Chapter 7
Working with Inquiry Activities to Encourage Creative Thinking

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7.1 Introduction

Inquiry is considered an inspiring way of learning science as it focuses on children's interests and stimulates active learning by enabling learners to explore their own ideas and conduct investigations (Braund & Driver, 2005). Children bring to school ideas formed about the world through their actions, observations and thinking in their daily lives and these forms the starting points for inquiry learning and the development of their scientific understandings (Harlen, 2013), capabilities and attitudes. Inquiry learning enables learners to link observations with ideas they hold from previous experiences, allowing new observations to consolidate or challenge previously held ideas. This process influences thinking and learning as children utilise their curiosity to work out how what they see connects with how they believe the world works.

It is well argued that through inquiry activities, children can develop a wide range of skills and competencies (Anderson, 2002; Furtak et al., 2012; Minner et al., 2010) while also fostering their confidence and capabilities to apply these skills in novel contexts (National Research Council, 1996, 2012). Through inquiry activities, learners become more active and agentic in their learning and teachers are able to guide student learning. Hmelo-Silver, Duncan et al. (Hmelo-Silver et al., 2007), coherently argue teachers' central position in scaffolding learning and how teachers are responsible for timely intervention to guide and scaffold developing ideas. Such

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timely intervention and 'on the fly' input during inquiry activity plays a crucial role in shaping science learning, while allowing for some aspects of learner agency within the inquiry process (Harrison et al., 2017).

This chapter explores how inquiry activities in science learning contexts can encourage learner creative thinking. It focuses on the children's creative thinking and the opportunities shaped by their teacher within the inquiry process, to use their imagination, consider possibilities and foster meaning-making. It takes the view that inquiry-based science education centres on the children's creative thinking, where learners begin with ideas, consider possibilities and share their thinking as they engage with activities. We will start with a literature-informed discussion on the nature and role of inquiry in science learning before exploring challenges in the wide-scale implementation of inquiry-based practices in science classrooms, followed by an exploration of fostering creativity through play and possibility thinking. The background of the SAILS and *Ninja Science* projects will be introduced before presenting three vignettes from the projects. Each of these vignettes is analysed to identify how science inquiry learning can create opportunities for children's creativity. The final discussion emphasises the role of the teacher in facilitating children's creativity in inquiry learning contexts.

7.2 The Role and Nature of Inquiry in Science Learning

The very nature of inquiry introduces opportunities for new ways of thinking to explain phenomena and events where pupils make connections between their existing knowledge and what they encounter (National Research Council, 2012), often introducing a degree of unpredictability for learners. Such activities challenge thinking by engaging children in investigating scientifically orientated questions where they learn to give priority to evidence, evaluate explanations in the light of alternative explanations and learn to communicate and justify their decisions (Crawford, 2000, 2014, 2016). Through inquiry activities, teacher-learner and learner-learner on-the-fly interactions create opportunities for children to articulate and share emergent ideas (Harrison et al., 2017), both building and challenging their scientific thinking. This approach tends to advance critical thinking and reasoning skills (Blanchard et al., 2008) and can motivate and engage students to learn (Crawford, 2014).

Osborne et al. (2004) argue that learners are better able to engage higher order thinking when they are involved in substantive dialogic exchanges between two or more people. Inquiry activities provide the opportunity for a wider range of questioning types by the teacher, leading to learner-talk that draws on discussion and dialogic exchanges, which research claims is central to learning (Alexander, 2006; Mercer et al., 2004; Johnston, 2009). Teachers' questions and attention to learner responses help reveal initial ideas (Chin, 2007) as learners engage with activities, and this is particularly evident in inquiry activities. While close-ended questions generally enable teachers to check 'if' learners know or understand something, open-ended questions often enable teachers to probe 'what' learners know and understand (Torrance & Pryor, 2001).

Crawford (2000, 2014) advocates for the role of teacher questioning within an inquiry-based science approach as the means to encourage dialogic exchanges between peers, and between the teacher and learners. Crawford (2014) argues that, through teachers' use of open-ended questions, it is possible to probe learners' understanding and lead them into elaborating on their thoughts and engage in discussions between each other. This creates opportunities for learners to open up the space where their thinking can be heard and shared with others and, through the classroom discourse, interactions implicitly convey to learners whether their initial ideas are considered to be productive lines of thought or highlight aspects that require further consideration. This legitimises creative thinking as a worthwhile and valued part of classroom learning, encouraging and shaping future classroom behaviours. The types of questions used and the ways in which teachers facilitate this, impacts on learner thinking (Alexander, 2006) and autonomy, in terms of the degree of freedom to explore and test ideas, and decide what to do next (Harrison et al., 2017). Howe and Mercer (2007) have shown that positive learning outcomes arise from learners engaging in dialogue where they have to justify their views and discuss and resolve differences in opinion and perspectives.

