Chapter 5: Creative Exploration

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Introduction

Children are naturally curious and explore in order to make sense of the world; play and exploration are vital to their learning and development. Space and support for children to think, ask questions, make predictions, experiment, look for explanations and draw conclusions is essential in primary science. This 'children's science' emerges naturally as they seek to learn about the world around them (Johnston 2008) and develop creative explanations of natural phenomena. Adopting such an exploratory approach to teaching and learning science can mirror aspects of the ways in which professional scientists work.

Children's spontaneous explorations are often prompted by aesthetic experiences that promote affective and emotional responses. Their explorations are associated with dispositions such as fascination, anticipation, engagement, awe, wonder, interest and curiosity and can lead to the use of scientific enquiry to develop explanations of natural phenomena. Inquiry-Based Science Education (IBSE) which is internationally recognised and fairly widely practised (Asay and Orgill 2010), builds upon children's playful explorations of the world around them. While definitions of IBSE vary, Minner et al (2009) argue that these variations relate to the stress given to: *what scientists do* (e.g. conducting investigations using scientific methods), *how students learn* (e.g. actively inquiring through thinking and exploring phenomena or problems, often mirroring the processes used by scientists), and *the* *pedagogical approach teachers employ* (e.g. designing curricula that allow for extended investigations). This chapter focuses on children's own inquiries and the role of play and exploration, highlighting the potential of IBSE. In particular it draws upon the voices of children from New Zealand and those involved in a recent EU project *Creative Little Scientists*, (CLS) undertaken in nine European countries - Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania, UK. In exploring the pedagogical connections between IBSE and creative approaches to learning, the CLS team noted that play and exploration were core features of both approaches (Cremin et al., 2015). In addition they recognised other common features, including: motivation and affect, dialogue and collaboration, problem solving and agency, questioning and curiosity, reflection and reasoning, and teacher scaffolding and involvement. This chapter focuses on creative exploration, provides examples of this in action and seeks to support teachers in planning for such playful scientific inquiry.

Creative exploration is a sequential or cyclic model of exploring for understanding in children's science. It is based on the assumption that children naturally seek explanations for experiences that have some effect on their feelings, attitudes and the manner in which they think about or view natural phenomena. Children will often construct novel explanations when seeking to understand and explain the phenomena observed in their aesthetic experiences. The outcome of such creative explanations is an enriched understanding, especially if the learner involved has communicated and justified his or her ideas with others. In educational contexts children participating in rich aesthetic experiences of natural phenomena can be guided by informed facilitation towards a greater depth of personal understanding. This authentic process of enquiry not only leads to the development of personal conceptual understanding, but can also promote procedural knowledge and a tentative appreciation of the nature of science. Although the approach is presented here in a linear fashion (Table 5.1), it can be viewed as cyclic or iterative in nature. A child can follow the whole process or may only engage in/complete certain parts. The more elements of the process experienced, the deeper the engagement and development of understanding.

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Children's science

Creative exploration, a co-constructive inquiry-based approach to teaching primary science, requires both the teacher and learners to be involved in experiencing scientific phenomena. In this way it mirrors IBSE. Harlen (2013: 1) provides the following rationale for this approach:

> Embracing (IBSE) recognises its potential to enable students to develop the understandings, competences, attitudes and interests needed by everyone for life in societies increasingly dependent on applications of science. Inquiry leads to knowledge of the particular objects or phenomena investigated, but more importantly, it helps to build broad concepts that have wide explanatory power, enabling new objects or events to be understood. It also engenders reflection on the thinking processes and learning strategies that are necessary for continued learning throughout life.

A fundamental cornerstone of this approach is that the nature of the science involved is made explicit. At any time the teacher and the children will be able to answer the question: 'How is this experience *science*?' This assumes that both the teacher and the learners have a personal understanding of the essence of science and that aspects of it are discussed, explored and applied in a natural enquiring manner. If the teacher wishes to foster children's creativity in and through science education then an understanding of the essence of creativity will also be needed. As discussed elsewhere in this book, children use their previous experiences and imagination to create and shape explanations for experiences of natural phenomena that intrigue or interest them. For these often highly creative ideas to be classified as 'scientific' children need to be able to identify and share the evidence they have used to formulate their explanations. These explanations supported by evidence are what can be loosely termed 'children's science', which – if they differ from accepted scientific ideas – have also been referred to as 'alternative frameworks' (Driver 1983). Children's creative explanations are the building blocks for further learning; however it is important that they develop an appreciation that there may be other ways of accounting for the same evidence and that this process of theory-building from experience and discussion is what we call science. The significance of their creativity and awareness of the existence of wider evidence, is recognised by the Creative Little Scientists (CLS) consortium in their dual definitions of creativity and creativity in science. (See Figure 2).

