

Strengthening Scientific Curiosity Through Science Experiences: Three Case Studies

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Abstract

This article focuses on pedagogical approaches for strengthening scientific curiosity in young children, arguing that scientific curiosity supports children to become scientifically literate, and to engage in a world in which science plays a crucial role. The article analyses data, including children's working theories about science from a research study in an Aotearoa New Zealand kindergarten. The focus is on three case study children from refugee and immigrant backgrounds, learning English an additional language, and whom teachers had identified were not accessing science learning. Teachers sought to enhance children's scientific curiosity, through inviting participation in a range of science experiences around the concept of transforming substances. Teachers' careful set-up of science experiences supported children's scientific curiosity and working theories about science. Teachers used a variety of techniques to provoke children to observe, describe, predict and theorise. Children's friendship groups supported active participation in and confidence in their science experiences.

Keywords: early childhood education, science curriculum, curiosity

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Introduction

In a complicated world, where science-informed issues such as climate change increasingly require attention (Dibner & Snow, 2016, p. 155), scientific and technical literacy have become necessary skillsets for all citizens (Gelman & Brennenman, 2012). Marshall (1950, p. 8) claims that citizenship entails “a kind of basic human equality associated with the concept of full membership of a community”. In the Aotearoa New Zealand context, Durie (2001) has advocated for people learning to live and participate as citizens of the world. Scientific literacy, which implies an ability to understand science processes and concepts (Kähler, Hahn, & Köller, 2020, p. 1989) can support people to better respond to challenges and issues arising in their lives and communities, as scientifically literate citizens are able to better engage in making informed, civic decisions (Dibner & Snow, 2016, p. 25). The journey towards scientific literacy begins in early childhood, building on young children’s natural curiosity about the world in which they live (Jirout, 2020, p. 1). This article gives examples of how teachers created intentional opportunities for young children from refugee and immigrant backgrounds to develop scientific curiosity through increased involvement in science experiences.

Scientific learning in the early years

Curiosity can be defined “as the desire to seek information to address knowledge gaps resulting from uncertainty or ambiguity” (Jirout, 2020, p. 1). Naturally curious, children possess an innate motivation to inquire about the world around them, which creates many potential connections for science learning (Baruch, Spektor-Levy, & Mashal, 2016, Jirout, 2020; Spektor-Levy, Baruch, & Mevarech, 2013).

Understanding a child’s expression of curiosity requires doing more than hearing their words. Baruch et al (2016, p. 126) note that curiosity is not directly observable, therefore, a child’s language cannot be the sole indicator. Attention should also be paid to sensorimotor indicators such as moving closer to the activity, looking, tasting, smelling, and to the child’s tone of voice (for example, excited vocalisation) (Baruch et al, 2016, p. 127).

Once curiosity is engaged, the additional matter of *what* the child is learning also becomes

important. Fleer's (2019, p. 1259) discussion of science learning in early childhood suggests two interrelated domains of knowledge: firstly, domain-specific knowledge (the knowledge that children acquire about a subject), and secondly, domain general knowledge (the cognitive skills needed to understand the domain specific knowledge, such as process skills). Science learning often focuses on domain-specific knowledge (Gelman, 2009), and frequently uses pedagogical models that have been developed for older children (Fleer, 2009, p. 1070). However, such approaches do not always work with young children, who may benefit more from a being able to play freely with a scientific concept or idea (Blake & Howitt, 2012, p. 298).

Science learning in the early years is further benefitted by the teacher who acts as both model and tutor (Spektor-Levy et al., 2013, p. 2229) rather than as the distributor of knowledge. Such teaching and learning experiences do not need to be didactic or explicitly instructional (Gelman, 2009). For example, specific scientific skills such as observation are supported through focused teaching (Blake & Howitt, 2012, p. 297), where a child's prior experiences are enhanced through their uses of the senses associated with smell, sight, touch, taste and sound. Teachers model inquiry skills as they conduct scientific inquiry with young children, creating learning experiences that generate uncertainty, and encouraging different types of information seeking in response to that uncertainty (Jirout, 2020, p. 2). Teachers who show interest and enthusiasm for scientific work support the emergence of those same attitudes toward science amongst the children they work with (Spektor-Levy et al., 2013, p. 2229). Children also benefit from the support of teachers when it comes to developing complex thoughts and understandings of why things are the way they are and why things work the way they do (Blake & Howitt, 2012, p. 282).

