A framework for identifying and developing children's creative thinking while coding with digital technologies

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We present research that explored digital coding in an Australian early years learning centre and how it impacted on a focus group of 3 and 4-year-old children's creativity. The questions that guided the design experimental method were: (1) how do young children develop and demonstrate creativity when learning through play with digital coding technologies? and (2) what does creativity look like in young children's engagement with digital coding technologies? After firstly discussing the STEM (science, technology, engineering and mathematics) context of the research, we explore the meaning of creativity in the early years and establish the conceptual framework for analysing children's play and learning with a *BeeBot* coding toy and *iPad app.* Importantly, our review and synthesis of significant literature led to the development of an innovative framework, the *'A' to 'E' of children's creativity*. This framework includes five proposed characteristic clusters of children's creativity, including agency, being curious, connecting, daring and experimenting. Using critical episodes in an illustrative learning journey analysed through the framework, the children's use of a *BeeBot* and a *BeeBot iPad* application showed that creativity can be largely impacted by digital coding. We conclude by proposing pedagogical principles that could better enable children's creativity when learning, especially when coding with digital technologies.

Introduction

Step into any early years learning environment and you will see young children playing, talking and acting creatively. In innovative learning environments, you may also see young children using digital technologies in individual and creative ways as they begin developing twenty first century skills such as critical thinking, creativity, collaboration, communication, technology literacy and social-emotional capabilities (Scott, 2019; Campbell & Walsh, 2017). Our research, reported in this paper, aimed to explore digital coding in early years education and the impact it had on young children's creativity. The data was collected from an Australian university-based early years learning centre and included four educators and two focus groups of children aged three and four. The study's design and analysis of data was theoretically informed by constructivist principles and early years pedagogical practices. From a child development perspective, opportunities for constructing important foundation capabilities should be introduced in early learning environments through play-based experiences (Australian Government Department of

Education, Employment and Workplace Relations, 2009; Berk & Meyers, 2016; Dockett & Fleer, 1998).

By maintaining a constructivist learning environment, young children's inquiry-based learning may be supported enabling them to develop understanding of concepts and important social and emotional capabilities. Collaborative learning opportunities, enriched with meaningful discourse support children to review their existing knowledge and reflect on experiences. As a result, young children's learning and development may be enhanced through their ability to assimilate and accommodate information developed through inquiry in a constructivist learning environment (Choudhry, 2013; Piaget, 1977; Queensland Government Department of Education and Training [QGDET], 2019; Vygotsky, 1978). Understanding effective integration and uses of technologies in an early childhood environment may bridge a gap between early childhood pedagogies and young children's experiences with digital technologies (Edwards, 2013).

In the research reported here, we explored and critiqued the assertion that during the early formative years young children can be introduced to, and develop, powerful digital ideas that may support constructive and creative engagement with digital technologies. We firstly provide a review of relevant literature to outline the connections between young children's science, technology, engineering and mathematics (STEM) learning and their development of 21st century learning skills such as digital literacy, computational thinking and creativity. Secondly, we provide a synthesis of critical literature on creativity to consider 'what is creativity?' and 'what does creativity look like in early childhood?', before introducing the innovative framework developed as a significant outcome of this study. We discuss how this framework, the *A-E of Creativity*, was operationalised and validated by mapping the activities of young children and their educators in classroom-based coding activities. We share evidence of how playing and coding robots fostered creative capabilities in the young children.

Young children, STEM and coding with digital technologies

Around the world young children are immersed in STEM learning opportunities in their everyday activities and through their play. Young children pose their own questions, make predictions, try out new construction ideas and playfully use digital devices. They use their senses to answer questions, talk about their activities and represent their understandings in a number of different ways (Murcia, 2013). We are observing young children increasingly using and or engaged with digital technologies such as mobile phones, cameras, *iPads*, computers and digital coding toys (Murcia, Campbell & Aranda, 2018). As reported by Marsh, Plowman, Yumada-Rice, Bishop and Scott (2016), we are seeing the 'nature of play' changing in the digital age as new opportunities are provided for children to explore their everyday experiences in increasingly connected and multimodal ways. In Australia, researchers Campbell and Walsh (2017) described the importance of introducing coding in the early years and highlight the links to the *Melbourne Declaration on Educational Goals for Young Australians* (MCEETYA, 2008, p11). These researchers recognised coding as an authentic element of digital literacy which enables the T in STEM to be introduced into early years and ensure young children are well prepared for future learning success. However, the increasing proliferation of technology does raise questions of how young children could play and learn with different types of digital technologies and the impact they potentially have on their developing 21st century learning skills such as creativity.

Digital technologies and coding in early childhood

A wider range of technologies are currently available to individuals than those of previous decades and contemporary children use technologies differently to the way they were used in the past. Rather than focus only on touch screen technology, children are also encouraged to experiment with hands on tangible technologies and robotics. Early Childhood Australia (ECA) described digital technology as 'based on the use of small microprocessors or chips that convert information into numbers or digits' (ECA, 2018). Similarly, the British Association for Early Childhood Education (2012) recognised digital technology as another useful tool to support children's early communication, language and literacy. Children have increasing access to a variety of digital devices and educators are exploring how to use the affordances of the technology to enhance learning opportunities.