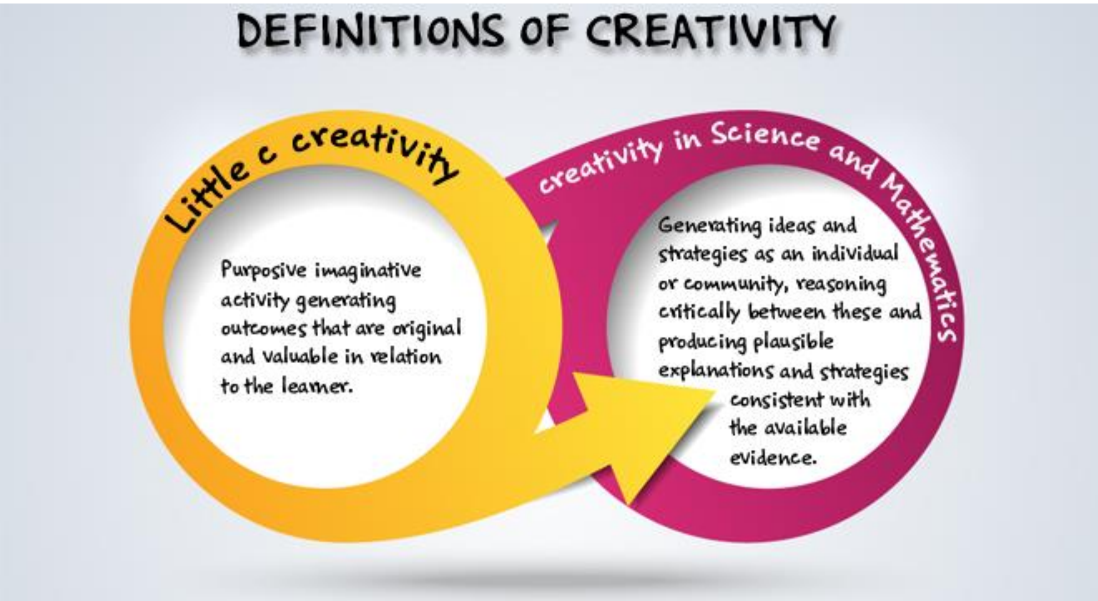

FIGURE 5.1

‘Creative Little Scientists’ definition of creativity in early years science and mathematics education (Stylianidou et al. 2013:5)

These definitions can help teachers in identifying opportunities for creativity in learning in science. The work of the CLS consortium (2011-2014) and the follow-up work being undertaken in the project *Creative Early Years Science Education* (2014-2017), highlights that IBSE and creative approaches to learning share a great deal in common, both recognise children’s exploratory and investigative engagement. However whilst playful experimentation and exploration is inherent in all young children's activity, policies in the majority of the 9 EU partner countries promote playful exploration in preschool science considerably more than in primary education. Observations of classroom practice in these countries also indicated that preschool teachers value scientific exploration more highly than their primary phase colleagues, where it is argued it should be more widely appreciated in generating ideas and questions, aesthetic engagement and a feel for phenomena. Both phases of teachers do however recognise the importance of children’s creative ideas and conceptions about science.

So what do children think science involves? The following extracts were taken from across Remuera Primary School, Auckland in preparation for a science expo (see chapters 7 and 10). After a school-wide emphasis on scientific ‘inquiry’ the children were sharing the outcomes from *their* science investigations with their families and other local community members. This is a selection of their responses to what they thought science is all about:

> ‘… something that helps you find out things and you do experiments’ (child in year 1)

'… discovering stuff and you find out about the whole wide world' (child in year 1)

'… things that you do. It makes water rise. Professors are scientists. It's like magic' (child in year 1)

'… about learning, doing fun things and you find out stuff. You learn new things. You can record ideas and find out information.' (child in year 2)

'… about lots of different things you haven't done before. You do stuff that is really different. It's about making things.' (child in year 2)

'… investigating new things. Science is finding things out information about things that is unknown.' (child in year 3)

'… about food. It is solids, liquids and gas. You test things you don't know about and you change one variable at a time.' (child in year 3)

'… everything – the world, biology, life, space, astronomy. You try to discover new things. You do experiments to find new things so the world can be better.' (child in year 4)