Science in the Aotearoa New Zealand early childhood curriculum, *Te Whāriki*

The national early childhood curriculum of Aotearoa New Zealand, *Te Whāriki* (2017), seldom refers directly to "science". Instead, the curriculum uses the term "making sense of the world" throughout the document, with the learning domain of science being integrated within the strands of *Te Whāriki*. Teachers/kaiako¹ are expected to "integrate domain

¹ Māori word for "teacher".

knowledge, (for example science and arts knowledge), into the curriculum” (Ministry of Education, 2017, p. 59). *Te Whāriki* states:

A curriculum whāriki² for young children provides a rich array of primarily play-based experiences. By engaging in these, children learn to make sense of their immediate and wider worlds through exploration, communication and representation. (Ministry of Education, 2017, p. 15).

This concept of “making sense” is strongly present in the Exploration-Mana Aotūroa³ strand: “Children experience an environment where they develop working theories for making sense of the natural, social, physical and material worlds.” Working theories are a key outcome of *Te Whāriki* that acknowledge children make sense for themselves as they explore their world and become interested, curious, and creative in finding solutions to issues. “More than about thinking and knowledge development, working theories encompass children’s embodied, communicative and social efforts to learn and participate effectively in their families, communities and cultures” (Hedges, 2021, p. 32). These learning outcomes, “making sense” and “working theories”, emphasise children’s growing understanding of their worlds and their developing creative, critical, physical and cognitive capacities. *Te Whāriki* recognises that over time, and with guidance and encouragement, children can become increasingly capable of:

- Playing, imagining, inventing and experimenting / te whakairo me te tuhurahura I te putaiao Using a range of strategies for reasoning and problem solving / te hirauroa hopanga
- Making sense of their worlds by generating and refining working theories/ te rangahau me te mātauranga. (Ministry of Education, 2017, p. 25).

Te Whāriki describes links between both the Exploration/Mana Aotūroa strand and the Belonging/Mana Whenua⁴ strand with Science in the New Zealand Curriculum (Ministry of

² Māori word for mat, and is used metaphorically to represent the “weaving” of curriculum that teachers, children and families do as they bring together content knowledge and children’s learning experiences. “*Te Whāriki*”, the name of the early childhood curriculum in Aotearoa New Zealand, is framed around the mat metaphor.

³ Māori term that refers to the exploration of the environment and curiosity about the world, and is the Māori equivalent for the curriculum strand of exploration in *Te Whāriki*. *Te Whāriki* uses both English and te reo Māori for the principles, strands, goals and learning outcomes in the curriculum.

⁴ The term Mana Whenua refers (generally) to the customary authority a tribe or authority has over the land, regarding rights and responsibilities. In the context of *Te Whāriki*, the term Mana Whenua is used to convey the meaning of the strand “Belonging”, in the sense of “belonging to this place”

Education, 2007)⁵: “Students explore how both the natural and physical world and science itself work so that they can participate as critical, informed and responsible citizens” (Ministry of Education, 2017, p. 57).

Methods

Aims

This article focuses on a six-month research cycle carried out by teachers in one kindergarten as part of a wider research study, *Refugee families in early childhood education: Constructing pathways to belonging* (Mitchell et al., 2018). The research aims focused on teachers developing young children’s scientific curiosity. The initial emphasis was on developing children’s domain specific knowledge about the transformation of substances. However, there was interest to see if domain general knowledges could also be developed during the study.