The Australian Early Years Learning Framework (EYLF) advocates providing children with authentic opportunities to use symbols in play to represent their learning and construct meaning (Australian Government Department of Education, Employment and Workplace Relations, 2009). The development of foundation literacies is evident when children playfully code as they are representing actions and events through symbols and patterns. Coding with appropriate technologies engages young children with fundamental computer science practices. Coding simply means to input instructions into a machine or robot (Campbell & Walsh, 2017) and is regarded as one of the most powerful aspects of educational technology (Strawhacker, Lee & Bers, 2017).

Research evidence suggests that young children can learn programming and engineering at an early age when given tools that are developmentally appropriate, encourage open ended play and allow the integration of technical skills (Sullivan, Elken & Bers, 2015). Researchers Murcia and Tang (2019) investigated 4-year-old children's use of multiple representations as they developed creative stories told and acted-out through coding a toy robot. Their findings highlighted the influence that coding experiences with digital toys can have on young children's creative storytelling and importantly their understanding of symbolic representations and developing digital literacies. Evidence exists to demonstrate the positive effects learning to code has among early learners, which includes children setting their own intentions as they are figuring out how to create conversations, trying things out, learning to embrace mistakes as a natural component of learning and creating, receiving and valuing immediate feedback, and developing proficiency with coding (Murcia, Campbell & Aranda, 2018). Coding, which is arguably an observable action reflecting computational thinking, is increasingly an important digital literacy practice.

Computational thinking in early childhood

Computational thinking is 'a problem-solving method that is applied to create solutions that can be implemented using digital technologies. It involves integrating strategies, such as organising data logically, breaking down problems into parts, interpreting patterns and models and designing and implementing algorithms' (ACARA, 2018). Sullivan and Bers (2016) claimed that when children learn a programming language they are solving problems in systematic ways, learning new powerful ideas and expressing themselves with a variety of computational media. Computational thinking can foster creativity by allowing students to not only be consumers of technology but also build tools that can have significant impact on society (Mishra, Koehler & Henriksen, 2011). Among early learners, computational thinking can be identified when children learn to push buttons to make different sounds, take digital photos themselves or use those provided to sort in different ways, or they may recall the order of their activities during the day. This suggests computational thinking could be observed through children's creative practice.

Creativity

Hence, in the early years, young children may be introduced to, and develop, powerful digital ideas as foundational knowledge and understanding for engagement with digital technologies for creative endeavours and thinking. Creativity has been identified as a key skill for twenty first century learning, when integrated with critical thinking, collaboration, communication, computational thinking, technology literacy and social-emotional development (UNESCO, 2015). These skills are integral to quality early learning experiences and equip young children for success on entering school and throughout life (Scott, 2019; Campbell & Walsh, 2017).

Creativity is important at individual and societal levels and is researched across disciplines including psychology, business, education, science and the arts. Creativity plays a part in day-to-day problem solving, in adapting to change, in new movements in art, scientific discovery, new inventions, innovative social programs, products and services, job creation and in remaining competitive in the business world (Sternberg, 2017). The development of creative thinking skills has been a desirable educational goal since the mid-20th century (Guilford, 1950; Vygotsky, 1978; 2004). Craft (2011) documented a global resurgent interest in promoting creativity as an educational goal, with education systems in various countries (e.g. Australia, Canada, China, England, the Middle East and Singapore) including the development of creative thinking skills as a curricular goal. Yet the policies are not always matched by classroom practice.

Creativity is a complex construct with many inherent tensions and contradictions. Despite divergent viewpoints, there is general agreement amongst researchers on the two core features in any definition of creativity: originality (or novelty) and value (or appropriateness) (Runco & Jaeger, 2012). Two other features occasionally included in definitions of creativity are quality and impact (or influence) on a particular field of endeavour. There are also differing views on whether creativity is an elitist capacity, demonstrated only by the great creators throughout history, or a democratic ability that every person can display (National Advisory Committee on Creative and Cultural Education [NACCCE], 1999). Four different levels of creativity have been defined: big-C, pro-c, little-c and mini-c creativity (Kaufman & Beghetto, 2009). Big-C creativity is associated with eminent individuals who have made lasting impact on their field, pro-c creativity is demonstrated through professional level expertise in a creative field, little-c creativity is associated with creativity displayed in everyday life, attainable by all, whilst mini-c creativity reflects the individual level new insights often associated with the learning process (Kaufman & Beghetto, 2009). We define creativity as the ability to generate original ideas that are appropriate to the task at hand. This capacity can be displayed in any discipline (e.g. science, the arts, humanities) and is not restricted to the disciplines traditionally regarded as the creative industries, e.g. arts and design.