While inquiry-based science develops pupils' skills around questioning and evidence collection and consideration, it can also allow learners to be more involved in the decisions that are taken within the investigative process. In many classrooms, the teacher makes most of the decisions, setting the inquiry question, method of data collection and form of analysis, with learners simply collecting and recording data within the activity (Harrison, 2014). In some classrooms, teachers allow learners to engage in inquiry decisions, from setting the question, choosing methods to deciding how much evidence to collect, and making sense of the evidence. Giving opportunities for decisions and choices to be made by the learners, not just the teacher, can bring to the fore the opportunities for divergent thinking and creative approaches. This creative and divergent thinking by learners is nurtured best when the teacher feels able to set-up a learning environment that supports risk-taking by them, and their learners. Harrison (2014) suggests that where teachers hold the control, learner agency is inhibited and can have a limiting effect on learners conceptual understanding and curb the development of a wide range of inquiry skills. In contrast, where authentic questions arise from the learners' genuine interest and become the focus of investigation, there is greater opportunity for learner affordance, which leads to more 'open' inquiries with opportunities for creativity and divergent thinking. However, it also needs to be recognised that relinquishing teacher control and enabling more open inquiries is more demanding on the teacher and the learners in the first instance, until they both become more skilled and confident in working differently.

7.3 Barriers to Implementing Inquiry-Based Science

An inquiry approach has proved its efficacy at both primary and secondary levels in increasing learners' interest and attainments levels (Minner et al., 2010; Osborne & Dillon, 2008) while at the same time stimulating teacher motivation (Wilson et al., 2010). Globally, an interest in using more inquiry-based approaches in classrooms has been evident for several years (Furtak et al., 2012; Lazonder & Harmsen, 2016; Grangeat et al., 2021). For example, the European Union (EU) has funded several STEM education projects that involve inquiry-based approaches in schools (European Commission, 2007)) and while this has strengthened awareness of the benefits of inquiry learning, there is still some way to go in terms of teacher confidence in this approach, partly caused by a lack of pedagogical knowledge about how to implement strategies and routines to make inquiry learning more effective and also because of concerns about appropriate assessment practices to service an inquiry approach (Harrison, 2014).

The *Rocard report* (European Commission, 2007) highlighted the importance of an inquiry-based approach to science in an attempt to engage more learners to continue with science in the upper years of school and at university. Inquiry as an approach to teaching the big ideas within STEM is generally embraced by teachers and educationalists around the globe (Anderson, 2002; Crawford, 2007; Hollins & Reiss, 2016; National Research Council, 2013). However, there is much literature that suggests teachers often hold naïve ideas as to what inquiry-based science involves (Abrahams & Millar, 2008; Capps & Crawford, 2013) and struggle to enact effective inquiry-based practice. Some claim these difficulties are due to a lack of a unified definition of inquiry (Anderson, 2002) resulting in the conflation the goals of any practical science activity with practical inquiry-based activities (Harrison, 2014; Osborne, 2014).

While teachers from around the globe frequently claim child-centred inquiry is centrally placed within their inquiry-based practice, reports of practice often reveal that if inquiry is occurring in classrooms, then it tends to be teacher-centred (Capps & Crawford, 2013; Capps et al., 2016), with teachers controlling all or most of the decisions, and often missing key aspects that distinguish practical inquiry from any other practical activity. Such missed opportunities include learners not being more intimately involved in making sense of evidence to answer questions or understand the phenomena under focus. In addition, opportunities for learners to reflectively evaluate the way they plan, shape and enact an inquiry activity, are often missing (Capps et al., 2016), reducing opportunities for learners to reflect on their thinking and choices within different aspects of the inquiry-process (Minner et al., 2010).

7.4 Fostering Creativity Through Play and Possibility Thinking

A good proportion of young children's lives can involve activities where adults model how to do things through directives and compliance, with little room for learner agency. On the other hand, when children are encouraged to learn through play, this empowers them to access and explore content that they find interesting (Haughton & Ellis, 2016), and consider the roles of others in a shared learning space. Play is well recognised in early years settings as a platform for learning. Most importantly, child-initiated play opens up the opportunity for making choices and, with this, decision-making. While chid-initiated play opportunities foster imagination as they 'play around' with objects and ideas, pursuing their own interests, in their own way, and for their own reasons (Haughton & Ellis, 2016), learning tends to be incidental rather than the focus, i.e. the process of play is more important than the end result. While recognising there is a need for a balance between both child-initiated play and exploration, and adult involvement, early years practitioners are able to provide opportunities to develop 'sustained, shared-thinking' (Haughton & Ellis, 2016) through classroom interactions. Collectively, through extended narratives, there are openings to clarify concepts, evaluate activities and enhance thinking.

