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Children's Creativity and STEM Inquiry Projects

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Abstract: Inquiry and creativity in STEM are essential for developing adaptive and innovative thinking skills. These skills and ways of learning can be nurtured in young children as teachers navigate and bring together play and intentional teaching. Evidence of these mutually enriching pedagogies and early learning practices is presented in this paper, as rich descriptive vignettes. The included critical reflection on the early years practice, through the lens of the A to E of Creativity Framework, aims to enrich our understanding of creative inquiry in STEM and provide transferable strategies for a range of learning environments.

Keywords: STEM Inquiry, Children's Creativity, Teacher's Pedagogy

Introduction

Internationally we are seeing children thinking creatively and discovering through STEM (Science, Technology, Engineering and Mathematics) inquiry in their classrooms, and during everyday activities and play. As children inquire, they can pose their own questions, make predictions, try out new construction ideas and playfully use and learn with digital devices. In integrated STEM inquiry projects, children are learning through a cross-disciplinary approach as they apply concepts from multiple fields, think creatively, problem solve and construct solutions. In this paper, richly descriptive vignettes of young children's creativity, fostered during a STEM learning project conducted in a Western Australian Early Years Centre, are considered through a constructivist lens. The aim is to explore how in practice children's creativity can be positioned as a social, interactional and a meaningful process, rather than only being focused on as a product. The technology element within STEM encourages educators to provide opportunities for children to be creative in construction tasks, and importantly extend their learning experiences with digital technologies.

STEM and Digital Technologies for Children

There are many initiatives, often driven from the top level of government and manifested in local effort, aimed at enhancing both the spread and quality of science and mathematics education, and the building of children's STEM capabilities. There are many factors that affect children's engagement in STEM education, including the views of the broader community and parents' beliefs about the relevance of STEM in the early years. Research has highlighted the importance of early childhood education for building

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foundation STEM capabilities (MacDonald et.al, 2020; Van Keulen, 2018). In the edited book, *Children's Creative Inquiry in STEM* (Murcia et.al., 2022) international researchers reported contextualized evidence of young children learning inquiry skills and being creative in both formal and informal STEM experiences. Emerging themes from the collection of international research chapters included assumptions that STEM disciplines were intersecting and promote meaningful learning when children's inquiry projects are based on their interests and real-world experiences. There were a diverse range of approaches taken by teachers to understanding children's knowledge and designing STEM experiences. However, children were generally placed at the centre of the learning experience and encouraged to apply and build knowledge in playful ways. Children were observed socially constructing knowledge and skills from multiple disciplines, thinking creatively, problem solving and constructing multi-modal solutions and representations of their learning.

In contemporary early childhood education, digital technologies are also recognised as an ever-increasing influence in children's lives as they are used with, by and, for learning. Digital technologies are an important element of a child's integrated STEM education. Recognising the critical nature of digital technologies and the influence they have on childhood; the Australian Research Council (ARC) has funded a seven-year program of research and capacity building through the Centre of Excellence for the Digital Child (https://www.digitalchild.org.au). Australian researchers in collaboration with international and industry partners, are exploring the technology element in children's STEM experiences and building an understanding of pedagogical principles that support children's agency and ability to be creative, connected, and active learners with digital technologies. Research conducted with the Centre of Excellence for the Digital Child aims to support children growing up in a rapidly changing digital age and in part to investigate children's digital experiences through a creativity lens.

It is evident that digital technologies are increasingly taking a role in children's learning, as a tool for locating information, connecting and collaborating with others and for capturing and representing experiences. Arguably, children have the right to safely access age-appropriate technology that is aimed at developing their critical thinking and problem-solving skills while engaged with relevant learning experiences (Fourtane, 2019). Particularly, children as young as 2-years have developed digital capabilities such as knowing how to swipe and tap on a touchscreen (Marsh, 2016). Children are becoming technologically fluent, whereby they can use technology in a range of ways, such as to write a story, make a drawing, model or program a robot (Marsh et.al, 2016). With ubiquitous technology use by many families, children have become accustomed to acquiring knowledge through digital platforms, using touch-screens for exploring, playing and, experiencing digital connections. As a result, educators in early years centres and school classrooms are increasingly offering blended learning experiences incorporating both digital and non-digital elements.