Theoretical framing

This research’s theoretical framing of participatory democracy regards democracy as “a mode of associated living embedded in the culture and social relationships of everyday life... a way of personal life controlled not merely by faith in human nature in general but by faith in the capacity of human beings for intelligent judgment and action if proper conditions are furnished” (Dewey, 1976, p. 227). A democratic educational community might be a place where all participants are able to belong, and make a contribution that makes a difference for learning, where children can collectively create a world of possibilities (Bruner, 1998).

Within this framing, children are conceptualised as citizens and contributors, with rights and responsibilities, integrally embedded within family, and also within conditions of

whether that place is the country, community, early childhood centre, or another appropriate location.
⁵ The New Zealand Curriculum is the curriculum document for all children and young people in Aotearoa New Zealand, covering from the start of school through to the completion of high school

childhood that are influenced by community and society. Dahlberg et al. (1999, p. 48) described the child produced under the “child as citizen” paradigm as a “co-constructor of knowledge, identity and culture”. This view acknowledges that children have agency: they are shaped by society, but also shape it through their own experiences and interactions with others. This vision of children as competent and active contributors to society is a founding aspiration for children in New Zealand’s national early childhood curriculum, *Te Whāriki* (Ministry of Education, 1996, 2017). It is also a core feature in other country curricula, for example *Aistear*, the national Early Childhood Curriculum Framework for children aged birth to six years in Ireland (National Council for Curriculum and Assessment (NCCA), 2009, p. 8), highlights in its principles:

Children are citizens with rights and responsibilities. They have opinions that are worth listening to, and have the right to be involved in making decisions about matters which affect them. In this way, they have a right to experience democracy. From this experience they learn that, as well as having rights, they also have a responsibility to respect and help others, and to care for their environment.

The Early Years Learning Framework for Australia (Australian Government Department of Education, Employment and Workplace Relations, 2009, p. 7) emphasises connectedness, relationships, participation and agency.

Fundamental to the Framework is a view of children’s lives as characterised by belonging, being and becoming. From before birth children are connected to family, community, culture and place. Their earliest development and learning takes place through these relationships, particularly within families, who are children’s first and most influential educators. As children participate in everyday life, they develop interests and construct their own identities and understandings of the world.

Our argument is that one of the big challenges in early childhood education is how to ensure equitable inclusion for all children and families. Our focus is on children from refugee and immigrant backgrounds, whose democratic participation may require intentional pedagogical attention. Participatory democracy, as a fundamental educational value that positions the child as citizen, provides a sound underpinning for pedagogical practice.

Ethical considerations

Great care was taken to explain the project carefully to teacher participants and parent participants, and to gain informed consent for participation, data gathered and use of real names or of a pseudonym. Parental consent to gather data about their child and children's assent were sought.

At the beginning of the project, the teacher tasks, data gathering and time for participation in the research were itemised and discussed with teachers. Teachers were allocated paid teacher release time to enable their participation. Each teacher signed an agreement to take part in the project, for each item of data to be collected and for their real name or a pseudonym to be used in publications and presentations. Teachers had an ongoing right to withdraw from the project at any time, on the proviso that any data gathered and already analysed for the project at that date, would remain in the project.

Teachers from the kindergarten were asked to help recruit 3 children and their families for case study. The criteria for selection of the families were that:

- the children were younger than 4 years and were likely to stay in the kindergarten for a year;
- the parents came to New Zealand as refugees or immigrants; and
- the families were, in the teachers' opinion likely to be positive about being asked and to benefit from being involved.

Teachers and researchers collaboratively made decisions about inviting participation.

Parents were invited informally to participate through a letter. If parents were interested, they were asked to talk with their child about whether their child was willing to participate. Informed written consent was then given by parents for collection of data about their child and its use in publication and presentations. Parents were asked whether they wanted their child's first name or a pseudonym to be used. In this article, children's first names are used.

Teachers, who were familiar with the children, talked with children about the project, showed the child data involving them and explained how it might be used. Children were asked to give verbal assent. In gauging assent, we also paid close attention during data gathering to the child's verbal communication and body language.

