Science in early childhood education

ECE resources

Why teach science in early childhood education?

Research demonstrates the importance of science learning in early childhood, as the development of science inquiry skills and foundational science knowledge in the early years positively influences lifelong science learning[1]. Science activities support sensory exploration which is crucial for building brains[2], but they also help children to understand their world in new ways and gain new perspectives on the situations they encounter[3]. Science learning has an important and valuable influence on the development of their thinking.

Scientific ideas and processes are implicated in children's construction of working theories, and also their development of dispositions, the two principal learning outcomes of Aotearoa New Zealand's early childhood curriculum *Te Whāriki*. Dispositions such as resilience and perseverance are essential to scientific inquiry, and engaging in the repeated cycle of predicting and observing, followed by re-visiting their predictions and conclusions over time[4] can support children in developing their working theories over time. Science experiences in early childhood help young children build important conceptual foundations and skills on which they will later construct more sophisticated understandings[5].

Meaningful science experiences in early childhood education can also help young children to develop positive beliefs about science as an interesting area worth learning about, and about themselves as capable of doing well in science learning later on[6]. How children feel about learning science matters[7]. Teachers can show children how science concepts help them to live, play, and solve problems in everyday situations[8]. Without opportunities to engage in science in the early childhood setting, it is possible children will infer that science is unimportant, irrelevant, or too difficult for them[9]. Note that often science learning is present but obscured within holistic experiences in early childhood settings, so it is important that early childhood teachers talk about and label activities as science for this to occur.

What is science?

Science is a social and cultural activity in which a variety of methods are used to investigate questions related to the natural world. It is a particular way of knowing (an epistemology) which focuses on organising information about the natural world into meaningful patterns[10], and on creating explanations and theories to predict phenomena[11]. Observations, experiences, and experiments are systematically connected with existing models and theories or used to construct new ones[12]. Science therefore comprises both a **system of concepts** and a **process for investigating** invented by humans. It is understood to be reliable, yet tentative and capable of change[13].

Scientific literacy incorporates an understanding of both **what science is** and **what scientists do** as key components. It is a common misconception that 'doing science' means following a step-by-step 'scientific method' or controlled experiment, when in fact science can also use descriptive, correlational, or epidemiological (for example, studying the incidence of disease via statistics) methods. However, while there is a strong relationship between science and technology, science is not itself concerned with practical outcomes[14]. Science can involve developing concepts, testing hypotheses, controlling variables, induction, interpretation, visualisation, and data modelling, among other things[15].

Can young children do and learn science?

Researchers have described the way that young children learn about their world as being similar to that of scientists[16]. Young children enjoy exploring and discovering, and they instinctively ask questions about their world[17]. They have an innate tendency to seek information and learn about how things work[18]. Their play mimics the way in which scientists make intelligent guesses about how things work and then set out to test their guesses against information they gather. Even infants and toddlers engage in science-like exploration in play, testing out their theories about how the world works and demonstrating their ideas and questions non-verbally.

Children use all their senses to gain information, and then use scientific processing skills such as counting, classifying, measuring, and matching to organise their understandings[19]. Piaget described these processing skills, in which children put different ideas into relationship in order to work out their features, as logico-mathematical knowledge[20]. Even the youngest of infants are developing logico-mathematical knowledge at the same time as they develop physical knowledge. For example, a 10 day-old infant begins to differentiate between, and respond differently to, a rubber nipple and a real nipple, using their physical knowledge of each. To do so, they also have to have begun to construct the relationship of 'different', which is a logico-mathematical relationship. Young infants use logico-mathematical understandings such as correspondence and classification to build their knowledge of their world. For example, using the knowledge that a rattle makes noises when it is shaken (the noise corresponds with the movement of shaking), they then begin to go on to shake other objects to see if they too make noises when shaken. Discovering that a spoon or a blanket reacts differently to being shaken, infants learn that a rattle is different from other objects (classification). They develop logico-mathematical concepts of seriation too, ordering things from 'small' to 'bigger', and from 'silent' to 'makes a noise', and to 'makes a louder and louder noise', as they shake the rattle gently or more forcefully[21].