Different factors have been identified in creativity and are evident in playful thinking. Importantly, possibility thinking was introduced by Craft (Craft, 2002; Craft, 2007; Craft et al., 2012), in her research focusing on young children, to describe the playful thinking process when children explore the transition from "what is" to "what might be". Following from this insight, five characteristic features of creativity were identified by Joubert (2001) as: imaginative activity (playing with ideas, experimentation); a fashioning process (involving transforming, or turning ideas into action); pursuing purposes (intentionality to produce an outcome); originality (involving elements of novelty or newness at individual, relative or historic level); and value (usefulness in relation to the intended outcome). A number of pedagogical approaches were identified that nurture creativity or possibility thinking in early childhood classrooms, including posing questions, play, immersion, innovation, risk-taking, being imaginative, self-determination and intentionality (Craft, McConnon & Matthews, 2012; Cremin, Chappell & Craft, 2013; Davies & McGregor, 2017; Glāveanu, 2018). Recent research by Danby, Evaldsson, Melander and Aarsand (2018) has identified children engaged in game playing activities, with both peers and siblings, to creatively collaborate. They recognise instructing others, monitoring the actions of others and problem solving as examples of creatively collaborating.

Educators can play a critical role in encouraging learners' creativity. A distinction can be drawn between teaching creatively and teaching for creativity (NACCCE, 1999; Lucas & Spencer, 2017; McGregor & Frodsham, 2019). Teaching creatively is defined as "teachers using imaginative approaches to make learning more interesting, exciting and effective" whilst teaching for creativity is defined as "forms of teaching that are intended to develop young people's own creative thinking and behaviour" (NACCCE, 1999, p.89). Thomson, Hall, Jones and Sefton-Green (2012) also highlighted the role that educators can play in developing intrigue through their pedagogical choices.

There is a growing body of research exploring creativity particularly in early childhood contexts. Craft et al. (2012) explored the concept of possibility thinking, which involves asking 'as if' and 'what if' questions, within an early learning context, whilst Cremin et al. (2013) discussed the dynamic interaction between children's question posing and question responding within an immersive play-based creative learning context. The importance of dialogue and collaboration to nurture creativity within early childhood STEM contexts is acknowledged by Kramer and Rabe-Kleberg (2011). Goldin-Meadow (2009) reminded us that children can often express their thinking through gestures before they can do so through spoken language and Glauert and Manches (2012) encouraged the utilisation of a variety of modes of communication in early childhood contexts, where some children may be non-verbal or pre-verbal, e.g. drawings, gestures, actions and even digital representation of thought. Distinctive early childhood pedagogies, e.g. inquiry learning, lends themselves naturally to the development of creativity. Cremin, Chappell and Craft (2015) identified a range of similarities between inquiry based learning and creative approaches to learning in STEM contexts, including play and exploration, dialogue and collaboration, reflection and reasoning, and questioning and curiosity. Glauert and Manches (2012), however, pointed out a key differentiator which is whilst inquiry learning involves the pursuit of a personal line of thinking, creativity involves the generation of alternative or divergent lines of thinking.

The A to E of creativity in early childhood

Based on a careful analysis and synthesis of the literature, we proposed a research framework *The A to E of Creativity in Early Childhood* (Figure 1), as a literature-informed and empirically tested operationalisation of creativity. Whilst creative teaching may seem a natural fit for early years pedagogues, Cremin et al. (2015) found that early childhood educators in the pan-European *Creative Little Scientists* project did not explicitly plan for creativity in STEM learning activities; they planned for science learning activities and the creative aspects of learning were either "unrecognised or implicit in their planning and practice" (p.412). We believe the *A to E of Creativity Framework* will support educators to make creativity more explicit in their practice and to enhance the identification and development of creativity in learning contexts.

The basis of our framework is an adaptation of the *Four Ps of Creativity* proposed by Rhodes (1961) that are product, person, process and press, with the final P defining the things that help or hinder creativity. We have opted to use the word place instead of press, since it is more reflective of an educational context, hence our framework expresses the role of product, person, place and process in children's creativity in the classroom. The aim of the framework is to synthesise the factors enabling and characterising children's creativity within the classroom context to answer the question: "What does children's creativity look like within an early childhood classroom?"

Product: Criteria for creative outcomes

At this level there are two key criteria, originality and fit-for-purpose required for outcomes of thinking and doing to be classified as creative. Products of creativity could be a physical artefact (e.g. a picture), or an abstract product (e.g. an idea). In this context, originality requires an element of newness or novelty at the individual level, similar to the 'little c creativity'. Creative ideas must also be effective or fit-for-purpose rather than random.

Person: Perspectives on who does the original thinking

We identify three different perspectives on the child's role in the creative activity. Firstly, the child can be engaged by the educator's creativity, i.e. the educator uses creative strategies to make the learning engaging and interesting for the child. Secondly, the child can be involved in creative doing, by following the educator's example or a predetermined sequence of steps. These, however, offer limited opportunity for young children to engage in original thinking themselves. The third perspective is the child engaging in creative thinking through the generation of ideas or outcomes that are original, to the child, and fit-for-purpose as established at the beginning of the activity. Creative thinking can be expressed through words, actions, drawing or gestures, but what differentiates it from creative doing or modelling is that the child is the initiator and generator of the creative thought.

