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Science, technology, engineering and mathematics learning through the lens of *Te whāriki: He whāriki mātauranga mō ngā mokopuna o Aotearoa: Early childhood curriculum*

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A personal reflection

When introduced to the acronym STEM (which stood for science, technology, engineering and mathematics) learning in early childhood education (ECE), I was immediately intrigued. Having been a kaiako (teacher) in rural New Zealand and growing up on a dairy farm, natural, hands-on, child-lead, and inquiry-based learning was my passion. It always sat well with me that *Te Whāriki: He Whāriki Mātauranga mō ngā Mokopuna o Aotearoa: Early Childhood Curriculum (Te Whāriki)* (Ministry of Education [MoE], 2017) backed by decades of research and literature supports a play-based approach to learning in the early years in New Zealand. It did not come as a surprise to me then that STEM learning, a term for the learning areas of science, technology, engineering and mathematics, a buzz phrase making its way around the international academic world, was something I recognised as intrinsically woven throughout early childhood curriculum and programs in Aotearoa/New Zealand. As a result, I presented on STEM learning in ECE with Fiona Woodgate, at the 2017 New Zealand Tertiary College symposium and have since been speaking with kaiako from different regions in New Zealand to get a broader idea of how STEM learning is integrated into their ECE programs.

Figure 1: Children at Little Einstein's Educare in Cambridge lead the design, planning, and execution of the construction of a hut made out of tree branches after recent stormy weather.

Due to a rapidly evolving, complex and technologically advancing society, it is now well recognised that future societies are going to need to be equipped with a range of problem solving and creative thinking dispositions, rather than specific skill sets (Allen, 2016; Smith, 2016; Rodriguez, 2016; Wise Lindeman & McKendry Anderson, 2015). The young children of today need to be involved in real world, contextually relevant learning, in order to support their communities, preparing them for educational opportunities in the future, as well as a wide range of careers that may not currently exist (Allen, 2016; Draper & Wood, 2017). This realisation has resulted in a strong international focus on the concept of STEM learning in today's varying education settings. Science, technology, engineering and mathematics (STEM), whilst a relatively new term in the early childhood education sector in New Zealand, is not a new concept. Its focus is to support children in learning problem solving, creative thinking, investigation skills and design, through multi-content curricula (Sharapan, 2012; Boston Children's Museum, n.d.; Gartrell, 2016).

This reflective article begins to explore the concept of STEM through the lens of *Te Whāriki* (MoE, 2017). The world renowned curriculum document is well known for its focus on dispositional, play-based learning, and the weaving of multiple curriculum content areas throughout daily and ongoing learning experiences. *Te Whāriki* (MoE, 2017) not only focuses on skill acquisition, but on dispositions and attitudes that support learning throughout a lifetime. This article presents an explanation of how teachers can support STEM concepts and experiences from ECE settings in Aotearoa/New Zealand are shared to provoke thinking and reflection.

Science, technology, engineering and mathematics – An introduction

In ECE, recognising individual aspects of STEM learning can be relatively simple. Children are naturally curious, and begin to explore the world around them from infancy, developing their own working theories about how the world works through the people, places and things that they interact with (MoE, 2017). In this sense, they are natural born scientists, investigating, questioning, exploring, and experimenting. As they explore, they are often confronted with simple scientific and mathematical concepts, such as learning about gravity, force and motion, quantity, number, weight, space, and time through play (Boston Children's Museum, n.d.; Sharapan, 2012; Hamlin & Wisneski, 2012; Bosse, Jacobs & Anderson, 2009).

Figure 2: Building a relationship with Papatūānuku (Mother Earth) is seen as an essential aspect of early childhood in Aotearoa/New Zealand, which can lead to increased environmentalism and sustainability in years to come. Children are encouraged to be involved in the care of the natural environment, and here, they are engaged with centre family members in exploring the garden, utilising and leaning valuable STEM concepts in the process.

"Working theories are the evolving ideas and understandings that children develop as they use their existing knowledge to try to make sense of new experiences. Children are most likely to generate and refine working theories in learning environments where uncertainty is valued, inquiry is modelled, and making meaning is the goal" (MoE, 2017, p. 23).