Creativity and early years education

The approach to researching children's creativity in STEM presented in this paper, was informed by the work of Vygotsky (2004). Philosophically, a constructivist lens was used for critiquing literature and considering the question, how is creativity expressed and developed by young children? STEM education was often associated with the development of 21st Century Skills and its four C's: creativity, collaboration, critical thinking and communication (Khalil & Osman, 2017). In particular, creativity is considered relevant in all aspects of life and is a critical capability for problem solving and innovation. Creative teaching can be important for engaging children with quality learning opportunities and with scaffolding, educators are increasingly seeing the creativity in children's play and inquiry learning in STEM.

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The collection of research projects presented in the book *Children's Creative Inquiry in STEM* (Murcia et.al., 2022) provided evidence of young children applying concepts from multiple STEM fields and thinking creatively as they were problem solving and constructing solutions. Emerging from meta-analysis conducted across all chapters, were pedagogical principles, applied practices and elements of quality learning environments that contributed to and supported children's creativity and STEM inquiry. Firstly, children's creativity was playful. It drew on curiosity, involved imaginative possibility thinking and was integrated into their everyday living and learning. Secondly, children's creativity was socially constructed as it involved dialogic conversations, questioning, and making connections whilst acting and interacting with personal agency. Thirdly, children's creativity involved problem solving, as the focus was on children experimenting, thinking divergently, reasoning and expressing meaning in their pursuit of solutions and new knowledge.

The 'A to E' of Children's Creativity Framework

The work of Mel Rhodes (1961) resonated with what was being observed in children's STEM projects and learning environments. With further elaborated and thematic analysis of the literature, a structure for understanding children's creativity was offered by the *A to E of Children's Creativity Framework* (Murcia et.al., 2020). The framework captured and operationalised criteria for creative outcomes (creative product), perspectives on who does the original thinking (creative person), elements of an enabling environment (creative place) and characteristics of children's creative thinking (creative process).

A creative product was considered not only original but also fit for purpose. However, through the framework, children's creativity was not simply evidenced by a product but rather required educators and researchers to consider who was doing the creative thinking during a STEM project. For example, we questioned if the creativity was evident and controlled in the design of a potentially prescriptive digital application or the practice of the teacher leading the children. Ultimately, we looked to find evidence of the children thinking creatively for themselves. Our research interest extended beyond the 'product' or learning artefact generated in STEM projects, to include critical reflection and evidence of the processes that children engaged with, when generating a creative output. Through inductive analysis, we also identified the elements that created a conducive learning environment for children's creativity.

The elements of a creativity enabling environment include:

- Resources: Time for creative exploration, sufficient stimulating materials for everyone and the inclusion of intentional provocations.
- Communication: Intentional learning conversations where the ideas of children were heard and valued. Open inquiry questioning and the facilitation of dialogic conversations between children and with adults. Children were encouraged to ask and explore their own questions.
- Socio-emotional climate: A pressure free, non-prescriptive, or judgmental learning environment where children were supported to make and learn from mistakes.

The A to E framework provided a lens for analysing and understanding of children's learning experiences observed during STEM projects. It provided a structure for monitoring the process skills demonstrated by the children, both contributing to and, as evidence of their creative thinking. The characteristics of children's creative thinking represented in the framework as the A to E processes are:

- **A**gency: Children are self-determining learning directions, demonstrating personal choice and freedom to explore personally relevant and meaningful projects and experiences.
- **B**eing Curious: Children are engaging in possibility thinking, questioning, wondering, exploring ideas, and imagining

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- **C**onnecting: Children are making connections, sharing ideas with others, and combining ideas to make something new
- **D**aring: Children are willing to be different, tolerating uncertainty, persisting when things get tough and learning from failure.
- **E**xperimenting: Children are trying out ideas, playing with possibilities, experimenting, and solving problems.

STEM learning vignettes from an early childhood classroom

The following vignettes capture and represent a STEM learning program conducted in a Western Australian Early Year's Centre with a small group of 4-year-old children. Three qualified early childhood teachers collaborated with a university researcher, co-designing and implementing a series of STEM inquiry experiences with the children. Critical events in the children's 8 week learning journey are presented sequentially in this series of vignettes. Each vignette is informed and shaped by critical reflection and collaborative analysis, conducted through the lens of the *A to E of Creativity Framework*, with the intention of providing a rich sense of the classroom environment, the learning design and children's experience.