Research ethics approval was gained from the University of Waikato Faculty of Education Research Ethics Committee (Approval number FEDU 028/18 13 April 2018).

The kindergarten

The kindergarten is a busy urban kindergarten with a diverse cohort of families. At the time of writing, the kindergarten had five fully qualified early childhood teachers on staff, and is licenced for up to 42 children aged 2-5 years. The kindergarten belongs to the not-for-profit group Whānau Manaaki, which manages 101 kindergartens and early learning centres in the lower North Island of Aotearoa New Zealand.

The teachers in this study were Anne-Marie, Brooke, Catherine, Erin and Rachel. The three case study children were Deih No, Christian and Waleed. The children in this article all came from refugee and immigrant backgrounds and were learning English as an additional language.

Research design

At the start of this project, teachers from the participating kindergartens in the wider research study met with researchers to frame their respective research projects. The projects drew on the broad theme of participatory democracy in education, a theme that had emerged as an overarching theory in the wider research study. Each teaching team, with a researcher, then developed a proposal for their own research cycle, related to this theme.

The teachers involved in this article focused their project inquiry around an internal self-review. Internal self-review is a process used by teachers to inquire into their own teaching practice, and consider areas for focus or improvement. Their review highlighted the need for enriched scientific learning with children, having identified that not all children were involved with this, particularly those from refugee and immigrant backgrounds.

The teachers focused on strengthening children's scientific curiosity through science-informed experiences, including equity of teacher attention for children who were identified as not engaging in science learning.

The science experiences

The scientific concept that teachers selected was the "transformation of substances".

Teachers hoped that the highly sensory nature of the transformation experiences, with opportunities to touch, smell, hear, look (and occasionally taste) would engage the curiosity of children, thereby strengthening their interest in scientific learning and supporting the development of domain-specific science learning.

Each teacher took responsibility for one of five scientifically-informed experiences, in which two or more substances were brought together and transformed in the process. The experiences were selected because the teachers were familiar with them, allowing their focus to be on children. The experiences were open for all children to freely participate in if they wished, with the case study children being specifically invited to participate. The case study children could (and occasionally did) refuse to participate. Data were gathered on the responses and interactions with four case study children. In order to build on a familiar activity, the teachers carried out their selected experience with children on 3-5 different occasions. The selected experiences were:

1. Combining different ingredients to make *cloud dough*. This is a stretchy dough made from hair conditioner, herbal tea bags and flour; and *oobleck* (cornflour and water).
2. The *chemical reaction* of baking soda and vinegar using different substances and across different activities.
 - *Baking soda ice cubes*. Baking soda was placed in small plastic containers and water added. The mixture was stirred, colour added, and then frozen. The frozen cubes were taken out and placed in a trough of water. Children were invited to spoon vinegar over the ice cubes and observe the changes occurring when the two substances reacted.
 - *A mix up*. A new experiment with baking soda in one tray and different liquids (vinegar, orange juice, dishwashing liquid, lemon juice, vegetable oil, water) singly in each of another tray. Children used a pipette to draw up the liquids and place into the baking soda to observe which ones fizzed.
3. How heat is used to create *popcorn*.
4. Adding air using an egg beater to turn runny dishwashing liquid into bubbles and foam – *cloud foam*.
5. *Liquid to solid* – water to ice. This started with water to ice cubes, and extended to different liquids. An aim was to take what was a familiar activity and encourage understandings gained to be applied to different liquids and develop the idea of

predicting and hypothesising. Later, different objects were added to the ice cube trays. The frozen blocks were sometimes hung in the sun for further observation.

Data collection and analysis

The following data were gathered by the teachers:

- Audio and some video recordings were made of the teacher interacting with children (including the case study children) during the experiences.
- Documentation: Teachers wrote descriptions and learning stories (Carr & Lee, 2019) of the experiences and each case study child's reaction to it.
- Teachers reflected in writing on the case study children's reactions to the experiences and on the children's interactions.
- Teachers described their role and interactions and recorded their reflections.

