised
Textual analysis	To elicit students' ideas about scientists' work and thinking, prior to and after they witnessed the TiR as atmospheric scientist, the technique of *Role on the wall was used.* Students wrote Inside a life-size outline of a scientist what they thought atmospheric scientists would think about. On the outside of the outline they wrote about what they think an atmospheric scientist would look like, wear and do.	Not utilised
Student work samples	These included : team plans of investigations, maps showing track designs and individual critiques of fair test reports.	Annotated design plans captured through photographing them as they emerged and through observation of the final product presented by each group to the patent committee.
Interviews	With the students to gather information about the students responses to the drama and its usefulness in supporting learning about science.	Focus group discussion with a small group of students (male and female) designed to elicit their views of the use of drama to learn science and their reflections of working-in-role as a scientist.
Questionnaires	Not utilised	Students were invited to complete reflective questionnaires after the interventional drama experience.
Researchers' field notes	Observations of teacher actions and pupil responses	Observations of teacher actions and pupil responses

Table 4 : Data collection methods applied in the two settings of the collective case.

Scientific practices (listed in Table 1)	Excerpts from transcripts of discussions or interviews illustrating engagement in scientific practices.	
	NZ setting	UK setting
Asking questions	Students asked questions in their teams to clarify each others' choice and control of variables. They also queried each others findings (researcher observations).	"It got you thinking quite a bit- do I need that? Should I put this back? Do we actually need this?" (Alex from Oxford school reflecting on making carriers from original materials in interview)
Developing and using models	This practice was not a focus in this setting.	" you needed to stick to the materials that they would have had back then" and "we were using the materials from Mattie's time" (Jordan reflecting on using drama to learn about science, being given materials that would have been available in C19th). " it got your mind thinking about how you could use materials from another era" "it was really interactive and…. involved with the lesson" (Rebecca reflecting on the drama helped to learn the science). "we needed to persevere" " we had to see what jobs the materials can be used for" (Laura in Oxford reflecting on the Mattie Knight drama where they made carriers for specific objects in interview)
Constructing explanations	Teams discussed and suggested possible explanations for their results in making choices about their design of the racetrack (researcher observations).	" when you were explaining your bag it was a bit nerve wracking with 20 children in front of you staring at you like this….but you've made it so you have something to talk about" (Ben reflecting on being in front of the Patent Committee consisting of his peers and being asked to explain the group design in interview)
Engaging in argument from evidence	"I thought about all the data, is it going to be wrong, or is it going to be right because if it's wrong, that means we have to go test it again and	Carriers are tested for purpose and the 'patent committee' is asked to make a judgement on whether the carrier is fit for purpose. This entails drawing

	we have to do the exact same stuff and see what went wrong." (Eli, NZ) "I reckon if we wanted to keep less CO_2 on the earth and for the environment 50 is the best speed because 50's our normal speed and it was the lowest CO_2 (points to graph). I reckon we should keep that speed. (Eli, defending his team's track design to the rest of the class, NZ) 5/6 group leaders referred to the data when defending their designs. (lesson transcript, NZ).	together the design explanation, the diagram and finally testing out the carrier. Children make a collaborative decision based on this data " you made it so you have something to talk about" (Jordan recalling the process of the patent committee in interview)
Planning and carrying out investigations	"There are two concerns I have about your data: first you are using three different types of car so you may not know if they affect the results. Also you are using different amounts of fuel and the engines are different, so this may change your results as well" (Zoe, NZ). 15 of 17 students identified at least one problem with the design; six students identified at least three problematic aspects. (Student work, NZ). "You should have done an equal amount of tests to be more accurate. Make the amount of petrol the same in each car" (Ephraim, NZ). Six of 17 students identified at least one improvement in the design (Student work, NZ)	Children plan together and test the bags. The work is carried out in groups. This in-role investigation elicited this response from a student: " We were real scientists and we got to actually pretend that we were designing a bag" "it made me want to be a scientist as it made me think and felt a challenge" (Amy, in response to how they are thinking and acting like a scientist and how this helped her to imagine the work of a scientist in interview)
Analysing and interpreting data	"We tested the straight section of the track and we decided to go 80 kilometers per hour because that was our lowest CO_2 out of 50, 80 and 100. We did not use the lowest speed because it produced more CO_2 than at 80 kilometers per hour. We think we got a higher result	This was evident when each of the student groups in turn presented and justified the originality and functionality of their designs to the patent committee (researcher observation).