Getting started: Learning about technology and using mathematics

In this case, the children were introduced to a Bee-Bot, which is a coding device specifically designed for introducing young children to coding practices. It has a simple mechanical or push-button interface that children use to input a sequence of instructions that create a movement in the robot. It comprises 4 simple button input options: forward, backward, left and right (Figure 1) that make the coding device a child friendly starting point for teaching skills associated with computational thinking.

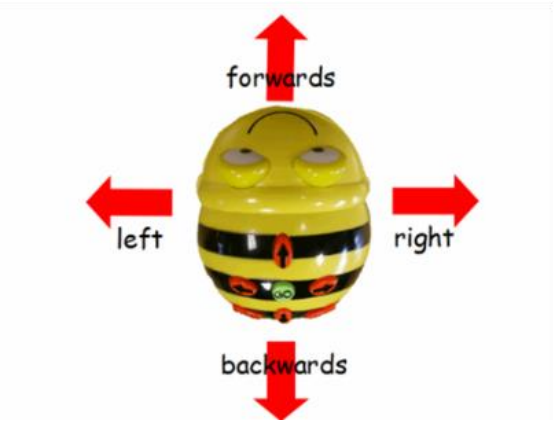

Figure 1. The push-button coding interface on a Bee-Bot

To begin the project, the teachers used the getting started guide from the Education Services for the Australian Government Department of Education, *Digital Technologies Hub* as part of their professional learning.

https://www.digitaltechnologieshub.edu.au. This open access, online Hub also provided learning resources that provoked planning for intentional technology experiences with the children.

After a series of free play exploration sessions with the Bee-Bot, a small group of children were observed intentionally learning about coding with their teacher. They were breaking down the steps needed to move the Bee-Bot along the road map that came standard with the device. The children liked the way each square on the map showed how far the Bee would go with one coded move. They were counting using one-to-one

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correspondence and completing simple algorithms to decide one more or less to reach a given destination. They were pushing the coding buttons in particular sequences to get the Bee-Bot to visit different places on the map. This required counting but also an understanding of orientation and direction. It was evident in this STEM experience the children were learning about technology, hardware, software, and coding but they were also developing important foundation mathematics concepts. While playing and learning, the children were demonstrating characteristics of creative thinking as they explored and experimented with the coding. They were trying out ideas and learning from failures which enabled them to 'de-bug' and re-code when a destination wasn't reached.



Figure 2: Measuring how far Bee-Bot moves

Going off the map: Learning about bees and the science of living things

The children's interest in bees and their curiosity about how they live was provoked by the book they had been reading with their teacher, *Willbee the Bumblebee* by Craig Smith and Maureen Thomson. This interested carried over into their play with the Bee-Bot and coding of travels on the road map. The STEM learning journey took a new direction when a child stated that the road play-map wasn't right and claimed, "bees don't live on the road!" His observation generated an intentional learning conversation between the children and with their teacher. The teacher asked open inquiry questions about what a living thing needed to survive, and she listened to the children's ideas. She asked the children, "what do you notice about the bees in the garden, and have you seen where a bee lives?" In the next cycle of planning, the teacher provided opportunities for children to explore their centre's garden and the bees on the flowers of a Jacaranda tree. They were encouraged to make observations, describe and draw pictures of the garden environment and find out about the living needs of a bee through guided internet searches with their teacher.

The science element of the learning program was child centered and importantly for the development of creative thinking capabilities, the children were given time and space to demonstrate agency in learning. Children's development of personal meaning was central to the inquiry project, and they displayed self -determination while voicing their ideas and taking charge of the learning direction. While being curious, the children were thinking creatively; questioning, wondering, and exploring how the bees lived in the garden.