Children of all ages make inferences about causal relationships through observation of statistical probability[22] (an informal reckoning of the number of times an event or outcome occurs as a result of an action). From the first months of life, children have mental representations[23] of the physical world (working theories[24]) with which they can model structural and causal relations. Children use the 'data' they collect from their observation and exploration to evaluate how their current theoretical model fits with their experiences, and mediate their understandings accordingly[25]. They can perform various cognitive skills, including observing, inferring, and finding patterns, which are the foundation of scientific thinking[26]. Young children can also ask questions to learn about science topics (infants and toddlers may not express their questions verbally) and gain specific information to resolve their questions. This question-asking can one day develop into creating theories and making hypotheses. Young children can use the evidence gained from their experimentation to make decisions, generalisations, or predictions[27]. They are often unfazed when their experiments and ideas do not work out as expected, simply revising their thinking, asking new questions and exploring new ideas[28]. Research shows that, from around 4 years of age, children can design unconfounded experiments (designed to isolate the effect of a specific independent variable on a dependent variable) by controlling different variables[29].

Young children can discuss basic scientific ideas[30]. They have developing ideas of science concepts, some of which are scientific, some of which are preconceptions, and most of which are firmly grounded in the everyday, such as learning about forces from playing in the park and being pushed on the swings or spun on the roundabout[31]. Riding a scooter, a child has to set the handles for dirction, balance their body to drive the scooter, and use one leg to push against the ground to move the scooter forward, thereby experiencing concepts of force and motion[32]. This is important because the big ideas of science actually result from the combination of a set of concepts. For example, force can be understood through the set of concepts of push, pull, pressure, motion, and friction[33]. Children are likely to develop misconceptions as they construct their own models and make sense of the world in their own way, because they tend to develop concepts based on their experiential knowledge which can make concepts such as light, vision, heat, and force hard to grasp[34]. However, they can also improve their understandings and develop more scientific conceptions[35], demonstrating considerable ability to do and understand science[36] if provided with appropriate opportunities and support[37].

How do children learn science?

Research into young children's science learning has predominantly focused on what young children know and can be expected to understand in the different areas of science[38]. This research has been firmly located within the theory of constructivism[39], which suggests that children build knowledge by constructing (and then later adapting) theories and concepts about their experiences that in turn lead them over time to more accurate concepts. Scientific concepts are presented as self-evident. While this is a useful, and largely accurate, perspective, constructivism also posits developmental limits to what children can understand at different ages, with little consideration of the impact of the support of teachers, other adults, and peers in children's ability to achieve conceptual change. Recognising scientific concepts as social, cultural, and historical phenomena deliberately created by social groups to meet specific purposes[40], rather than as self-evident, suggests that there is a large role for social transmission of concepts, practices, and ideas.

Drawing on Vygotsky, a cultural-historical perspective suggests children are capable of learning complex concepts when supported by peers, adults, and cultural tools[41]. A cultural-historical perspective values the everyday concepts that children develop through play and activity with others and within their culture, and sees these as foundational to, rather than getting in the way of, scientific learning. Rather than a case of large-scale conceptual change in which children replace old ideas with new ones, scientific concepts are seen as forming through a constant and gradual movement between everyday concepts and more formal ones, so that, for example, children's everyday knowledge of animals becomes paired with a scientific understanding of animal adaptation for a particular habitat[42]. While the developmental abilities of children will guide teachers' pedagogical approach, they do not need to limit the scientific concepts to be introduced[43].

Beliefs about what children can learn have an impact on how teachers plan for children's science learning[44]. A well-established body of literature suggests that with intentional exposure and teaching, young children can learn many scientific concepts at an early age[45], building their empirical knowledge[46] and moving beyond intuitive assumptions to higher and more complex levels of understanding. For example, guided questioning helps to focus children's attention on certain aspects of their experiences and supports more complex conceptual development[47]. While scientific types of exploration are natural for young children, the formal knowledge and processes of the discipline of science must be learned. To achieve the sophisticated science process skills demonstrated by trained scientists, children require ongoing instruction, support, and scaffolding from teachers and cultural tools[48].