'… something to find out things from objects and sometimes it helps people with problems. It can help people in space. You do research and investigate things.' (child in year 5)

'… when you put a little bit of something and a little bit of something else and what ever happens you use that information to find out new information. Science is always truthful, it can't lie, it's the bare facts!' (child in year 6)

'… something that you research and find things out. You can do experiments so you can test things out and learn stuff.' (child in year 6)

By year 6 the children have moved from viewing science as a way of 'finding out stuff' to understanding that it is way of testing out ideas. In the process the children have developed an understanding that science is important and can help solve problems. The children's definitions begin to include knowledge, skills and value elements, supporting the contention that an emotional attachment or involvement with the experiences is essential to understanding science. A feature of creative exploration is the assumption that the expression of an aesthetic reaction of wonder to experiences of natural phenomena increases the engagement and subsequent science learning for the children involved.

Aesthetic approaches and the teacher's role

A more aesthetic approach to teaching and learning in science education is needed if children are to become engaged with and continue their studies in science (Girod and Wong 2002, Wickman 2006). This is an approach to teaching and learning in science that Wickman (2006: 145) suggests '… shows the intimate connections between learning science and interest in science'. The 'wow' factor (Feasey 2005) can become the focus or motivator for further thinking and inquiry. Other work has also highlighted the role of aesthetic experience in promoting children's affective and emotional responses to science activities. Milne (2010), for example, argues that fascination, engagement, awe, wonder and interest can prompt aesthetic engagement, spark children's curiosity and lead to the use of scientific inquiry to develop explanations of phenomena.

Although the affective dimensions of science learning has received less attention by researchers than the cognitive dimensions, it is not, Perrier and Nsengiyumva argue, simply a catalyst, but 'a necessary condition for learning to occur' (2003: 1124). Certainly creativity research highlights the importance of engaging children affectively and emotionally (Woods, 2001; Jeffrey and Woods, 2009) and the role of narrative as a playful imaginative context in which young children's creativity can be nurtured is an area for potential exploration in science. This connects to children's emotional engagement, when involved in narratives children’s ‘possibility thinking’- pondering what is to what might be (and why) is fostered (Craft, McConnon and Mathews, 2012; Cremin, Chappell and Craft, 2013). Stressing the relevance of science through issues-based hands-on experience of an aesthetic nature can also help children start to see connections between science and their close surroundings and significantly this can act as a motivating factor, driving inquiry (Kobolla and Glynn, 2007; Kramer and Rabe-Kleberg, 2011).

Whatever teaching and learning approaches are used, there needs to be a period of exploratory activity that - with teacher guidance - provides aesthetic experiences of natural phenomena that will assist the promotion of a sense of wonder, leading to a desire for understanding and explanation. However, in analysing the findings from a Flemish project entitled ‘Haus der Kleinen Forscher’ (the House of Little Scientists), which sought to develop preschool children’s scientific undertsanding, Kramer and Rabe-Kleberg (2011) note that open discussion in problem solving contexts *without* a teacher appeared to nurture their creativity. In their interactions without their teacher, the children’s collaborations often displayed creativity and fostered effective task-management and scientific understanding. Kramer and Rabe-Kleberg (2011) argue that children need space/opportunities in science to experiment and work on their own or in peer groups as well as space for dialogue with their peers and their teachers and this is also applicable to the primary phase.

Additionally, in investigating the implications of explicit instruction on exploratory play in a science museum, Bonawitz et al. (2011) claim that during periods of playful exploration, such instruction can constrain children’s discoveries. It is important for all teachers to finely balance their framing and facilitation of IBSE - of children’s scientific inquiry. Since ‘instructional pedagogy promotes efficient learning but at a cost: children are less likely to perform potentially irrelevant actions, but also less likely to discover novel information' (Bonawitz et al., 2011: 322). This work on the 'two-edged sword of pedagogy' as Bonawitz et al., (2011) describe it, has implications for teachers. For example it may be that even simply delaying instruction until the children have had a chance to investigate on their own could promote innovation and discovery. Too much teacher intervention, in the form of set activities, set questions to answer, and set inquiries to undertake, may reduce children's agentic and aesthetic engagement in the problem or phenomenon. Thus 'children's science' may become the 'teachers' science', undertaken for the purposes of schooling and distanced from the children's own interests and inquiries.