Data were collected over a six-month period. The data collected by the teachers were stored and accessed through the online assessment portal Storypark, which families accessed.

Thematic analysis was used to analyse the teaching experiences of each of the case study children. Themes here are identified as broad units of information, containing several codes, and amalgamated to form a common idea (Mutch, 2013). Thematic analysis was selected as this was an approach that could yield a rich, detailed and complex account of the data (Braun & Clarke, 2006).

In the analysis, the topic of scientific curiosity was used as a broad starting point, with no other categories identified prior to analysis. Analysis was conducted by coding the documents teachers provided, assigning one colour for each item of interest. Once preliminary themes were identified, these were further analysed for relevance to scientific curiosity, further refined, and clarified with respect to the project's aims.

The data was analysed and related with respect to each child, rather than collectively for all children in the study and are. This approach supported a particular focus on the details of children's learning, and the reporting of that learning within the context of the child.

Results

In this section, we present vignettes and key themes from data gathered about each case study child as they participated in the experiences.

Vignette One: Deih No

Deih No took part in all five sets of science experiences. Her curiosity showed through her increased language use, her language choices, and her sensorimotor responses.

Increased language use and language choices

Deih No was learning English as an additional language. This was both a parent aspiration⁶ and a teacher goal for her learning. Regular involvement in the science experiment groups created lots of opportunities for Deih No to use the language she already had, as well as developing new language. As Catherine wrote:

The teachers have noticed that she is increasingly using more language, responding to our questions and comments, and increasingly offering her own ideas.

Deih No's language strategies included repeating words she heard her friends use. While creating a baking soda and vinegar volcano with teacher Ann-Marie, and her friends Christian and Waleed, Deih No repeated their words of "awesome", "wow" and "lava". In a later experiment, the same group was working with baking soda ice cubes and vinegar, which would be dropped onto the cubes using a pipette. Ann-Marie asked the children what they thought would happen when the vinegar was deployed. Waleed thought it would go fizzy, and Deih No repeated the word "fizzy".

Deih No also began to offer her ideas independently of repeating her friends' language. This happened concurrently with her repetition strategy. Deih No had a preference for using

⁶ In Aotearoa New Zealand early childhood, parents/families are commonly asked by teachers for "aspirations" or goals that they might have for their child, and these aspirations are incorporated into the planning for that child's learning.

her senses to explore substances. She connected her sensory experiences with descriptive language. Working with Brooke on the cloud foam, Deih No shared the short sentence of “It smelled good”. In making popcorn with Rachel, Deih No stated “Tastes good”. In working with Catherine to make the oobleck, Deih No combined her two strategies. She heard Waleed say “We are cooking”, to which she repeated the sentence “We are cooking”, then also added, “I see colour”.

Deih No’s increased use of language is indicative of her developing curiosity as she observes changes in the material she is working with. She uses words that both express enthusiasm and offer short observations about smell, taste, and colour.

Sensorimotor responses

Deih No gives a variety of sensorimotor responses during the science experiences. Catherine records some of Deih No’s reactions in a learning story, where Deih No, Waleed and Christian are making cloud dough together.

“What does it smell like?” I ask. Deih No lifts the dough to her nose smiling and nodding. Lots and lots of giggling. Deih No encouraged Christian to touch the dough with gesture, and he did.

Rachel recorded Deih No’s sensory engagement with popcorn-making.

You observed with your eyes the changes to the popcorn kernels, once I had put them in the popcorn machine. You told me that I needed to add ‘heat’ to the kernels to get them to pop. You felt the machine up with your hand and the air near it. You also felt the popcorn kernels in your hand before we put them into the machine and then after when they had popped.