Thinking creatively includes children developing their own ideas, making links between ideas, knowledge and experiences (Craft, 2000), and developing a range of skills for doing this. Though inquiry activities, the teacher is able to open up space for imagination to flourish, for new ideas to be explored and novel ways of working to be initiated. In this way, inquiry-based science provides opportunity for children to use their creative thinking and imagination, especially where aspects of learner agency are deliberately factored into activities. Inquiry activities can provide a segue between children's play activities and more formal educational approaches in that they allow some aspects of learner agency to function alongside support and direction from adults. This can allow children to make some choices within the inquiry process, maintaining a sense of belonging, engagement and sustaining curiosity.

It is through agentive opportunity that even young children can draw on their ideas, explore ideas, make choices, use materials and artefacts in new ways, and take 'risks'. In such learning environments, it is reasonable to argue that children can more easily draw on their creative thinking and have confidence in trying out their ideas. This process is more likely to occur within a collaborative learning environment where children's ideas are valued, and the learning journey is a joint venture with peers.

Nurturing children's creativity requires opportunities where learners are motivated to actively engage with the processes of meaning-making. Craft (2011) believed that creativity encompasses a wide array of cognitive and affective capacities that are key for children's development and learning. She describes creativity as an everyday and lifelong imperative that involves problem-solving capability with 'possibility thinking'—the transformation from 'what is' to 'what might be'—at its centre. This notion of 'possibility thinking' is the means in which children explore and refine problems through a process of exploratory meaning-making. Craft (2000) argues that possibility thinking emerges through interactions with objects and others, and the means whereby puzzlement is stimulated, and questions arise. 'What if' thinking is often experienced unconsciously in the flow of engagement, such as in the exploratory phases of an inquiry, and is, in essence, the transition in understanding from 'what is this?' to 'what can we do with it?'. This develops learners' capabilities as confident explorers and decision makers and is in harmony with Crawford's (2007, 2014) notion that effective inquiry-based learning embraces the 'struggle' and 'grappling' that learners do, in their process of making better sense of evidence.

Craft (2000) conceptualises creativity as being twofold; big 'C' creativity and little 'c' creativity. big 'C' or high creativity, occurs in relation to the "extraordinary contributions and insights of the few" (Craft, 2000, p. 56), such as Einstein and his ideas of the theory of relativity, Vincent Van Gogh's painting of sunflowers, or Rudolf Nureyev's dancing and choreography. In contrast, little 'c' creativity is about inspiring everyone into a can-do mindset, wherein little 'c' is a concept that emphasises individual agency (Craft, 2000, p. 126), accepting every child is capably of little 'c' creativity. This form of creativity and creative thinking capability is the cornerstone of children coping with every-day challenges as a process of conscious invention and resourcefulness. It includes using information in new ways, responding imaginatively through exploration at a physical and cognitive level, and creating discoveries that are new to them. Creativity centres on being curious and explorative, and at the core of creativity is 'possibility thinking' (Craft, 2000, p. 57).

7.5 Background to the Inquiry Projects

The *Strategies for Assessment of Inquiry Learning in Science* (SAILS) was a large project funded by the European Union under the *Framework Seven Programme* (2012–2015) to support teachers across Europe to adopt *Inquiry Based Science Education* (IBSE) and assessment practices. The project involved more than 2500 science teachers in 12 partner countries. The project aimed to "prepare teachers, not only to be able to teach through Inquiry Based Science methods, but also to be confident and competent in the assessment of their students' learning" (SAILS, 2016, p. 4). The project directly addressed the concerns raised above that teachers often struggle to enact effective inquiry-based practice. It involved developing strategies for assessing inquiry learning in science as an active aspect of their teaching, while developing teachers' understanding of formative assessment approaches. This project resulted in the development of inquiry and assessment units which showcase IBSE and sharing practice across different partner countries.

The *Ninja Science Project* is a collaboration between researchers from King's College London and the Consortium of Local Education Authorities for the Provision of Science Services (CLEAPSS, an organisation that provides Health and

Safety advice for teachers) intended to support greater use of practical activities in science learning in primary schools. It involves 12 primary schools and their staff and supports classroom teachers in recognising, rewarding and developing practical skills in children.