The role of wonder in creative exploration

Three specific aspects of wonder - 'wonder at, wonder about, and wonder whether' – are significant in creative exploration (Goodwin 2001; Naylor and Keogh 20090. The first focuses on questions relating to the processes of exploring in science: 'How does that work?' 'What will happen if we change this?' 'I wonder what made that happen?' 'How long will it take?' 'What will happen next?' When children 'wonder at' they may make exclamations like: 'Wonderful!' 'Wow!' 'How interesting!' 'How exciting!' 'How beautiful!' relating to the appreciation phase of an aesthetic experience of nature (Dahlin 2001). The third a- 'wondering whether' -involves value-laden questions such as: 'Should I do this?' 'Would this be better than that?' 'Why is this significant or important?' These aspects of wonder represent the humanising of the science content that may be involved as science activity is presented in contexts that are engaging and contextually relevant.

The importance of wondering is supported from historical and contemporary perspectives that include Socrates' 'wisdom begins in wonder', Aristotle's 'it was through the feeling of wonder that men now and at first began to philosophise', Gasset's 'to be surprised, to wonder is to begin to understand', Carson's (1956) need to develop 'a sense of wonder' in all children, and Neil Armstrong's 'mystery creates wonder and wonder is the basis of Man's desire to understand.' From an educational perspective the significance of developing a sense of wonder and its conjoint elements awe and interest are also highlighted in the goals of science education *Beyond 2000* (Millar and Osborne 1998).

McWilliams (1999) not only identifies nine classroom indicators of children's 'wondering' including; questions, observations, hypothesis-making, theories, art, imaginative play, stories, myths, and conceptual play in language, but also notes teacher actions necessary for providing opportunities for wonder to emerge in the classroom. These include:

- eliciting theories and predictions associated with observations and experiences,
- encouraging risk-taking by children when making hypotheses,
- active listening by the teachers involved,
- positive and humanising responses by the teachers to children's questions and answers,
- specifically modelling wonder-type questions when interacting with the children,
- having a time for 'messing about' with science and allowing children to explore their own questions.

It could be argued that these indicators should be characteristic of all classroom science which seeks to foster creativity, foreground exploration and adopts a co-constructive approach to teaching and learning. Whilst exploring primary school children's appreciation and interpretation of natural objects presented on a nature table, Tomkins and Tunnicliffe (2007) discovered that when asked to choose an object to photograph and talk about, a number of them expressed both wonder and aesthetic appreciation when deciding what object to select. The children tended to use terms like “I just really like it”, “they are so pretty”, “it’s just weird and interesting,” indicating that they were wondering at the structure and form of the object and the sensory perceptions they experienced.

Solomon (2004) too identifies a range of sensory delights that children experience in response to surprising phenomena that range from the first encounter (which initiates an awakening of senses leading to a growth of wonder), followed by marvelling, before becoming curious. This results, he asserts, in activity to seek causes for such phenomena which in turn can lead to the development of scientific explanations. When involved in sensory activities, many of the children’s questions, generated by a sense of awe, wonder and interest, were of a spiritual nature (Solomon, 2004). The central role of children’s own questions as a context for their inquiries has also been noted by other researchers (Drayton and Falk 2001) as has the importance of IBSE within a community, fostering a climate of discussion and debate about individual children’s wonderings with peers (Hmelo-Silver et al 2006).

Examples of creative exploration

Creative exploration is a teaching and learning approach in science that is based around children seeking understanding of their experiences of natural phenomena. It is a closely aligned with IBSE and requires the learners involved to create tentative explanations and in the process test the evidence they have used before sharing it with peers and other members of the community. The next section offers some examples of aspects of creative exploration in action.

The natural environment

In one school in Scotland, which took part in the *Creative Little Scientists* project, the staff planned visits to a local wildlife area each week for a term in order to offer the 3-5 year old children opportunities to explore the natural environment and observe different changes over time. These changes included for example, changes in the weather and the consequnces on the land and in the life cycles of living things. The planned visits were specifically designed to nurture children's own interests and explorations and to enable them to make their own connections as they observed and explored the environment. The school planned carefully to enable visits in all weathers, and sorted out clothing and resources such as mats, blankets, thermal clothing, warm drinks and snacks to take with them. They also organised equipment to support activities at the site, for example tarpaulins and ropes were taken to make a shelter, and magnifiers, binoculars and a camera to support observations, and collecting pots, litter pickers and spades were taken to support the young people’s activities at the wildlife area.