Deih No engaged all her senses across these teacher accounts. Teacher questions and prompts encourage some of this sensory engagement, with the senses providing opportunities for Deih No to “know” through her own experience. With opportunities to respond verbally, but without pressure to do so, Deih No is able to immerse herself in this learning, where she can deeply observe these experiences. Deih No’s extended engagement in her play indicates

that the science experiences have captured her attention. Her sensory engagement, which supports close observation, could also be considered an emergent scientific approach.

Confidence

Deih No's engagement also led to her becoming more confident, even adopting small moments of leadership with her friends, Christian and Waleed. These small acts of leadership are notable in a child who had previously waited for her friends to arrive, and would only speak directly to them. All the teachers mentioned Deih No's increased confidence. For example, the cloud dough made with Catherine was initially very sticky. Neither Waleed or Christian liked this and ran off to wash their hands. When Christian returned, Deih No encouraged him to re-engage.

Deih No held the cloud dough up to Christian, "Look, look". She seemed to be encouraging him to touch it as it was no longer sticky. She understood he was not so keen on having sticky hands.

Encouraged Christian tried again with the dough. On another occasion, when using pipettes to drop vinegar on to the baking soda ice cubes Ann-Marie noted how Deih No spent considerable time exploring this activity, something that subsequently meant she could show her friend Christian how to use the pipette.

Deih No was more confident in making contributions in the second water to ice experiment. She took the lead in calling the other children in the group over to inspect the ice, which was hanging by a string from the tree. Later, when all the ice had melted, Erin observed Deih No and Christian returning to the area to find just the string hanging. They were talking to each other and making gestures that indicated to her "Where is the ice?" The repeated inspections, and now questions, showed how the children's developing curiosity. Building scientific curiosity was a key purpose of the experiences, and this curiosity is seen emerging through the children's engagement with the different experiences.



Figure 1. Deih No checking the ice cubes

The benefits of Deih No's involvement with the science experiences continued. Several weeks after the episode with the ice, Erin documented the following observation in StoryPark.

A few weeks after this evaluation, ... Deih No was helping me. As we walked past the water trough ... Deih No noticed that some rain had collected in the trough "Look, water", she said. I asked how the water got there. "Rain" answered Deih No. I congratulated her on her idea and repeated what she had told me. As she walked away, Waleed walked towards her. "The rain made the water" she proudly told him, pointing to the trough. I was thrilled to see this confidence and conclusion from Deih No. I saw it as another example of how we see her transferring her knowledge and observations into a different area, being able to articulate her ideas, share curiosities and understand that her thoughts and ideas are valued by teachers and peers. When I shared this with the team later, we were convinced that we would not have seen this level of confidence in Deih No before undertaking the science experiences. Deih No was able to build on her understandings and apply theories in a different time and place. It was very exciting to see Deih No develop these positive strategies and judgements about herself.

Deih No's confidence is an example of domain-general learning that supported her domain-specific science learning.

Vignette Two: Christian

Christian took part in all five experiences. Photographs and teacher comments showed Christian's intent interest in those experiences where he played an active role that involved a degree of judgement, care and skill, such as in pouring juice into the ice cube trays for the liquid to ice experiment.



Figure 2. Christian pouring juice in the liquid to solid experiment

Christian seemed to hold back from activities that involved getting his hands messy. For example, he did not touch the cloud dough with Waleed and Deih No, until directly encouraged, and showed limited engagement with bubble foam. He showed enjoyment making the Cloud dough, where participating in the process of making the material captured his attention, but playing with the dough itself did not. Another interpretation is that participation in the sensory aspects of these activities was less demanding in terms of his interest and need for concentration.

Christian's working theories developed over the experiences. When Rachel undertook the popcorn experiment, Christian was a focused observer. Rachel recorded in a learning story:

Christian, thank you for joining me in the kitchen to make some popcorn. We started by observing

the corn kernels. As the experiment progressed you answered many of my questions about popcorn, such as, “do you make popcorn at home?” Yes, my daddy and I make popcorn at home.” “Do we add heat or cold to the popcorn kernels to get them to pop?” Initially you told me cold. After I had the machine on and asked you to feel the air near the machine, you changed your answer to hot. Great challenging your working theory Christian. Yes, you need to add heat to the kernels to get them to pop, ka rawe⁷.