7.6 Vignettes

This section looks at three vignettes that arose from the above-mentioned projects the authors were involved in and describe science inquiry activities in a number of classrooms. The intention is to provide illustrations of inquiry in practice to highlight the opportunities for creativity within the inquiry process that fosters learners' creativity and to outline some of the teachers' creative practices that make these activities work in the classroom context.

Vignette 1: Racing Green Water

The first vignette involves a Year One class (5-year-olds) and is called Racing Green Water. The children had previously been working on properties of materials with their teacher in a whole class inquiry where the teacher demonstrated, with their help, how to investigate and come to a collective decision about the best material for *Paddington Bear's* raincoat. Four different materials were investigated—wool, plastic, cotton and felt. A cup of water was slowly poured onto a piece of material, that had been fastened over the top of a jar, and the amount passing through each material was observed and compared. The teacher helped the class decide that plastic was the best material for the raincoat because it did not allow water to pass through it and introduced the word 'waterproof' to describe the plastic material.

The teacher introduced the Racing Green Water Activity by talking through the raincoat activity with *Paddington Bear* and asking children to explain how they had helped the bear make a decision about the best material for a raincoat to keep dry in a rainstorm. She then announced that *Paddington* now wanted to find the **best** material for his kitchen mop. Children came up and explained and demonstrated what a mop does in the kitchen, talking both about cleaning the floor and wiping up spills.

The children returned to their tables where the teaching assistant had placed a small dish of green water (water plus food colouring) and a strip of paper towel and a strip of kitchen cloth for each pair of learners. The children were asked to put one end of each strip into the green water at the same time to observe what happened to the green water. Great excitement ensued as the green water started to move along the two material strips with several children pointing at the front edge of the green water in each material strip and describing what they saw happening. The teacher asked the pairs of children to take the ends of both material strips out of the dish of green water as soon as the green water reached the end of one of the strips.

The children were then asked to sit down and talk with one another (buddy-talk) about what they saw happening during the activity. This enabled them to say what they had noticed about the green water moving along the two strips of material and share this with their partner. Some children talked about one strip being better; others suggested the green water moved faster in one strip or that one strip had more green water. Some children seemed to move quickly to a decision about which material strip was better at soaking up water and the discussion with their partner enabled them to justify their decision with the evidence from the observations. Others began with their observation and their interaction with their peers and the teacher and teaching assistant paved the way to move from observation to consideration of evidence to a decision about the material strips.

This vignette highlights how inquiry activities support a creative approach to science. Craft (2002) refers to these types of classroom episodes as ‘possibility thinking’ because the learners are unconsciously considering the ‘what if’ during the flow of their active engagement. Such exploration within an inquiry activity allows the learners to consider what they can do with this information.

Through considering possibilities of the ideas in their heads, many of the children were able to reason and decide that the ‘faster’ and ‘more water’ strip would be a better material for the bear’s mop. The teacher challenged the children who described one strip as ‘better’ asking them “what makes you think this?” making them reflect on what led them to their decision. Most of these children responded by pointing to or holding up their ‘better’ strip. They could reach the decision that one of the materials was better for making a mop but they found it more difficult to articulate why. The teacher helped them find the language and scaffolded opportunities for the children to explain their decision. The children were then given two fresh strips and asked to do their inquiry again to check they had given Paddington good advice for his mop material. The teacher and teaching assistant circulated asking questions of different pairs, checking on what children thought would happen, what their observations were indicating and probing how confident the children were in giving *Paddington* their advice.

In this vignette, the teacher was fostering children’s creativity by valuing children’s ideas and encouraging them to explore, share and check their ideas out. This enabled the children to become more confident in linking what they thought about the evidence they witnessed for themselves. These young scientists were encouraged to link evidence with their ideas and were being nurtured as meaning-makers and decision-makers; a central aspect of inquiry-based science.

Vignette 2: Bean Diary

This second vignette dips into life cycles, a project that a Year Three class (7-year-olds) were doing where each child had begun growing bean seedlings in jars the previous week. In this structured inquiry, the children checked their beans each day and were asked to write and draw in their Bean Diary any changes they could see as the beans germinated and started to grow. In this lesson, the children were asked to look back through their Bean Diary and to reflect on their entries and explain to other children on their table what changes had occurred to their beans over the week. Several children were asked to tell the class their summary of the first week’s growth and the teacher selected some of the words they used and wrote these on the board.