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Designing a bee's environment: Imaging, drawing and measuring

The children decided they wanted to make a new world for their Bee-Bot to explore which, required them to construct their own play-mat environment. They drew inspiration from their favourite storybook *Willbee the Bumblebee* and other ideas they had about needs of living things. Pictures were drawn of places and insects in their imaginary garden. The children shared ideas and drew pictures that were brought together to construct their play-mat environment. However, the environment couldn't be constructed until they had solved the problem of how far the bee-bot travelled in one coded movement and hence how big to make each square of the play-mat. Initially guided by the teacher, the children used a cardboard template, which was a non-standard unit of measurement representing the distance travelled by the Bee-Bot in one movement. One child was listening and watching as the group tried to use the template to measure the movement of the Bee-Bot. He appeared to lose interest and left the learning experience. However, he quickly returned with a standard ruler from the storeroom. It was evident that his understanding of length and the concept of a standard unit of measurement was beyond what the teacher had expected for a four-year-old (Figure 2). By making connections and a willingness to be different, he created an element to the children's learning journey that was beyond what the teacher had initially planned. For educators, this illustrates the value of listening to the voice and watching the actions of children and responding by adjusting the learning experience to meet their needs and interests. In this part of the learning journey, the children were seen collaborating, challenging ideas, trying out ideas, and ultimately putting ideas into action. They engaged with a range of processes that were characteristic of creative thinking and produced an original, fit-for purpose creative product.



Figure 3. An original beehive construction and science informed play-mat.

Constructing a bee's 'house': Tinkering and using materials differently

The newly constructed play-mat included elements from the storybook which, supported the children's telling and re-telling of the events in the story. They also imagined new adventures for their Bee-Bot and created sequences of code for setting their robot on pathways around the play-mat. During a play session, a child asked where bee's sleep at night because he had noticed their Bee-Bot didn't have a house. This created another cycle of action for the children where they explored the structure of a beehive and considered the properties of materials and objects for constructing a home for the Bee-Bot.

Aiming to provoke the children's thinking, the teacher asked what they knew about a bee's home and introduced the term hive. Together they searched the web and looked for pictures of beehives. They then explored ideas for how they could make their own beehive for the Bee-Bot playmat. Surrounded by construction materials and tools intentionally introduced by the teacher, the children were encouraged to think like an engineer and draw

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a plan for constructing a hive. Together, they tinkered with a range of materials that they tried using in different ways. Ultimately, with the help from the art specialist teacher, the children learned paper mâché techniques for covering a balloon that they had decided was just the right size for creating the hollow interior for the Bee-Bot. Later they painted the hive black and were delighted when they could code the Bee-Bot to move inside (Figure 3).

Writing code: Telling and re-telling stories

During free-play with the Bee-Bot and the new playmat children were observed creating adventures and sharing their stories with each other, both verbally and by showing each other how the Bee-Bot moved when coded. While collectively reflecting with the teachers', the researcher questioned if the children could also use symbols to represent the sequences of code they were creating. Developmentally, these children were pre-formal literacy, not reading or writing. However, given earlier experiences when the children were demonstrating understandings and abilities beyond what was expected, the teachers agreed to intentionally include a story board activity into the children's learning. As shown in Figure 4, with scaffolding, the children quickly understood the concept and were confidently representing on paper, the coded journeys with a series of symbols in sequence. This further enhanced their ability to share their Bee-Bot travel stories with each other. It was evident as the children played that they were not only reading and writing the code, but that they could read each other's written code and re-tell stories.