Often within children's play arises the opportunity to use varying tools to support their learning. Utilising tools with a purpose for design or problem solving can be understood as technology (Dietze & Kashin, 2012; Young & Elliot, 2003). Technology in ECE is often viewed by kaiako as digital technology, and the use of information communication technology (ICT) (Wise Lindeman & McKendry Anderson, 2015), however it is imperative to recognise that technology is anything that has been designed for and is used for a purpose, generally being to make a task easier, quicker, or more productive (Young & Elliot, 2003; Fleer & Jane, 2011). In my experience, engineering is perhaps the more challenging notion to identify as part of young children's learning and development, in part due to some teachers' lack of content knowledge in this area, but also the complexities of this concept for children in the early years. Much of the literature on STEM learning focuses on engineering for children from preschool age onwards (3+) without mentioning the infant and toddler years. Perhaps this is due to the perception of what design and engineering is for differing ages. Is a toddler not engineering when they are constructing with sand in the sandpit? Is an infant not designing when creating art with finger paints or food on different surfaces during experiences every day?

"The day-to-day programme and environment are organised in such a way that children can initiate purposeful, problem-solving activities and devise and solve problems to their own satisfaction using a variety of materials and equipment" (MoE, 2017, p. 49).

Science is a way of investigating, understanding, and explaining our natural, physical world and the wider universe. It involves generating and testing ideas, gathering evidence – including by making observations, carrying out investigations and modelling, and communicating and debating with others – in order to develop scientific knowledge, understanding, and explanations (MoE, 2007, p. 26).

Technology is intervention by design: the use of practical and intellectual resources to develop products and systems (technological outcomes) that expand human possibilities by addressing needs and realising opportunities.

> Adaptation and innovation are at the heart of technological practice. Quality outcomes result from thinking and practices that are informed, critical, and creative.... Technology is never static. It is influenced by and in turn impacts on the cultural, ethical, environmental, political, and economic conditions of the day (MoE, 2007, p. 26).
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> Engineers design technology using a combination of science and math (Pantoya, Aguirre-Munoz & Hunt, 2015, p. 61). Engineering is solving problems, using a variety of materials, designing and creating, and building things that work (Boston Children's Museum, 2013, p. 3).
>
> Mathematics is the exploration and use of patterns and relationships in quantities, space, and time. Statistics is the exploration and use of patterns and relationships in data. These two disciplines are related but different ways of thinking and of solving problems. Both equip students with effective means for investigating, interpreting, explaining, and making sense of the world in which they live (MoE, 2007, p. 26).

Whilst internationally, the concept of STEM focuses on inquiry and project-based learning, often planned for, facilitated and led by adults, I see this concept being represented in a range of educational settings, woven through a range of pedagogical approaches and philosophies of teaching in New Zealand. In line with the vision of *Te Whāriki* (MoE, 2017), STEM learning occurs naturally in children's play, need not be teacher-led or project focused (Gartrell, 2016; Draper & Wood, 2017) and can effectively be supported in a socioculturally relevant context for individual learners and their learning communities (Hamlin & Wisneski, 2012; Moomaw & Davis, 2010; Neill, 2009).

Science, technology, engineering and mathematics learning is important for all children, individually, and within social groups of learners. The common theme within the four STEM concepts, is that they are all content areas that occur naturally through play. When children are natural learners, curious in nature, they do not require adults to give them answers to questions, and do not benefit greatly from this method of teaching (Allen, 2016; Sharapan, 2012). Instead, children develop life-long dispositions of inquiry, curiosity and independent thinking by having inquiry skills scaffolded or modelled to them. Often children embrace the opportunity to investigate for themselves, experimenting, exploring, making mistakes, and using trial and error. In this sense, STEM learning is a way of being, a way of playing and a way of learning (Boston Children's Museum, n.d.). So where do kaiako fit into STEM learning?