The focused explorations of one child, Ian were noted in particular. On one occasion, as he actively pursued his own interests and engaged in semi-silence in the environment, he became very observant. Initially he spent a long time at the ice covered pond. He looked intently at it and noticed bubbles and then began breaking up the ice 'so they (the frogs) can breathe'. Another focus of activity, involved Ian in taking photographs of the different fungi on the site to add to his growing collection. In reflecting on his visit towards the end of the day Ian highlighted these two activities (breaking ice and photographing fungi), and made several connections with previous visits. 'I think I saw frogs in the summer – and before I saw frogspawn.... It was sort of jelly – and tadpoles inside the ball of jelly.... Not the kind of jelly from what you eat and got tadpoles inside it'. It was evident that the space, time, and resources which enabled young Ian to observe and explore the natural environment and the non-interventionist, but supportive role of the staff enabled him to ponder and wonder in the wildlife area and his aesthetic engagement and curioisty triggered his scientific connection making.

Ice Hands

In another school, this time in New Zealand, Ian Milne, (the lead author of this chapter) spent time with a class of five-year-olds exploring changes that take place when food or drink is heated or cooled in the kitchen. The introductory stage of the lesson was spent revisiting the children's understanding of melting. There had been some prior exploratory activity and experiences of changes in material when heated. Firstly the children were asked to share their understanding of melting in a general way. To support this, they sat around a pan on an electric hot plate and were asked to predict what would happen when materials were placed firstly on the cold pan and then heated. In the process of testing the materials Ian and the class established the idea that some form of heat energy was required for materials to melt. The children also noted that some things melted whilst others did not, they only got hotter.

Several children were asked to touch the cold pan and hold their hands above the hot pan to establish that there was temperature change between the two.

The children were next introduced to an ice hand made out of frozen water and red dye and asked to predict what would happen to it in the hot pan. They enthusiastically responded 'it will melt.' Ian then wondered aloud 'what part would complete melting first?' The most common response was 'the pinkie (the little finger) would melt first.' Their reasons included 'because it is smaller than the other parts.' A short discussion established the children's shared theory: 'the size of the piece of ice will affect how long it will take to melt'. As a class they set out to test this theory. Working in pairs the children were each given three different sized pieces of ice and a dish and established that the only thing that was different was the size of the ice cubes. In their pairs they found places around the classroom to observe the melting process. Ian visited each group, discussed the progress of their investigation and asked them to identify the relationships between the different size ice cubes and the different parts of the ice hand.

Then the class returned to the hot plate and the investigation was redone. Sets of different sized ice blocks were tested and the prediction that the smaller sizes would melt first was confirmed. The slowly melting hand was placed on the hot pan and the children observed the melting process. They were spellbound; their engagement was intense. At the conclusion of the melting process the children revisited their theory and decided that their observations from the investigation had confirmed their prediction and explanation. To further aid their understanding the children were then asked to act out what had happened to the ice blocks. Each child was asked to pretend they were a very cold ice block. They stood tall and erect and then acted out the melting process until they were spread out on the floor. Selected children were asked to model the process in front of the class; the observing class members explained the process that was being modelled. There was an emphasis throughout on working with the children's ideas, prompting and challenging their thinking, and introducing them to the key idea that science is about developing explanations that can be supported by evidence. Throughout the process the classroom teacher took photographs, which were later used in literacy time to develop an account of the activity and to revisit later when the experience was relived as a Powerpoint presentation.

The gingerbread man

In yet another school, Ian was invited to work with the staff who wanted to 'put a bit of excitement back' into their science lessons. They decided to take their literacy theme of traditional stories as a starting point to explore the material world.   *The Gingerbread Man* provided a natural context for developing creative exploration, starting with the question 'Why on earth did the gingerbread man decide to climb on the fox's back to cross the river?' What did he already know and why did this knowledge influence his subsequent actions? The children responded that he would go mushy and soft quickly; this provided a context for exploration and investigation. The children immersed gingernut biscuits and ginger cake into jars of water and watched closely. Slowly the gingernuts and cake sank to the bottom and the colouring and sugar started to diffuse through the water making it a dark yellow colour. After a while the gingernuts absorbed water and expanded, they slowly floated to the surface where they stayed until touched. The children quickly discovered that the hard crisp gingernuts were now soggy.