The children were then provided with a pre-drawn table with column headings, providing space for them to enter their own data of the bean changes they noted over the week. The teacher then displayed the pre-drawn table on the whiteboard, pointing out the columns and explaining how to record their summary of weekly growth. The teacher explained that the children needed to summarise their evidence about the bean's growth each week and pointed out where on the table they needed to record their weekly summary. She also explained the table was a way of collecting their evidence together in a simple, yet clear way so that they could use this to tell others the story of their bean growth. Each child then took responsibility to record their own weekly summary of bean growth into their table of evidence.

Each week the teacher took the class back to their growing beans, their diary entries and the bean growth summary table. This stimulated a class discussion where the children both looked at the variation in ways of summarising evidence and the similarities and differences between how their bean was growing compared to others. The teacher began to introduce new language into this activity in weeks three and four, where she began to talk about pattern seeking and range, and also encouraging the children to compare their growing bean with others and with how their bean had grown over the previous few weeks.

One girl wrote in week 3: "My bean was last to grow a root but now is one of the best and biggest shoots".

Another girl wrote in week 4: "My bean has grown straight and tall and much faster than before. My bean is the nicest because it has tiny little leaves".

In this vignette, the teacher decided to focus on supporting the recording of observations over a sustained period of time in order to help the learners identify patterns in data. Because the children have their own individual bean, they form an emotional attachment with the seed as it grows; for example, many gave their beans names. This personalisation provided a motivational aspect and gave an authenticity to the activity of data gathering. From Monday to Friday, the children recorded details about the beans in their Bean Diary daily. They completed this task as they chose, with many drawing their bean, sometimes exaggerating any change and annotating, such as when the root started to develop. Many also wrote a sentence or two about how their bean had changed or how it was different to other children's beans. Sometimes children had actively sought help from the teacher with their diary and while the teacher discussed with them what they could observe that day and directed them towards noticing any differences from previous days, the children were encouraged to decide for themselves what they should note about their bean.

Giving the children responsibility for their bean growth and diary entry allowed them to use their imagination to draw together evidence and ideas about what they believed was happening as the bean grew. One boy wrote: "My bean seed looks a bit bigger today. It has been drinking up the water (in the jar)". Here we see this boy starting to make connections between his observations and making a claim about his evidence. Interestingly, few of the children noticed changes in the conditions in the jar nor mentioned anything about the water. A few children noted that the teaching assistant added water to the jars when the paper support for the beans became dry but did not connect this with what was happening to their bean.

The teacher then moves the focus from single daily observations to looking across several observations to build evidence of what is happening as the bean grows. Getting them to revisit and read their diary entries helped the children actively reflect on their observations and the changes that had taken place with their bean. Using ideas of what is similar and different helps the children understand and articulate change and how this relates to their conceptual understanding of growth. Using their imagination and possibility thinking as they considered their individual evidence from their 'bean story' alongside the stories of the others in the class, helped them notice patterns and themes leading to them making better sense of what has happened. This enables them to consider change over time and the reasons why things change and linking that with the present, allowing them to generalise to other related but different situations. Such lines of thinking provide a footing for also making connections with the future and predicting what may happen next.

In the Bean Diary and in the Racing Green Water vignette, the teacher plays a pivotal role in offering opportunities for creative development and providing scaffolding to encourage children to draw their ideas together to support science learning within these inquiry activities. They highlight ways into collecting and considering evidence for decision making within the inquiry process. While the activity is stimulated and mainly controlled by the teacher, it still fosters the emergence of student agency, allowing the learner freedom at various points to share and reflect on their own thinking and that of others. In the final vignette, for lower secondary students, we see these processes flourish as teachers more directly and explicitly pass control to their learners, while at the same time providing guidance towards a fruitful endpoint.

Vignette 3: Floating Fruit

This final vignette arose from the SAILS EU project as an aspect of the teacher development programme. The lesson was with a Year Eight class (12-year-olds) who were given a small orange and a beaker of water and asked what they might investigate with this apparatus. The teacher believed that his students may find this task difficult and that they would possibly only come up with slight variations around what might make the fruit sink or float. In fact, the learners discussed ideas in groups and seven questions emerged from the class:

1. What makes the fruit sink or float?
2. Can you make the floating fruit sink or the sinking fruit float?
3. Does floating change if you take off the skin? bake it? break it into piece?/squash it? put holes in it?
4. Why does a peeled satsuma always float the same way up?
5. Will it float differently in salt water? hot water? iced water?
6. Do all fruits float? … at the same height in the water?
7. Does changing the water depth alter how the fruit floats?