	for 50 because the engine had to work harder at that speed."(Tina, justifying the track design, NZ)	
Using mathematical and computational thinking	"Multiple hills produced less CO2 than a very high steep hill so we've got multiple hills. (Matthew, justifying the track design, NZ)	The carrier is planned as a design on paper before children are given materials to use. Discourse during this activity suggested mathematical thinking in a technological setting "We're going to get two pieces of fabric in equal sizes. We will sew down the sides and one handle will be here and the other on the opposite side." Students talked about making a "2D symmetrical shape" (Zoe interacting with another student during the carrier making activity and how they were going to construct their bag for the specific purpose they had been given from lesson transcript)
Obtaining, evaluating and communicating information	Not everyone wants this track, but we need this track. This will help global warming…CO2 will go down. We need this track. (Barrie, NZ). Trees are helpful. More small cars. We need to keep finding out about gas and air. (Noah).	" you are concentrating more because you have to put yourself in someone else's shoes" (Ben reflecting on how the drama helps the learning of science in interview). "It got your mind thinking","we acted quite a bit like a scientist cos you had to draw a diagram and send it off" (Emily recalling the activities and how it enabled them to act like a scientist in interview).

Table 5 : Illustrative excerpts from transcripts of lessons from the two settings to demonstrate engagement in scientific practices.

Nature of scientists work (identified in Table 3)	Excerpts from transcripts of discussions or interviews illustrating enactment of scientific practices.	
	NZ setting	UK setting
Context for work	I was actually a real scientist and I was in my lab, out in the field, testing the pac man machine and how CO2 pollutes the air (Eli, NZ).	'It felt like that one day the bag could be all over the world and everyone could be using it in the future' (Abi, UK reflecting on the bag her group made).
Problems to solve	'I think they [scientists] just experiment, how we did the car thing … and try and come up with ways to replace that [fuel], for other things.' (Zoe, NZ).	' I need to try something and see if this works' 'Wet sports gear will get wet and it will fall out. I think it should be made out of fabric' (Jordan UK trying out different ways of making her carrier secure). 'It feels like a whole new world of creativity and thinking- what am I going to do today? What do I need and how am I going to do it?' (Gemma UK).
Equipment used	'You know, like having the badge on and having the books to write in and all of the data' (Mathew, NZ).	'when we were making the bags we only had original materials to choose from and a scientist would have had these things as well' (Abi, UK).
Scientists' dispositions	'I thought about all the data, is it going to be wrong, or is it going to be right because if it's wrong, that means we have to go test it again and we have to do the exact same stuff and see what went wrong" (Eli, NZ).	'My mother is a scientist and it felt good to learn what they do' (Emily, UK). 'It made me feel in a whole different world with a team of scientists' (Joe UK) 'Our team's first plan was to use sacking but the thread was hard to get through the sacking and it developed my strength just trying to get it through' (Emily UK in interview reflecting on the process of making the carrier).
Perseverance	If the stuff is wrong you just need to rethink it. …. I think it was good all together because we could remember it really fresh. (Zoe, NZ)	'It made me feel really good drawing our diagram and doing it because…we actually got to finish it and that made me feel like a proper scientist' (Ben,UK) 'It made me think quite a lot because you had to plan out

		everything and think a bit more' (George, UK being asked what it felt like to be a scientist)
Collaboration	Getting into a team was difficult, [getting] some particular people to listen and not be silly. I learnt about team work and how you need to keep trying (Zoe, NZ).	'All scientists have to share ideas and work as a group because if a scientist tried to make something by themselves, it would probably just end up failing or it wouldn't be that good' (Joe, UK reflecting on team work).
Children's' perceptions of being in-role	You're being like, being included, like having a badge on and having the books to write in and all the data and like when we had to design a track, it made you feel like you were actually doing it and you were actually in the proper meeting room (Mathew, NZ**).**	**'**I felt like we used our imagination..we had to imagine what was inside the building, what it would look like and what it would be like' (Emily, UK). 'You got to experience what it felt like to be under pressure of doing it in a limited time' (Sam, UK). 'You felt, because you were in role, you felt like you were actually a real scientist who was trying to change the world by making this bag that would work and be easier' (Abi, UK).
	Scientist field notes were very useful because I forgot a lot of stuff so you could just write it down while you still have them in your brain (Jason, NZ).	
	Just having a character helped me be more confident: I liked being a character and I liked sticking to that character, making everything how it should be (Tina, NZ).	

Table 6 : Quotations from transcripts of discussions in the two settings to illustrate the students' views of working as a scientist

	% childrens' responses in UK setting post intervention lesson (n = 22)
asking questions	100
thinking of new ideas	100
testing ideas	96
observing how things change	68
comparing things	86
use evidence to make conclusions	91
use scientific words	100
make decisions like a scientist	86
think like a scientist	96
act like a scientist	96
be a scientist	96

Table 7 : A summary from the reflective questionnaires the students completed in the UK setting. *This data was analysed through chi-square testing and the difference with what would be expected was shown to be statistically significant at the P = 0.05 % level.*