Ian wondered aloud if there was any other reason why the gingerbread man climbed onto the fox's back. 'Could it be that he wanted to protect his special buttons?' (He explained these were made of M&M sweets). Placing an M&M into a clear glass jar of water and watching it offered the children an aesthetic experience. The diffusion of the coloured coat and then the white sugary layer left children 'wondering at' the form and beauty of the swirling eddies of coloured water. Both Ian and the children started to explain it by talking about everything being made up of 'little bits'. A quick stir and then pouring off the liquid left a chocolate-only M&M. They then modelled the whole process together; firstly an M&M was constructed with three children bonded together (a bit like a rugby scrum), each person representing a particle of chocolate. Two layers of colour were added, with the first layer of children being the white bits and the second layer the colour. At this point each child was given an M&M and bit it in half to identify the different layers and the respective parts of the model. Then the remaining class members became water particles and as a class they modelled the changes that had taken place. Firstly the outside colours were tugged away from the M&M and diffused across the room, followed by the white parts. Despite being bombarded with water particles the chocolate particles stayed bound together as a lump.

This M&M exploration has been undertaken by Ian with five to fourteen year olds and a range of student teachers. It is important – particularly with the teachers - to discuss the importance of the use of models to demonstrate our ideas and understanding in science. It is also important to ensure that the science ideas being modelled are made explicit and reinforced, including the use of scientifically-accurate language. Creating models in the form of drama and movement can be a very effective way to communicate understanding of the phenomena involved; it is also a creative way to provide formative feedback to the learners about their understanding of the scientific concepts.

Air pressure

In the final example, children's drawings were used to help them develop their thinking, share their ideas and make connections with phenomena they had experienced. After investigating and exploring properties of air, including the effect of temperature change and pressure, one class settled on the following 'big question' to investigate: 'Can air lift or carry heavy things?' Their initial thinking was that air cannot lift or carry heavy things, such as a book or a person. However Ian challenged them by asking: 'If you put a person on top of some balloons filled with air, what will happen? Will the balloons pop? Will the balloons be squashed? Can the air lift the person off the floor?' In exploring possible ways to investigate this, the children decided to illustrate a set of instructions:

> 'First blow up some balloons.'
>
> 'Then put the balloons in a bag.'
>
> 'After that put the balloons on the floor.'
>
> 'Next put something flat on the balloons.'
>
> 'Lastly carefully get down and lie on the balloons.'

When they actually tried this out the children expressed wonder and incredulity that the air could actually hold them up! After trying out the air platform with children *and* adults they investigated the effect of changing the independent variable of 'weight of person on the balloons' on the dependent variable of their height off the floor. After talking and thinking about the results the children were asked to draw a picture that explained what had happened. As a class with the teacher's help the children created the following three statements as a record of their current thinking: 'The air in the balloons could not escape out of the balloons. The people stayed up off the ground because the air in the balloons pushed the people up. There was a lot of balloons and so there was a lot of air pushing up.' When asked if they had found an answer to their questions the class jointly came up with the following response: ‘Yes, air can lift heavy things. It can lift people and books. If air is trapped inside tyres, it can carry bikes, trucks, cars and buses. When air is trapped inside a bouncy castle, it can carry us.’ The final stage of the investigation was making connections to their world and again drawings were their chosen medium to express the strength of air pressure in bicycle tyres, footballs and swimming floats. The drawings were later photographed and turned into a Powerpoint presentation to show at the school ‘science expo’ (see chapters 7 and 10). This example clearly demonstrates that even very young children as a group, can with assistance and support, follow through the whole process of creative enquiry.

Summary of Chapter 5

Playful creative exploration is key to engaging children emotionally and motivating their inquiries, it builds their natural wonder at the world around them and is an approach to teaching and learning that models many aspects of scientific enquiry. Such IBSE requires an exploratory phase that essentially provides children with rich aesthetic experiences embodying everyday scientific phenomena, to which they often respond with various kinds of wonder and engagement. Out of these aesthetic experiences authentic questions are generated that children can investigate to test out their own creative explanations. IBSE requires enthusiastic teachers who personalise the science activity, who not only provide support for children’s own interests and inquiries, but also challenge the children’s thinking as they develop and share their explanations. Such teachers effectively support children as they move their creative thinking from ‘children’s science’ towards the creative world of ‘real science.’

In fostering creativity and creativity exploration in science, using a self-evaluation checklist (see Figure 5.3) can help, and considering the definition of creativity in science (See Figure 5.1) , combined they afford the opportunity to review practice and plan forwards.

Practical resources to carry out the creative enquiries in this chapter

- Ice hand, made by filling a (rubber? or rubberised?) glove with coloured (food dye) water and freezing
- Gingerbread men, gingernuts or ginger cake, M&Ms (or Smarties), water
- Balloons, very large plastic bag, large flat piece of hardboard

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