The teacher was somewhat surprised by the number and range of questions and some he had concerns about, worrying on safety grounds about the students baking an orange or using boiling water. The teacher also rejected question 4 since it was out of topic for where he hoped to take the learning. He also had some concern over questions 6 and 7 because his subject expertise informed him that the water depth did not affect how the fruit floated, plus the students only had access to oranges on the day. In the end, the teacher decided to allow questions 1, 2, 3, 5 and 7 and students (in small groups) could select which question they wanted to explore. Questions 1, 3, 5 and 7 were selected.

Each group had to come up with a reasonable method to investigate the question they had selected. They were encouraged to take some initial measurements and observations to check whether the data they were collecting was providing adequate and sufficient evidence to answer their inquiry question. Once they had checked their ideas and initial evidence with the teacher, each group proceeded to collect a set of data and analyse their results. Their findings and conclusions were shared with the whole class through 5-min group presentations in their next lesson. The teacher encouraged the class to look at some of the similarities and differences between each of the group's choices in working by asking questions such as:

This group collected more data—how did this help them in answering their inquiry question?

This group repeated some of its measurement—was that a wise move or not?

This group made its decision on three data points—was that enough evidence to answer their question?

How has this group's way of working differed from others answering the same question? Was it a better method? How would you judge that?

In this third vignette, the students' opportunity for decision making is factored into the teacher's planning from the outset, encouraging and enabling learner decision-making within all phases of the inquiry process. The stimulus of the orange and beaker of water instigates a range of 'possibility thinking' with students making connections with phenomena they have met in their everyday lives, such as 'bobbing for apples' and with ideas they had met previously in science classrooms such as floating and sinking. By pooling and discussing their ideas in groups, they were able to decide questions to investigate.

The students then move from their question to formulate ways of making measurements or observations to help them investigate whether the orange floats as they anticipate and the reasoning behind the phenomena. In this way, they identify what evidence is relevant to addressing their researchable question. They decide how to capture that evidence, how much data they might need and use these to analyse and draw conclusions.

The teacher probes for reasons and explanations in order to scaffold students' capabilities to critically review their process and their thinking. This approach challenges learners to consider how confident they are in their thinking and how their evidence supports or refutes what they claim. Such reflexivity encourages the learners to examine their beliefs, judgements and practices and go beyond the obvious. In doing this, learners can revisit their first ideas, to stand back and think creatively and, if necessary, reframe their initial thoughts and ideas and explore differently.

7.7 Discussion: Opportunities for Creative Thinking in Inquiry Classrooms

Our analysis of the three vignettes point to the pivotal role of the teacher in facilitating children's creative inquiry. In conclusion, we maintain that when teachers are helped to implement inquiry learning in science classrooms, children of different ages, gain opportunities to develop their creative thinking skills. In all three vignettes, the teacher plays a key role is offering engaging, authentic inquiry-based opportunities (Crawford, 2014). Creative thinking promotes diverse ideas, including deciding what would be relevant data, how to record data and engaging with what Crawford (2014) refers to as grappling with the evidence to draw conclusions. It is this thinking creatively and actively engaging with the processes of meaning-making that allows learners to explore novel information in new ways.

Despite reasonable agreement on the processes and aims of inquiry teaching, there remains considerable variability in the way that inquiry has been understood and operationalised within schools and reported in in the literature (Furtak et al., 2012; Jerrim et al., 2019). In many Inquiry-based science education studies, there has been an emphasis on either the types of activities learners engage in or the degree of guidance provided by teachers (Rönnebeck et al., 2016). This chapter represent a somewhat different view on inquiry in the science classroom. It centred on the children's creative thinking and the opportunities shaped by their teacher within the inquiry process, to use their imagination, consider possibilities and foster meaning-making. It took the view that inquiry-based science education centres on the children's creative thinking through opportunities shaped by their teacher, where learners begin with ideas, consider possibilities and share their thinking as they engage with activities.

The teacher enables children to use their imagination through careful planning, observation and responsivity, bringing structure to the inquiry activity. The first two vignettes are similar to what Tafoya et al. (1980) describe as structured inquiry, where the learners get the experience of investigating, yet the focus of learning is specifically on developing specific inquiry skills such as collecting data, organising data, making inferences and drawing conclusions from the evidence. In these cases, learners gain first-hand experience of working scientifically, focusing on gathering and evaluating evidence. Children are guided to make connections between things they notice in new situations and trawl through previous experiences to make connections that build and reshape ideas. Such an approach enables learners to engage in several iterations of creative thinking cycles within a structured inquiry activity, as children share their developing ideas with peers. While the locus of control still lies mainly with the teacher, there is space and encouragement for learner decision-making that is embedded into the learning process and recognised in the learning goals.