Place: Elements of an enabling environment

In our framework place focuses on the role of the educator in shaping the environment and enabling children's play and learning agency. We have identified three elements of an environment that supports children's creative thinking. These are resources, communication and the socio-emotional climate, each focusing on what educators can do to proactively shape the environment to facilitate children's creativity. Intentional provocations, stimulating materials, adequate materials for everyone and time for creative exploration are the resources that help enable children's creativity. Intentional learning conversations, hearing and valuing children's ideas, open inquiry questioning and facilitating verbal or non-verbal dialogic conversations between children are all features of communication that facilitate children's creativity. A stress and pressure free environment that is non-prescriptive, non-judgemental and allows room to learn from mistakes are features of a socio-emotional climate that are likely to enhance children's creativity.

Process: Characteristics of children's creative thinking

Five characteristic clusters, articulating what children are demonstrating when they are acting and thinking creatively, are synthesised from the literature and described as the 'A' to 'E' of children's creativity. These clusters are: Agency, Being Curious, Connecting, Daring and Experimenting ('A to E'). Firstly, creative thinking requires agency on behalf of the children, i.e. the ability to take ownership of their ideas, to initiate actions and to let their personal voice be heard. The second cluster of process characteristics involves being curious: being driven to inquire, to find out, to dream up new possibilities. Thirdly, children's creativity is characterised by connecting: the ability to link together what was previously apart. Fourthly, creativity involves an element of daring: the willingness to have a go, to take a risk, to be adventurous or even audacious. The fifth set of characteristics comprise experimenting: the ability to develop new ideas and outcomes through trial and error. These elements are brought together and presented in Figure 1.

The 'A' to 'E' of creativity: A framework for young children's creativity

<table>
<tr><th colspan="5">PRODUCT: Criteria for creative outcomes</th></tr>
<tr><td colspan="3">ORIGINAL</td><td colspan="2">FIT-FOR-PURPOSE</td></tr>
<tr><th colspan="5">PERSON: Perspectives on who does the original thinking</th></tr>
<tr><td colspan="2">CHILD ENGAGED BY EDUCATOR'S CREATIVITY</td><td colspan="2">CHILD'S CREATIVE DOING</td><td>CHILD'S CREATIVE THINKING</td></tr>
<tr><th colspan="5">PLACE: Elements of an enabling environment</th></tr>
<tr><td colspan="2">RESOURCES</td><td colspan="2">COMMUNICATION</td><td>SOCIO-EMOTIONAL CLIMATE</td></tr>
<tr><td colspan="2">Intentional provocations</td><td colspan="2">Intentional learning conversations</td><td>Stress and pressure free environment</td></tr>
<tr><td colspan="2">Stimulating materials</td><td colspan="2">Hearing and valuing children's ideas</td><td>Non-prescriptive</td></tr>
<tr><td colspan="2">Adequate materials for everyone</td><td colspan="2">Open inquiry questioning</td><td>Non-judgemental</td></tr>
<tr><td colspan="2">Time for creative exploration</td><td colspan="2">Facilitating dialogic conversations</td><td>Allowed to make mistakes</td></tr>
<tr><th colspan="5">PROCESS: Characteristics of children's creative thinking</th></tr>
<tr><td>AGENCY</td><td>BEING CURIOUS</td><td>CONNECTING</td><td>DARING</td><td>EXPERIMENTING</td></tr>
<tr><td>Displaying self-determination</td><td>Questioning</td><td>Making connections</td><td>Willing to be different</td><td>Trying out new ideas</td></tr>
<tr><td>Finding relevance and personal meaning</td><td>Wondering</td><td>Seeing patterns in ideas</td><td>Persisting when things get difficult</td><td>Playing with possibilities</td></tr>
<tr><td>Having a purpose</td><td>Imagining</td><td>Reflecting on what is and what could be</td><td>Learning from failure (resilience)</td><td>Investigating</td></tr>
<tr><td>Acting with autonomy</td><td>Exploring</td><td>Sharing with others</td><td>Tolerating uncertainty</td><td>Tinkering and adapting ideas</td></tr>
<tr><td>Demonstrating personal choice and freedom</td><td>Discovering</td><td>Combining ideas to form something new</td><td>Challenging assumptions</td><td>Using materials differently</td></tr>
<tr><td>Choosing to adjust and be agile</td><td>Engaging in "what if" thinking</td><td>Seeing different points of view</td><td>Putting ideas into action</td><td>Solving problems</td></tr>
</table>

Figure 1: The 'A' to 'E' of creativity: A framework for young children's creativity

The A to E of creativity conceptually framed our qualitative research project and was used as the interpretive lens in analysis. Using the framework in our empirical study of young children's coding, enabled its testing and validation.