The science, technology, engineering and mathematics environment

There are a number of areas worth considering when planning for and facilitating learning in diverse and unique education settings. One of the most obvious in play-based, child-led settings is the physical environment. Those familiar with the Reggio Emilio approach will have heard of the notion of the environment as the third teacher (Delany, 2011) and providing opportunities for child-led learning through the design of and resources available in the child's physical learning environment. It is imperative that the environment supports STEM learning so that children may engage in STEM learning experiences both independently, as well as with peers and kaiako (Hamlin & Wisneski, 2012). Long gone are the days of including a science, mathematics or technology corner in your classroom or setting (Neill, 2009; Delany, 2011), instead the emphasis is on saturating the environment in resources that encourage authentic, real-world, familiar and culturally relevant ways of exploring. These resources do not need to be expensive and single purpose, and can easily be found in our natural environments. As New Zealand makes more of a move towards environmental sustainability, and eco-schools become more popular (Vincent-Snow, 2017; Enviroschools, n.d.), reusing and recycling materials becomes an exciting way to make the most of what we have available to us, and supports children's creativity.

Figure 3: Through their natural urges, infants and toddlers explore mathematic and scientific concepts through play with the support of their kaiako, as well as through environmental prompts, provocations and play invitations.

Figure 4: Uninterrupted play allows these tamariki time to work together to create, design, problem solve, and imagine. Here, children in the Tui room of Little Einstein's Educare have created a structure to protect themselves from the 'Lava' beneath.

Another popular move in recent years appears to be the inclination to get out into nature to support real life, hands on learning. Emphasis has been made on preventing a generation of children with Nature Deficit Disorder, a term coined by Richard Louv (2005) in his book *Last Child in the Woods*. Kaiako and children are venturing out into whatever natural environments they have available to them, such as local parks, reserves or forests to make the most of natural learning that occurs when children are empowered to explore, question, and discover. science, technology, engineering and mathematics learning could not be more evident in these opportunities to explore and build a relationship with Papatūānuku.

Figure 5: Nature Days are becoming increasingly popular in ECE settings that can accommodate such expeditions. Children are empowered to use a variety of tools to explore, create and design, and developing working theories through the relationship they are building with the natural world around them.

Reflective Prompts:
Consider the ECE settings and environments you are familiar with.

Does your environment invite exploration? Are there spaces, in which children can taste, touch, smell, listen and look?

Are there gardens and natural spaces for children to independently explore nature science, earth science and opportunities for children to play with different matter to build working theories about the natural and physical world?

Are there loose parts provided both inside and out for children to construct, build, design, create and begin to develop theories around science and mathematics through size, weight, height, gravity, momentum, trajectory and more?

Do you have pen, paper, clipboards, scissors, cameras and other technological tools available to children in different areas that they can easily access and use to document, plan, take notes and draw about their learning and discoveries – inviting engagement in the concept of engineering?

"Children have opportunities to explore how things move and how they can be moved by, for example, blowing, throwing, pushing, pulling, rolling, swinging and sinking. Children have access to technology that enables them to explore movement, for example, wheels, pulleys, magnets and swings. Children have opportunities to develop spatial understandings by fitting things together and taking things apart, rearranging and reshaping objects and materials, seeing things from different spatial viewpoints and using a magnifying glass" (MoE, 2017, p. 49).

Science, technology, engineering and mathematics books

Books are an essential resource for any STEM learning environment (Bosse, Jacobs & Anderson, 2009; Boston Children's Museum, n.d.). Not only is it important for children to access reference books with correct images and names of items, something Fred Rogers found instrumental in supporting children's language acquisition and development (Sharapan, 2012), but also fictional and non-fiction story books about people and characters whom are investigators, explorers, inventors, designers and problem solvers themselves (Pantoya, Aguirre-Munoz & Hunt, 2015). Children's scientific and engineering identities are supported as they explore literature that introduces concepts, dispositions and attitudes children recognise within themselves, and they are able to develop deeper understanding of STEM concepts as they explore these in context through stories, characters and the arts (McLean, Jones & Schaper, 2015; Sackes, Trundle & Flevares, 2009).

In addition to this, Kathy Trundle's work on inquiry-based learning emphasises the opportunities that arise through purposeful interactions between kaiako, children and books to scaffold children's inquiry skills.