What science should we teach?

There are two types of interrelated knowledge, domain-specific knowledge (knowledge about particular scientific concepts and processes) and more general scientific knowledge (process skills and scientific thinking)[49]. The most important process skills for children to learn about in early childhood are asking questions, conducting investigations, and using and interpreting findings[50]. Engaging in their own scientific inquiries helps children learn about scientific practices, deepen their understanding of scientific concepts, and develop problem-solving skills, as well as empowering them with ownership of science knowledge[51].

When young children have opportunities to experience the process of constructing scientific knowledge, they are later able to appreciate the social, cultural, and historical influences on science[52].

Children also need to have strong conceptual understandings in a range of science areas so that the 'facts' they know can become usable knowledge[53]. This conceptual knowledge includes:

- understandings about themselves and other creatures (biology or natural sciences),
- understandings about physical science or physics (for example, as they explore gross motor movements such as moving down a slide),
- understandings about materials and their properties (physics and chemistry, or the physical sciences, as well as earth science)
- an understanding of the social and ethical aspects of science, such as the impact of humans on environments, and how to respect and care for the natural environment[54] (environmental science).

Science learning in early childhood incorporates a range of other disciplines, such as mathematics. In fact, mathematical concepts are often necessary for understanding scientific concepts[55]. Social studies can also be involved[56], as science often is applied to the way that we live our lives together. Children's exploration can include the visual arts, music, movement, drama, language, and literacy, so all kinds of connections can be made between science and other curriculum areas[57].

Learning science is a complex process that takes place over extended periods of time. Children will come to science experiences in early childhood setting with ideas they have developed from their experiences thus far in the world[58]. Science learning should be based on children's interests and current science understandings, reflecting children's views and promoting their voice[59]. At the same time, children may be most motivated to learn about and discuss science concepts if they experience some uncertainty or challenge to their pre-existing ideas[60]. This makes it important to be responsive to children's developing understandings and to regularly collect observations and record dialogue that shows learning over time[61]. There are many ways to assess what children know, through observations, conversations, and also children's drawings[62], perhaps by dictating their comments on their drawings[63]. It can be particularly useful to track children's understandings of ideas before and after particular planned experiences.

Key science skills

Specific skills and dispositions for science are highlighted as important in the literature, and can be modelled and nurtured by teachers. These are:

- **Scientific curiosity and wonder**. Wondering and question-asking offer important opportunities for science learning (as long as these are followed up)[64]. Teachers can excitedly record children's questions, theories, and ideas, as well as documenting their discoveries[65].
- **Theory-building** (more important than obtaining correct answers). Young children may have non-scientific and magical beliefs, for example, attributing the wind to a person blowing in the sky, or believing miniature people are directing the processes in their bodies [66]. Sometimes teachers can be overly concerned with teaching science content as facts and accurate explanations, while research shows it is important that children have opportunities to imagine and be imaginative about science concepts, knowledge, and theories[67]. This enables children to have more agency, and connect play with science[68]. Over time, children will develop increasingly accurate understandings. The history of science is full of examples of imaginative and fantastic theories that have been refined – and often replaced – over time!

- **Imagination**. Many science concepts, such as movement of atoms during the cooling process, are not directly observable and must be imagined. Imagination also helps children to understand the ideas and explanations of other children, and to use these vicarious experiences to come up with theories and plans for problem-solving[69]. In addition, when children have practised assigning imaginative meanings to objects in play, assigning new meanings to objects, such as using a block as a measurement tool, is much easier for them[70].
- **Reflexivity** for reflecting on science learning and experiences, to help children review and consolidate science concepts and vocabulary[71]. Reflecting helps children to remember and draw conclusions from what they have observed and experienced. Older children can be helped to reflect when they are asked to draw their understandings of science experiences.

Endnotes

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