Methods: The *Creative Coding Project*

Our project was a collaboration with researchers and educators from an Australian university's Early Years Centre located on their metropolitan campus. In this Centre's kindergarten rooms, there were a minimum of 1 educator to every 10 children. However, in small group intentional teaching experiences there are generally between 4 and 6 children participating at a given time. There were four educators participating, who worked as a pair in each of the Centre's two kindergarten rooms with one shared assistant educator. For the research, the educators invited 8 children (ages 3 and 4) from their kindergarten program to join two focus groups. The invitation was determined and based on parental return of a signed ethics consent form, and children's interest and engagement with digital technologies during the 6-month research period. It should be noted that the size of the focus group was variable as the children had agency in the learning environment and could choose to join in or leave the activity. All children attending the kindergarten program had access, at some stage, to the activities. However, only children who had informed and signed ethics consent were photographed and described for inclusion in the research. For the purpose of this article, we have presented a learning journey which ran over a series of two fortnightly planning and implementation cycles with a single focus group.

An assertion of the research team was that digital coding technologies should sit integrated across the learning areas and create provocation for children's inquiry, development of computational thinking and creativity. Questions underpinning the study were:

- How do young children develop and demonstrate creativity when learning through play with digital coding devices?
- What does creativity look like in young children's engagement with digital coding technologies?

A design experimental method was used to structure the research and also to inform protocols for working with the educators. This iterative approach valued the classroom expertise of the educators as they partnered with the researchers in developing pragmatic solutions to the integration of digital coding technologies and associated pedagogies into the learning environment (McKenney & Reeves, 2018). The educators aimed to plan and implement innovative learning design, while observing, documenting and critically reflecting on children's learning outcomes with the Researchers. Formal project meetings, including shared critical reflection, were held with the educators every 4 weeks (Fichtman-Dana & Yendol-Hoppey, 2019).

The research involved a series of design cycles which included the integrating of the *BeeBot* and *iPads* (locked to the *BeeBot* coding app) into the learning environment. There were two *BeeBots* made available to the children and four *iPads* were set out on a table for small group play. Critical reflection on the outcomes of a design experiment cycle (learning journey) informed the educators' subsequent planning, and professional learning sessions were held with the educators as a part of the research process.

The following data was collected during the design experiment cycles:

- digital photos of the activities and learning stories about focus children;
- researcher site visits, field notes and photographs;
- briefing and debriefing activities in each centre (cluster meetings with educators - talking circles), sharing practice, building shared language and understanding.

Digital photographs were taken of the children playing and learning with the *BeeBot* and the *iPads*, by the educators. These photos were deidentified and used as further evidence to inform the observational notes and checklists made by educators during the design experiment. Educators wrote reflective learning stories, a normal practice in this Centre, about the children's engagement with the digital coding technologies, as this required them to focus on an individual child's experience. Educators wrote a minimum of two learning stories per week for the research project. Importantly the Centre's Director valued the research and professional development gained by the educators and provided additional time during the week for their reflection and writing. In the learning stories, educators described 'What' happened in the learning experience, followed by 'So what' was significant in this observation, and then 'Now what' in terms of how learning from the experience could be used to inform activities going forward.

The qualitative data set was viewed and analysed by the researcher team through the lens of the *A to E of Creativity Framework*. The researchers looked critically at the data set for evidence of creativity both in the educators' pedagogy and the children's activity. We compared our interpretations and interrogated significant episodes identified in the learning journey.

Findings: Illustrative learning journey

We present here one illustrative learning journey selected from the comprehensive data set titled "Willbee needs a home", where there was evidence of children doing, thinking and reflecting creatively, and also of educators engaged with creative thinking, doing and teaching. Critical episodes are described in the learning journey and matched with our analysis of creativity. The researchers' description of each episode is a synthesis of data that draws from the educators' learning stories, field observations and de-briefings with the educators.

Willbee needs a home: Introduction

One of the children's favourite story books, *Willbee the bumble bee,* which is based on the adventures of a bee through a garden environment, was used to introduced *BeeBots* (Figure 2).

In this two week learning project, the educators aimed to advance STEM knowledge; build biological understandings and encourage coding skills development. Episodes 1 to 5 focused on the children's learning based on their use of the *BeeBot* and episodes 6-8 focused on the children's learning with *iPads* locked to the *BeeBot* app, where they were engaged with computational thinking and sequencing instructions into code.

Figure 2: Introducing *BeeBots*

Episodes in the learning experience	Analysis of creativity
E1: Willbee the robot, had only been played with and coded by the children for movement on the commercial 'road' map that comes with the device. Children commented that "Bee's don't live on the road". The educator used an inquiry questioning model to encourage children's thinking and creative ideas, beginning with observing, "what do you notice about the bees in the garden and have you seen where a bee lives?" The children explored and investigated bees in the Centre's garden and, with their educator, they searched the Internet and looked at pictures of beehives.	**Product:** At this stage of the learning journey there was no product generated by the children that was original. **Person:** The *educator was thinking creatively* to engage the children with learning. **Place:** The *open inquiry questions* enable the children's creative thinking. A *range of stimulating materials* were available as resources for creativity (creative doing and/or creative thinking). The educator is using *intentional provocations* and *providing time for creative exploration*. **Process:** The children were *being curious* as they were *exploring* nature, *seeing different points of view* and *discovering* information on the Internet.