The final vignette is an example of a more open inquiry (Tafoya et al., 1980), where the locus of control resides with the learners more than the teacher. However, the teacher's role is far from passive as they must still be aware of learner intentions and actions and provide timely intervention to probe and challenge the learners' thinking processes and knowledge construction.

The three vignettes that we described and analysed in this chapter provide a small inlet into the large array of practices which teachers use to plan and implement inquiry activities that generate opportunities for science learning. Inquiry-based science activities draw on engaging scenarios to motivate learners to think creatively and actively engage with the processes of meaning-making. It encourages learners to focus on novel information in new ways, by responding imaginatively through exploration and discussion. This shapes experiences into evidence-collecting activities that informs their science meaning-making. In this way, children are able to take ideas that are new to them while moving in a direction that their teacher has steered for them; at the same time strengthening science processes that support such practices. The role of the teacher is pivotal in this journey in generating opportunities for 'possibility thinking' (Craft, 2011) within inquiry activities, with differing degrees of learner agency, and different learning foci. Such practices enable children to retain capacity, capability and enthusiasm for exploration and curiosity as they gain knowledge and confidence in science.

References

Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education, 30*(14), 1945–1969. https://doi.org/10.1080/09500690701749305

Alexander, R. (2006). *Towards dialogic teaching: Rethinking classroom talk* (3rd ed.). Dialogos.

Anderson, R. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13*(1), 1–12. https://doi.org/10.1023/A:1015171124982

Blanchard, M., Southerland, S., & Granger, E. (2008). No silver bullet for inquiry: Making sense of teacher change following an inquiry-based research experience for teachers. *Science Education, 93*(2), 322–360. https://doi.org/10.1002/sce.20298

Braund, M., & Driver, M. (2005). Pupils' perceptions of practical science in primary and secondary school: Implications for improving progression and continuity of learning. *Educational Research, 47*(1), 77–91. https://doi.org/10.1080/0013188042000337578

Capps, D., & Crawford, B. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education, 24*(3), 497–526. https://doi.org/10.1007/s10972-012-9314-z

Capps, D., Shemwell, T., & Young, A. (2016). Over reported and misunderstood? A study of teachers' reported enactment and knowledge of inquiry-based science teaching. *International Journal of Science Education, 38*(6), 934–959. https://doi.org/10.1080/09500693.2016.1173261

Chin, C. (2007). Teachers questioning in science classrooms: Approaches to stimulating productive thinking. *Journal of Research in Science Teaching, 44*(6), 815–843. https://doi.org/10.1002/tea.20171

Craft, A. (2000). *Creativity across the primary curriculum: Framing and developing practice*. Routledge.

Craft, A. (2002). *Creativity and early years education: A lifewide foundation*. Continuum.

Craft, A. (2011). Creativity and early years settings. In A. Paige-Smith & A. Craft (Eds.), *Developing reflective practice in the early years* (2nd ed., pp. 93–107). Open University Press.

Crawford, B. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching, 37*, 916–937. https://doi.org/10.1002/1098-2736(200011)37:9<916::AID-TEA4>3.0.CO;2-2

Crawford, B. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching, 44*(4), 613–642. https://doi.org/10.1002/tea.20157

Crawford, B. A. (2014). From inquiry to scientific practices in the science classroom. In N. G. Lederman & S. K. Abel (Eds.), *Handbook of research in science education* (pp. 515–541). Routledge.

Crawford, B. A. (2016, January 12–15). *Supporting teachers in inquiry/science practices, modelling, and complex reasoning in science classrooms*. [Conference presentation]. South African Association for Research in Mathematics, Science, and Technology Education (SAARMSTE), Pretoria, South Africa. https://www.researchgate.net/publication/290996573_Title_Supporting_Teachers_in_InquiryScience_Practices_Modeling_and_Complex_Reasoning_in_Science_Classrooms

European Commission. (2007). *Rocard report: Science education NOW: A renewed pedagogy for the future of Europe* (EUR 22845). https://www.eesc.europa.eu/en/documents/rocard-report-science-education-now-new-pedagogy-future-europe#downloads

Furtak, E., Seidel, T., Iverson, H., & Briggs, D. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research, 82*(3), 300–329. https://doi.org/10.3102/0034654312457206