Christian modified his theories about whether heat or cold was needed to make the kernels pop, as Rachel encouraged him to test his initial theory (cold) through directly feeling the air emanating from the machine.

Later, at the kai⁸ table, Christian responded to a question from Rachel, “Why does popcorn pop?” with “Because I want to eat it”.

Conferring actions, intentions or motivations to non-human agents is known as anthropomorphism (Epley et al., 2007), and is commonly encountered in science learning. Anthropomorphism is a way for young children to make sense of the physical world in terms of their own experiences (Watts & Bentley, 1994). Both Rachel and Christian take an anthropomorphic approach in the second part. Rachel’s question of “why does popcorn pop?” implies that popcorn has a reason of its own to do so. Christian replies in kind, stating it pops so he can eat it, indicative of intention. This working theory, while emergent, shows a developing understanding that a change of state can be purposeful, and shows how Christian is making sense of the world.

In the experiment on the chemical reactions of baking soda with different substances, Christian displayed curiosity and emotional engagement. He was able to predict which two substances would “fizz” when mixed together. Anne-Marie wrote:

Christian’s reaction was full of amazement as he watched the reactions of those substances that bubbled but a little puzzled when they didn’t. . . . Through trial and error and with Deih No’s help, Christian began to notice that the vinegar and juices caused fizzy bubbles and the water, oil and dish washing liquid did not.

⁷ “Ka rawe” is the Māori term for “excellent” and is used as a compliment.

⁸ “Kai” is the Māori word for food, and “kai table” in this context means the space where meals are eaten

During the four months of participation in the science experiences, Christian developed the domain-general skills of observing, evaluating evidence, and developing working theories. Contributions to his domain-specific knowledge included the role of heat in transformation.

Vignette Three: Waleed

Waleed attends five days a week, and took part in all five experiences.

Drawing, story-telling and gesture were channels for Waleed's learning and communication. Rachel's popcorn experiment the red popcorn, grown in the kindergarten garden, and harvested by the children, including Waleed. The account from the transcript of Rachel's interactions illustrates how Rachel encouraged children to focus their observations through their senses, to compare and make predictions.

At the beginning we talked about the kernels, what colour they were. All three children said they were red. I then got them to hold a kernel in each hand and asked them to look at them. Did they think they would pop? Yes, they all thought they would. I then got them to remind me how we get the popcorn to pop, do we add heat or cold to them? Waleed told me 'heat'. I then got out the yellow kernels for them to look at and compare with the red kernels. One of each different kernel in each hand. Which were bigger? Waleed told me the yellow kernel was bigger than the red kernel.

On tasting the popcorn, children were asked whether the red kernel popcorn tasted different from the yellow kernel popcorn. Waleed and Christian thought the same; Deih No thought it was different. Waleed made links with home with popcorn making and had prior knowledge from home that he shared. His teacher's account shows his understanding of the concept of heat affecting transformation.

Catherine- why does pop corn pop?

Christian- Because I want to eat it.

Waleed- People want to eat it. Someone wants to eat a lot of pop corn.

Catherine- how does pop corn pop?

Waleed- you turn it on- then pop! Pop! (hand gestures moving up and down)

Catherine- What do you turn on?

Waleed- you turn it on, it pops. It jumps (hand gestures to demonstrate jumping).

It jumps and it pops.

Christian- I like to eat it.

Catherine- Maybe you need to make pop corn hot, to pop it?

Waleed- Yes, up there (points to the bench where the popcorn machine is located). Up there, and it jumps.

Again, as with Christian, Waleed interprets aspects of the experiment through an anthropomorphic lens (Watts & Bentley, 1994), stating that it “jumps”, something he also interprets through gesture. A New Zealand study of multimodal literacies (Simonsen et al., 2010) observed that combining modes often enabled children to strengthen and/or diversify their communication and meaning making. This seemed to be the case with Waleed, where the explanations through different modes enhanced his communication.