E2: The Educator then planned for a design and construction project where the children made their own map and home for Willbee. This extended STEM project created opportunities for children to also investigate in a range of different ways how far Willbee travelled in one coded movement or 'step'. They measured using a ruler and, with the educator's support, constructed a grid on a paper play mat. There was intentional inclusion of mathematical concepts in the construction including size, shape and distance.	**Product:** At this stage of the learning journey there was no product generated by the children that was original. **Person:** The children were responding to the educator's creative teaching but were not engaging in original thinking themselves. **Place:** *Children's ideas were being heard* by the teacher. All *ideas were valued* and there was *not one prescribed approach*. The educator was supportive and created a safe, *non-judgemental* place for exploration. **Process:** The children were *experimenting* with ways of measuring; non-standard measures and a standard ruler. *Connections* were being made between coding, Willbee's movement, measurement and places for inclusion on the map.
E3: The educator and children talked about all the places, plants and insects they wanted in Willbee's environment. The children used their imagination, shared their ideas and drew pictures onto the grid mat which became Willbee's new environment.	**Product:** The children's collective thinking and planning for Willbee's new environment was original and suited to the task. **Person:** Children were using their imagination and generating original ideas, thus children were thinking creatively. **Place:** The educator was *facilitating dialogic conversations*, *hearing and valuing children's ideas* in a *non-judgemental* environment. **Process:** Children were *being curious, wondering* and *imagining*. Children were *connecting* and *sharing ideas*.
E4: The educator presented the children with a problem: "Willbee doesn't have a home". Provocations were set up to encourage creativity. These included a mixture of interesting resources/ materials and also photographs of real beehives. The educator questioned the children and engaged them in a purposeful ideation conversation which led to them drawing designs on paper for Willbee's house. Their educator wrote their ideas and descriptions onto the design drawings. The children then helped the art specialist educator make a paper mache home and place it onto the grid playmap.	**Product:** The children made house designs that were *original* and enabled Willbee to move inside (*fit-for-purpose*). **Person:** The children were doing the creative thinking as they drew house plans. They were engaged in creative doing when they build the paper mache home with the art specialist. **Place:** *Stimulating materials* and *adequate resources* were provided for everyone. They were encouraged to develop ideas in a *stress and pressure free environment*. **Process:** The children had *agency* and *acted with self-determination* as there was a *purpose* for the task and they *found personal meaning* in make a home for Willbee.

E5: The children shared their ideas for Willbee's new adventures. They extended the story and told new stories about adventures for Willbee which they then coded and set in motion as they played with their robot bee.	**Product:** Willbee's new adventure stories were *origina*l and relevant (*fit-for-purpose*). **Person:** The children were doing creative thinking as they told new stories and as they coded they were engaged with creative doing. **Place:** The educator was *hearing and valuing the children's ideas*. She was accepting and non-evaluating of their ideas in a *non-prescriptive* way. The educator *facilitated dialogic conversations* amongst the children. **Process:** The children had *autonomy* and could *demonstrate personal choice and freedom* in which story they chose to code. They had a *purpose* for the coding sequence created as they *put their ideas into action*.
E6: Children got started by turning on the iPad and opening the BeeBot app. Simon had worked out how to use the arrows to get the BeeBot to go in the direction required. He helped Annie, who was struggling with direction. He pointed out which arrow to push if Willbee was stuck and not facing forward. He had worked out for himself that simply pushing the back button would get BeeBot out of a block. He was able to move the BeeBot around the maze with ease.	**Product:** No new product generated that was original. **Person:** The children were engaged through the app designer's creativity, but were not engaging in original thinking themselves. **Place:** The educator established a *non-judgemental environment* by avoiding evaluation of children's performance. The educator is *allowing the children to make mistakes* and help each other. **Process:** The children were *connecting* and *sharing* ideas. A child demonstrated *agency* and had a *purpose* for his actions.
E7: Charlie was also struggling with how to move Willbee with the arrows. The educator asked him to stand up and turn his own body in the direction Willbee was facing and asked him, "do you need to move forwards or backwards?" The educator also pointed to left and right directions for Willbee on the iPad screen and then showed him his left and right hand. He used his body direction and hands to understand the arrows and he made some progress with moving the BeeBot through the Maze.	**Product:** No new product generated that was original. **Person:** The educator demonstrated creative thinking as she aimed to engage the children with learning content and concepts. **Place:** The educator used *intentional learning conversations* and was *non-judgemental* in her tone and actions. **Process:** The children were progressing in their development of coding skills. The child was *trying out* and applying the ideas provided to him by the educator and Charlie was encouraged to *see patterns and connections* between his body movements and the app.

E8: It became apparent to the educator that most of the children were struggling with orientation on the iPad and hence left and right. To assist the children, she made cards with an image of a BeeBot and red arrows pointing in the 4 directions, forward, backwards, left and right. She also included the real BeeBot at the table so the children could turn it to face the direction on the app. This helped Charlie but Liam was still struggling to understand the directional language and its use within the app.	**Product:** BeeBot direction cards were produced by the educator to support the children's learning. **Person:** The educator's creative thinking was contributing to the children's learning opportunities. **Place:** The educator was *providing intentional provocations* and *stimulating materials* to support the children's understanding of orientation and their use of directional language. **Process:** The children demonstrated *persistence* as they were struggling with the task.