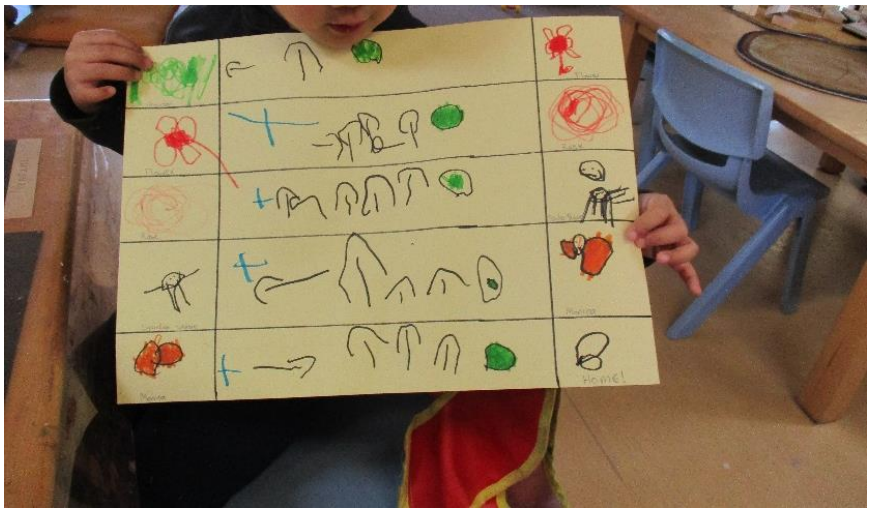

Figure 4. Writing code and storytelling

Critical reflection and discussion

The children's learning journey, captured in the preceding sequenced vignettes, illustrates key findings in relation to Murcia et.al (2020) four P's, (Product, Person, Place and Process) that was used to frame the critical reflection conducted in collaboration with participating teachers. It was evident that the teachers were demonstrating creative practices but importantly they provided the time, space, and resources for children to think creatively for themselves. When critically reflecting during the STEM inquiry project, it became apparent to the teachers that there were a range of process skills being demonstrated by the children as they were being creative. Importantly, these were used as evidence of children's creative thinking which, by nature, couldn't be directly observed. Expressions of children's creative thinking could be observed in multiple modes, such as discourse, by how they manipulated materials, or facial expressions and gesturing.

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Creativity was not simply defined by what was produced but evidenced by the process skills that were characteristic of children's creative thinking.

The importance of the learning environment in which these children were engaging with their STEM inquiry project cannot be under-estimated. Teachers in the research project, resourced the learning environment with intentional provocations that sparked children's curiosity and thinking. Adequate resourcing was required for creative processes and producing creative products, however, resourcing in this sense means more than simply tools and construction materials. Ensuring there were enough materials for all children to participate played a part, but the time given to inquiry projects was a critical resourcing element. Children needed time to explore their ideas and develop creative thinking practices. When children were experimenting, tinkering, designing, testing, and reflecting, they required time and the teachers needed to be agile and responsive in their cycles of planning.

Another critical element enabling children's learning and creativity was the nature of communication, both between the children and with their teachers. The conversations facilitated by the teachers were intentional as they focused on the learning objectives, included key vocabulary, and used open questions to encourage children's thinking and sharing of ideas. During the research project, the teachers became increasingly aware of actively listening to what each child was saying, responding to their ideas, and engaging them in two-way or dialogic conversations. The teachers were using an inquiry questioning approach, aiming to elicit children's ideas and in turn, encouraging them to ask their own questions.

Stress and pressure free learning environments were found to be most supportive of children's creative thinking. When children were allowed to make mistakes without judgement, they could reflect, learn, and try out new ideas. In open and non-prescriptive learning tasks, children made choices and were encouraged to talk about their ideas and actions. As teachers were talking and reflecting with the children, they modelled the value of other children's ideas and encouraged collaboration. Within the pressure free and emotionally supportive environment, children's well-being and creativity were found to be connected. When a child felt happy and safe in their learning environment, they were more likely to take risks, play with possibilities and, to be comfortable making and learning from mistakes.

Conclusion

A premise of our research was that creativity and STEM engagement are exhibited in children's every-day play but can be enhanced by teachers intentional resourcing of the environment and inclusion of age-appropriate digital devices and provocations. In this study, the positive social-emotional climate of the Early Years Centre, fostered the children's STEM inquiry and creativity. Children were daring to be different and trying out new ideas when they were encouraged, participated in dialogic learning conversations and collaborated with others. In this learning environment, the children had agency, they could play, explore their own interests and seek solutions to challenges. They used their imaginations as they created the new playmat for their coding device, Bee-Bot. The children's design and construction of a 'hive' was also informed by their willingness to ask questions, seek information and investigate with both digital and non-digital tools. The richness of the children's learning environment was critical to their creativity and STEM engagement.

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Collegial research activities encouraged the teachers to critically reflect on their design of learning and to monitor the children's experiences for evidence of creativity and inquiry skills. In cycles of reflection and planning, the teachers were designing learning experiences where children had a range of opportunities to apply and build knowledge from across the STEM disciplines. From this integrated perspective, the inquiry learning projects were designed to intentionally stimulate children's interest and desire to explore and be creative when problem solving. While playing and inquiring, the children were observed constructing multimodal representations of their learning, as they produced original and creative products from their STEM inquiry, such as digital stories, photos of their constructions and also science informed original coding maps for exploring with programmable robots. Beyond simply producing a creative product, the children's creative practice and thinking was a valuable social and interactional learning process.

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