Grangeat, M. Harrison, C., & Dolin, J. (2021, in press). Exploring assessment in STEM inquiry learning classrooms. *International Journal of Science Education.*

Harlen, W. (2013). *Assessment & inquiry-based science education: Issues in policy and practice.* IAP. https://www.interacademies.org/sites/default/files/publication/ibse_assessment_guide_iap_sep_0.pdf

Harrison, C. (2014). Assessment of inquiry skills in the SAILS project. *Science Education International* (EJ1022890). ERIC. https://eric.ed.gov/?id=EJ1022890

Harrison, C., Nieminen, P., Correia, C., Serret, N., Papadouris, N., Tiberghien, A., Grangeat, M., & Rached, E. (2017). Assessment-on-the-fly: Promoting and collecting evidence of learning through dialogue. In J. Dolin & R. Evans (Eds.), *Transforming classroom assessment in STEM*. Routledge.

Haughton, C., & Ellis, C. (2016). The national picture. In I. Palaiologou (Ed.), *The early years foundation stage. Theory and practice* (3rd ed.). Sage.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller and Clark. *Educational Psychologist, 42*(2), 99–107. https://doi.org/10.1080/00461520701263368

Hollins, M., & Reiss, M. J. (2016). A review of the school science curricula in eleven high achieving jurisdictions. *The Curriculum Journal, 27*(1), 80–94. https://doi.org/10.1080/09585176.2016.1147968

Howe, C., & Mercer, N. (2007). *Children's social development, peer interaction and classroom learning.* (Primary Review Research Survey 2/1b). University of Cambridge.

Jerrim, J., Oliver, M., & Sims, S. (2019). The relationship between inquiry-based teaching and students' achievement. New evidence from a longitudinal PISA study in England. *Learning and Instruction, 61*, 35–44. https://doi.org/10.1016/j.learninstruc.2018.12.004

Johnston, J. (2009). Observation an important enquiry skill. *Primary Science, 106,* 15. https://www.ase.org.uk/resources/primary-science/issue-106/observation-important-enquiry-skill. Accessed 23 Sep 2020.

Lazonder, A. W., & Harmsen, R. (2016). Meta-analysis of inquiry-based learning: Effects of guidance. *Review of Educational Research, 86*(3), 681–718. https://doi.org/10.3102/0034654315627366

Mercer, N., Dawes, L., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: Ways of helping children to use language to learn science. *British Educational Research Journal, 30*(3), 359–378. https://doi.org/10.1080/01411920410001689689

Minner, D., Levy, A., & Century, J. (2010). Inquiry-based science instruction—What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47*(4), 474–496. https://doi.org/10.1002/tea.20347

National Research Council. (1996). *National science education standards*. National Academy Press.

National Research Council. (2012). *A framework for K-12 science education: Practices crosscutting concepts, and core ideas*. National Academy Press.

National Research Council. (2013). *Next generation science standards: For states, by states*. The National Academies Press. https://doi.org/10.17226/18290

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education, 25*(2), 177–196. https://doi.org/10.1007/s10972-014-9384-1

Osborne, J. F., & Dillon, J. (2008). *Science education in Europe*. Nuffield Foundation.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching, 41*(10), 994–1020. https://doi.org/10.1002/tea.20035

Rönnebeck, S., Bernholt, S., & Ropohl, M. (2016). Searching for a common ground – A literature review of empirical research on scientific inquiry activities. *Studies in Science Education, 52*(2), 161–197. https://doi.org/10.1080/03057267.2016.1206351

Strategies for Assessment of Inquiry Learning in Science (SAILS). (2012–2016). *Report on mapping the development of key skills and competencies onto skills developed in IBSE*. McLoughlin, E., Finlayson, O., & van Kampen, P. [Authors]. http://www.sails-project.eu/sites/default/files/outcomes/d1-1.pdf

Tafoya, E., Sunal, D. W., & Knecht, P. (1980). Assessing inquiry potential: A tool for curriculum decision makers. *School Science & Mathematics, 80*(1), 43–48. https://doi.org/10.1111/j.1949-8594.1980.tb09559.x

Torrance, H., & Pryor, J. (2001). Developing formative assessment in the classroom: Using action research to explore and modify theory. *British Educational Research Journal, 27*(5), 615–631. https://doi.org/10.1080/01411920120095780

Wilson, C., Taylor, J., Kowalski, S., & Carlson, J. (2010). The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning and argumentation. *Journal of Research in Science Teaching, 47*(3), 276–301. https://doi.org/10.1002/tea.20329

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