Discussion

In the learning journey the BeeBot was introduced and used as a vehicle for the children's exploration of the world around them. Educators were observed identifying and designing inquiry opportunities for children to develop coding and computational thinking skills while playing with BeeBot and responding to the intentionally designed provocations included in the learning environment. Similar to findings from researchers Berson, Murcia, Berson, Damjanovic and McSporran (2019), it was evident that tangible design features of the coding device (BeeBot) encouraged children's explorations and creative doing and thinking. There was also evidence of computational thinking observed through coding.

Later in the learning journey, iPads were introduced to the learning environment and these were locked to the coding app for BeeBots. This kept the focus on coding but did potentially restrict the children and educators use of the device for more creative activities and potentially inhibit children's creative thinking. It seems the iPad BeeBot app activity was focused on learning the right solution or sequence of instructions but not on encouraging children's original thinking and own voice. The children were engaged by someone else's creativity (the game designer), but they were not generating their own creative ideas. However, the educator was thinking and acting creatively to address children's difficulties in using directional language and establishing orientation to the desired direction for movement (Figure 3). The iPads appeared to stimulate passive observation rather than active participation from some children as they waited for a turn. As also observed by Edwards (2013), the challenge for the educators was to design and guide learning experiences that were developmentally appropriate and meeting the play and inquiry learning needs of the children.

The adapted 4Ps Framework proved to be useful for analysing children's creativity within an early years learning environment. In the illustrative learning journey we saw examples of where both criteria for PRODUCT were met, for example in Episode 4, students were developing and drawing original house designs for Willbee which were fit for purpose and

Figure 3: Directional challenges with the *BeeBot* app on an *iPad*

allowed the devise to move inside. Whilst some ideas might not be historically original, they were original to that child. We also saw examples of where the two conditional criteria for creativity were not both met, such as in Episode 6, when the children were interacting with the iPads. They were engaged in purposeful thinking, following the directional language instructions to control the BeeBot, but this thinking lacked originality, thus failing to meet the bipartite criteria for creativity: fit-for-purpose and original. It is important to recognise that there is an important time and place for logical, purposeful thinking, and a time and place for creative, original thinking within a classroom context (Runco & Jaeger, 2012; NACCCE, 1999). Ideally these styles of thinking are well-balanced to create sufficient opportunities for children to develop their skills in both of these modes of thinking.

In the classrooms we saw examples of the three different levels of creative engagement from the PERSON perspective, for example, we saw children engaged through the educator's creativity in Episode 1 when the educator is posing open inquiry questions to encourage students to notice things about bees; we saw children involved in creative doing when they built the paper mache house for Willbee in Episode 4 (Figure 4), and we observed the children engaging in creative thinking in Episode 5 when they generated purposeful, original ideas for new Willbee adventure stories. The operative question remains: who does the original thinking, the educator, the game designer or the child? It is pertinent that educators create sufficient opportunities for children to develop their own creative thinking, not only participating in creative doing or watching the teacher's creativity (McGregor & Frodsham, 2019; Joubert, 2001).

Figure 4: Willbee's house and adventure map

Capturing the contribution of the educator to create an enabling environment for creativity to flourish is described as PLACE. All the elements of a creative place as articulated by the A to E framework and consistent with researchers Cremin et al (2013) and Lucas and Spencer (2017), were present in this inquiry-based early learning environment. Educators used rich resources to stimulate children's creativity (Episode 8), the communication style of the educators encouraged intentional learning, thinking and dialogic conversations using words, actions or gestures (Murcia, 2013) through the use of open inquiry questioning (Episode 7) and the educators established a safe, non-threatening socio-emotional climate where students were allowed to make mistakes (Episodes 2 and 8). It is important to recognise that inquiry-based learning (QGDET, 2019) is a well-established practice throughout the Early Childhood Centre involved in this research project.

Whilst we saw indicators of all 5 PROCESS categories in the children's actions, Agency and Experimenting were most frequently represented. This could be a unique feature of inquiry-based early childhood settings where these skills are strongly encouraged (Murcia et al, 2018). All six characteristics of Agency were identified in the classrooms, often facilitated through the skilful use of inquiry questions by educators (Episodes 1, 4, 5, 6). Children were also observed Experimenting as there were many opportunities for trying out new ideas, playing with possibilities, investigating, tinkering, using ideas differently and solving problems (Episodes 1, 2, 5), within this Early Childhood Setting.

Evidence of children Being Curious was found when they were wondering, imagining, exploring and discovering (Episodes 1, 3). Whilst educators were constantly using questioning skills and asking what-if questions, we did not see the children engage in these two activities themselves to achieve the balance of children answering questions and posing their own questions for exploration, such as "I wonder" statements and "what if" thinking as described in the literature (Chappell & Craft, 2011; Cremin et al., 2015).