Fictional children's books to support STEM learning and identity in the early years:
Inventor McGregor by Kathleen T. Pelley
The *Grandma McGarvey* series by Jenny Hessell
Oh the Things they Invented by Dr Seuss
Rosie Revere, Engineer; and *Iggy Peck, Architect* by Andrea Beatty and David Roberts
Anything is Possible by Giulia Belloni

Risk taking

Wise Lindeman and McKendry Anderson (2015) emphasise that children need real-world experience and real-world problems in order to have a chance at developing solutions to these. Pawlina and Stanford (as cited in Wise Lindeman & McKendry Anderson, 2015) add that educators must view mistakes as opportunities to grow children's brains. Here, teachers must consider both physical risk taking, as well as emotional and mental risk taking. In today's society, maintaining the physical health and safety of the children in our care settings seems to have counterbalanced the human need to take risks in order to learn. Kaiako are finding themselves challenged beyond comfort when it comes to children's safety, and the balance between safe and calculated risks, children learning from experience, and adults protecting children from physical injury is out of sync. However, research shows that children need these experiences to learn for themselves, and that without these risk-taking experiences, children will not be adequately prepared for challenges they will face in the future, both physically and mentally (Brynes-Swiatek, 2017; Curtis, 2010; Gramling, 2010; Warden, 2010). When it comes to emotional and mental risk taking, we must consider how we are supporting children to try new things, supporting them to push themselves out of their comfort zones, and risk making mistakes and being wrong, all whilst remaining confident that their holistic wellbeing needs are being met to maintain a safe learning environment.

Figure 6: When the tolerance for risk is zero, children don't really risk loss of life or limb, but more often than not, they risk losing valuable experiences with the world they inhabit. (Gramling, 2010, p. 51).

Te Whāriki (MoE, 2017) supports this through its sociocultural approach to learning, outlining the need for children to learn in culturally and socially relevant contexts. In addition to this, aspects of dispositional learning such as perseverance, persisting with difficulty, and facing challenges or uncertainty (MoE, 2017), are outlined as important for life-long learning. Risk taking is highlighted as a desirable learning outcome throughout the Exploration strand of *Te Whāriki* (MoE, 2017), particularly for toddlers and young children. Risk taking, mistakes, failure, trial and error are all significantly important in STEM learning and developing perseverance, inquiry skills, attitudes towards exploration and creative thinking.

Reflective Questions:
Does your learning environment, both material and otherwise, provide opportunities for children to take risks physically, cognitively and emotionally?

Are children encouraged and supported to experiment, to trial, to make mistakes, to fail or succeed, and to revisit their learning?

Do your environments allow for independent and group creative thinking and problem solving?

Time

Providing children with not only the space and resources needed for exploration and enquiry learning, but the time to discover at their own pace, and the opportunity to document or revisit their learning is crucial. Gifting children the time to figure things out for themselves, without interrupting their learning with a quick answer, supports an attitude and disposition towards creative thinking and problem solving. Dr. Emmi Pikler (as cited in Christie, 2012) emphasised the importance of slowing down one's practice and interactions to deeply engage with the children during interactions. Toni Christie (2012) states that the practice of taking adequate time deepens teachers' awareness and knowledge of each child. The same concept can be applied to children's interactions with the world around them. Can giving children the time to explore, think and discover deepen their awareness and knowledge of the world around them, teaching them more about science, mathematics, engineering and technology in real-world, contextually relevant and authentic ways?

"The learning outcomes in each strand are broad statements that encompass valued knowledge, skills, attitudes and dispositions that children develop over time" (MoE, 2017, p. 22).

Figure 7: Hands on Science in action! Many New Zealand ECE settings are making a move to embrace children's natural inclination to get messy during their exploratory play. Science occurs in many forms, why not through mud and water play?

Figure 8: Working together as a team to solve problems, think creatively and develop theories about how things work. Science, technology, engineering and mathematics all evident through child initiated play experiences.

In addition to giving children the time needed to learn, do teachers support children to stay on task and be focused on the interest they have taken, or do they interrupt this learning with routines? In Carr and Lee's (2011) research on children's learning wisdom, they highlight the importance of teachers adopting strategies to support children to revisit their learning. One strategy suggested is that "Teachers can document the changes in children's understanding" (Fleer, 2008 as cited in Hamlin & Wisneski, 2012, p. 85). This allows children to deepen their engagement, and develop an openness to experiences and a capacity to reflect, in order to make sense of their learning.