In the ice experiment, Waleed could predict what was happening and articulate his observations. Erin asked questions, including, “What do we need next?” “What will happen to the water in the freezer?” “Will the ice be cold or warm?” Waleed observed “When the sun melts the water, it will be ice”. Erin agreed and reframed his observation, “When the sun melts the ice, it becomes water again.” Here, Erin both observes and subtly adjusts Waleed’s working theory. Waleed’s scientific thinking was also recorded by Brooke, who wrote:

You have been such as active learner developing your research skills by making predictions, sharing your observations and asking questions involving: How? What? And Why? All in the pursuit of increasing your own knowledge and understandings ... what an engaged young scientist you are. I wonder where your curiosity will take you next?

Brooke’s observations indicate how Waleed’s thinking was evident with different teachers, and in different settings.

Waleed demonstrated the development of both domain specific science learning, and domain general knowledge. His domain specific knowledge was shown through his emerging working theories regarding heat and ice, while his domain general knowledge came through his ability to make predictions and to understand the processes of the experiences.

Discussion

This project was focused on developing scientific curiosity amongst young children. Teachers used a variety of techniques to provoke children to observe, describe, predict and theorise. They invited children to make observations using their senses and then to describe, compare and predict. They used a mix of explanation, open questions, and sometimes, closed questions in order to open discussion or prompt thinking.

A significant realisation was that access to science-based experiences was not just supported, but facilitated by positive social interaction. The friend group of Waleed, Deih No and Christian often participated in the activities together, and supported each other's engagement. For Christian, some of the experiences likely took place because he was with his friends, as Erin observed. Making positive connections with science through friendships enabled greater access to science learning through participation, and also supported children's positive associations with science-based activities. Friends were influential in supporting their peers to extend their participation with science, as Deih No did in encouraging Christian to touch the cloud dough. Social interactions also provided opportunities for the sharing of language and ideas, including exposure to other ways of thinking about the world. Hearing the language choices of friends made words and ideas more approachable and acceptable.

Access to science learning was supported through multimodal ways of experiencing science, and multimodal ways of being able to share thinking about science. Teachers did not restrict the way children chose to communicate about science, resulting in communication through gesture and body language, drawings, language, and combinations of these modes. Teachers provided experiential ways of engaging with the science experiences they designed that provided for different levels of engagement. Waleed needed more detailed explanations and opportunities for extension, while Deih No benefited from teachers' prompts.

Communicative competence was also built through the use of language married with rich personal experience. New language was reinforced through context and through activity, with language coming from teachers and peers. This is most evident for Deih No, who adopted her peers' words in the midst of her science learning. Such activities also encouraged children to use the language they have with confidence. The non-judgemental approach of

the teachers meant there were no wrong answers, only opportunities to contribute and to listen to the contributions of others.

There are three significant implications for practice here. The first is the importance of teachers being open to both domain-specific and domain-general knowledge. Even though it was the teachers' ultimate intention to develop children's scientific knowledge, significant, sometimes unanticipated domain-general knowledges were also developed. In Deih No's case, domain-general knowledges were the main learning gained. Being open to these possibilities and working with them could be a significant aspect of developing scientific learning pedagogies specific to young children in future research.

The second implication came from the variety and frequency of the science experiences made available by the teachers. This leans into the democratic framing of this project, by providing multiple entry points over time and across contexts, into scientific experience. In this environment, curiosity was nurtured. Teachers were able to identify what caught the attention of different children, and what would draw them back. Additionally, this approach created a science-rich environment for children, where not only experiences, but process and language created more equitable access to the sciences.

The third implication is the realisation of how significant the social aspect was to the development of scientific curiosity. The three case study children in this group were friends, and this friendship frequently supported engagement where scientific experience alone would not. While the influence of peers is not new to teachers, conscious recognition of this aspect could factor into planning and create additional points of entry in the development of scientific curiosity.

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