Children were also observed Connecting and at times being Daring with ideas as they felt comfortable in the small group. They were Connecting as they built onto or joined ideas to prior knowledge of science (Episodes 2, 3, 6, 7) with some seeing patterns in ideas, reflecting on what is and what could be, sharing ideas with others and seeing other points of view, similar to that observed by Campbell and Walsh (2017). Interestingly, there was no evidence of the children combining ideas to form something new as noted by Danby et al. (2018). Whilst children were being Daring when they were comfortable to be different, persisting when things became difficult, learning from failure and putting ideas into action (Episodes 7, 8), we didn't observe them challenging assumptions and tolerating uncertainty.

Overall, five of the thirty subcomponents of the creative process characteristics were not observed in this learning journey: questioning, engaging in what-if thinking, combining ideas to form something new, tolerating uncertainty and challenging assumptions. This could be because these characteristics of creativity were not the focus of these specific inquiry lessons, it could merely be that not all 30 of these creative skills can be applied simultaneously and our reported learning journey research just captured a snapshot in time. Alternatively, it may suggest that different creative characteristics come to the fore at different ages. In this case the children were only three and four years old and were demonstrating developmentally appropriate skills (Marsh et al., 2016). With time and experience they may well demonstrate higher order thinking, greater questioning and challenging of assumptions.

Conclusion

The intention of the literature review, development of the innovative *A to E Framework of Children's Creativity* and the resulting analysis of the children's digital coding capabilities, was to address the research questions and provide evidence of how these young children developed and demonstrated creativity when coding and learning through play with the BeeBot and iPad App. It was evident from the analysis of learning episodes that the practices of the educators critically influenced how the children learned, as they planned and facilitated rich integrated coding projects where they were creatively thinking and trying out innovative pedagogies. The children followed the educator's thinking and were doing creative inquiry activities, and at other times they were also thinking creatively as they imagined and coded new adventures for their BeeBot. We recognised that creative teaching was an important method for engaging children in productive learning, though an unintended consequence maybe that at times it masked opportunities for the children to develop their own creative thinking skills. Educators may involve children in creative doing, for example when children are copying instructions or actions of the educator to generate a creative outcome (e.g. construction task, science experiment or a piece of coding), but are the children doing any creative thinking? The operative question has to be: "who does the original thinking?"

Our study provided evidence that inquiry-based pedagogies commonly used in early learning contexts complement and afford opportunities for children's development of creativity. In relation to our second research question, what does creativity look like in young children's engagement with digital coding technologies?, the *A to E Framework of Children's Creativity* was empirically tested and found to be an effective tool for identify and diagnosing children's creativity. It is anticipated that the framework could also be used to inform and support educators aiming to intentionally develop children's creativity. Intentionality in educators planning for children's creative thinking would address Cremin et al.'s (2015) concern that educators do not explicitly plan for creativity. We found in this study that the use of an integrated STEM learning context such as the life and needs of a bee, and meaningful provocations in the environment for coding the digital toy, created opportunities for children to engage in creative doing and importantly, creative thinking.

As a further outcome of the study, we recommend three pedagogical approaches that could be introduced in early years centres to foster children's creativity, especially when learning with digital technologies. Firstly, for educators to critically reflect on who does the creative thinking when planning and implementing STEM inquiry projects that incorporate digital devices. The aim is for children to not only be engaged by the educator's creativity, or to simply follow their educator's thinking by doing creative tasks, but also for the children to think creatively for themselves. Secondly, for educators to create a learning environment that is non-prescriptive, encourages children to wonder, imagine, and to foster opportunities for young children to design new ideas that integrate digital technologies. Lastly, to use thoughtful and focused inquiry questions and dialogic learning conversations that encourage children to be flexible, adaptable and persistent with open ended tasks. Each of these recommendations may further encourage children to engage in creative thinking through tasks they engage with in the learning environment.

We remain mindful that in an early years play-based STEM project, it is important to balance the development of understanding of concepts such as the living needs of a bee ("what does a bee need to survive?") and the structure of a beehive ("what does a real beehive look like?") with the development of personal imagination and creativity ("if you could design a house for a bee what would it look like?"). The sequence of activities is often important for stimulating a child's creativity. For example, first fostering a climate that is non-prescriptive, conducive to creativity, encouraging students to speculate, imagine, design new ideas, and then integrate learning so the science concepts can be layered over their imaginative thinking with what we see in nature.

When teaching for creativity educators step back, open up the task, allow time and resources for children to purposefully engage in creative thinking. With this pedagogical approach children are more likely to develop and demonstrate agency, being curious, connecting, daring and experimenting. While this project focused on children's creativity in a STEM coding project we also see applications more broadly for the framework. The *A to E of Creativity Framework*, makes explicit the criteria for identifying, developing and, potentially in future practice, for assessing children's creativity. It also highlights the environmental and social-emotional conditions that are conducive to fostering and evoking children's creative thinking processes. While this study focused on children's creativity in a STEM coding project, the framework could be applied in wider contexts, and further research interrogation of the framework will prove useful for the future of creativity and education.

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