Reflective Questions:

Are children gifted the time needed to explore, design, create and learn in uninterrupted environments?

Do the routines of the day disrupt this learning or do they support busy learners to continue their work?

Are children given the tools and strategies required to support them to document and revisit their learning? Are kaiako skilled in the art of observation, knowing when to step in, and when to step back?

Are kaiako gifted the time to support children's learning in this way, or are they too busy with the organisational tasks of the day?

Do teacher - child ratios support quality STEM interactions?

Purposeful, intentional teaching

Once we have decided as kaiako whether we should step back to observe, or step in to add value to the child's learning experience, the responses we provide must consist of high quality, purposeful, thoughtful interactions with children (MoE, 2017). In these moments, teachers need to be highly sensitive and aware of what the child needs from them – more often than not, it is not an answer they need, but stimulating investigation habits and behaviours being modelled to them (Sharapan, 2012). Kaiako must embrace opportunities to model moments of wonder, using questions that may prompt curiosity within children, and the opportunity to co-construct ideas and working theories in collaborative settings (Allen, 2016; Boston Children's Museum, n.d.; Sharapan, 2012).

The key to these experiences is not to make the mistake of answering children's questions with an answer, but to provide intentional, open-ended questions and comments that get the children thinking (Boston Children's Museum, n.d.; Sharapan, 2012). Equally as important, is the need to model and introduce the use of varying tools to support their enquiry, so that they may seek their own answers independently in future.

Modelling STEM language is crucial to a child's ability to learn STEM enquiry and thinking themselves. In addition to questions, modelling scientific, mathematical and investigative language is important to support children's inclination to develop their own working theories. Supporting children by modelling language, describing using scientific, mathematical and technological words will give them the tools to use to do the same in future experiences. This will also normalise STEM concepts and learning for children (Sharapan, 2012).

It is important to support children's scientific enquiry in new ways too – perhaps in ways they had not thought of themselves. This is where we are scaffolding their learning, in that they are learning new ideas and knowledge in a social situation from others. Part of STEM learning is how children understand investigative thinking and processes. Imperative to science, engineering and design are STEM process skills (Neill, 2009). The Ministry of Education supports this by adding that children should have opportunities to demonstrate "curiosity and the ability to enquire into, research, explore, generate and modify working theories about the natural, social, physical, spiritual and man-made worlds… [and the] ability to represent [these] discoveries using expressive media, including digital media" (2017, p. 47).

"Kaiako are the key resource in any ECE service. Their primary responsibility is to facilitate children's learning and development through thoughtful and intentional pedagogy. This means they require a wide range of capabilities [including being] knowledgeable about play-based curriculum and pedagogy and able to conceptualise, plan and enact curriculum that is motivating, enjoyable and accessible for all children, [and] able to integrate domain knowledge (for example science and arts knowledge) into the curriculum" (MoE, 2017, p. 59).

Conclusion

The rapidly changing world that we live in, is providing us with many new and exciting technologies that make our lives easier, more enjoyable, and enable quick access to new information at a rate never seen before. However, with these new and exciting changes, also come challenges for children's natural, enquiry learning. More and more ECE centres, particularly in city environments are designing spaces with little-to-no large open natural spaces for children in the outdoors, and are resorting to man-made environments of turf, concrete and other year-round, all-weather materials to support indoor/outdoor play. Does this mean that these children miss out on the opportunity to learn natural science? Or can nature be woven through the environment and program in other ways? Children are also more inclined to want to be engaged with digital media, as their parents and society are modelling the use of these in everyday interactions. Is this cause for concern in the ECE setting, or can children be empowered to use technology in constructive ways? Are kaiako equipped with the understanding of STEM learning and child development that they need to support life-long learning dispositions of enquiry, problem solving, risk taking and perseverance, or are current pedagogies failing tamariki (children)? As learning and information consumption grows exponentially to the highest it has even been, it is now more than ever that children need teachers to be the facilitators of learning, the models of curiosity, the inspiration to learn, explore, discover, think, design and to be leaders of the future. Dispositions, rather than skills, are what tamariki need to succeed in the future. A final question for reflection therefore asks are educators preparing tamariki adequately for life-long success?

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Image credits:
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