australasian journal of
TECHNOLOGY EDUCATION

Editor: Associate Professor Wendy Fox-Turnbull, University of Waikato, New Zealand

The Australasian Journal of Technology Education is a peer refereed journal and provides a forum for scholarly discussion on topics relating to technology education. Submissions are welcomed relating to the primary, secondary and higher education sectors, initial teacher education and continuous professional development, and general research about technology education. Contributions to the ongoing research debate are encouraged from any country. The expectation is that the Journal will publish articles at the leading edge of development of the subject area.

The Journal seeks to publish

- reports of research,
- articles based on action research by practitioners,
- literature reviews, and
- book reviews.

Publisher: The Technology, Environmental, Mathematics and Science (TEMS) Education Research Centre, which is part of the Division of Education, The University of Waikato, publishes the journal.

Contact details: The Editor, AJTE, wendy.fox-turnbull@waikato.ac.nz

Cover Design: Roger Joyce

This journal provides immediate open access to its content on the principle that making research freely available to the public supports a greater global exchange of knowledge.

ISSN: 2382-2007

australasian journal of TECHNOLOGY EDUCATION

Let’s Play Together: Fostering Children’s Creativity and Computational Thinking Through Play with Coding Robots

Professor Karen Murcia
ARC Centre of Excellence for the Digital Child
Curtin University
Australia

Dr Emma Cross
ARC Centre of Excellence for the Digital Child
Curtin University
Australia

Sarsha Mennell
ARC Centre of Excellence for the Digital Child
Curtin University
Australia

Abstract

In early years education, fostering computational thinking and creative problem-solving through digital play can potentially help children develop essential skills for future learning and everyday life. This paper reports an action research project that explored how collaborative play with tangible coding robots could support children's creativity and computational thinking. The study involved five young children (aged 4 and 5), their parents, and two early years specialist educators, positioned as practitioner-researchers. Video data analysis from three digital play sessions within a longer 'stay and play' programme revealed that guided play with age-appropriate tangible coding robots like Cubetto, Blue-Bot, and Botzee could foster young children’s development of problem-solving underpinned by creative and computational thinking skills. To illustrate, key findings are shared through narrative style vignettes which elaborate learning episodes from each digital coding robot play experience. The vignettes highlight the dynamic interplay between children and co-playing adults in fostering computational thinking. Insights and recommendations are shared for nurturing computational thinking in young children and effectively integrating digital technologies into early childhood education.

Keywords

Tangible coding robots, collaborative play, computational thinking, creativity, early years education

Introduction

Creativity and computational thinking are regarded as contemporary literacies and crucial skills for success in today's digital world (Bers, 2018; Edwards & Bird, 2017; Murcia et al., 2018). These thinking skills underpin problem-solving abilities and logical reasoning needed in various aspects of life, from

STEM (Science, Technology, Engineering, and Mathematics) fields to everyday tasks (Murcia, 2022). However, the development of creative and computational thinking skills does not need to be limited to older age groups. Young children can be introduced to these thinking skills through play experiences with tangible coding devices such as toy robots (García-Peñalvo et al., 2016; Merrill, 2017; Murcia et al., 2022). Integrating the devices with hands-on materials and kinaesthetic learning principles is aligned with Australian early years education principles and fosters children's development of creative thinking and foundation coding concepts such as algorithms and logical sequencing (Bers, 2018; Lee et al., 2023). Using a hands-on approach with tangible coding devices arguably allows children to develop the foundational skills needed for later digital coding while enhancing problem-solving, critical thinking, and creativity (Bers, 2018; Ching et al., 2018). By nurturing creative computational thinking abilities in early childhood, the aim is to equip our youngest generation with the tools they need to thrive in an increasingly complex and technology-driven world (International Society for Technology in Education [ISTE], 2021; Murcia & Tang, 2019).

This article explores the concept of creative computational thinking, the importance of introducing it to young children, and the ways in which coding activities with programmable robots can foster these thinking abilities. The literature provides an overview of the development of creativity and computational thinking skills in young children. These concepts are used to frame and elaborate vignettes of children's collaborative play with tangible coding devices. The coding experience shared involved three devices, a Cubetto, Blue-Bot and Botzee. These digital coding experiences were part of a larger digital play programme and research project, titled 'Creative Cove', that was designed to identify pedagogical principles supporting children's creativity and computational thinking development within digital play. The study involved five young children, their parents, and two early years specialist educators and used an action research approach. Narrative style vignettes are used to illustrate key findings emerging from the thematic analysis of the video data capturing the children's coding and digital play. The article concludes by providing practical recommendations for early childhood educators.

Literature review

The conceptual framework for the study draws from the literature in the areas of digital technologies in early childhood education, creativity and computational thinking. With this framing, children's digital play experiences were viewed in the research study through a social constructivist lens which contributed to the identification of practical applications for tangible coding devices in early years classrooms.

Digital technologies in early childhood education

Understanding the evolving role of digital technologies in children's play is critical to the provision of contemporary early childhood education experiences. Recent research shows that children's play is becoming more complex, involving both digital and non-digital elements (Fourtane, 2019; Plowman, 2015). Digital tools, especially tangible coding devices, can be powerful tools to boost creativity, imagination, and various types of play (Highfield et al., 2018; Wilson et al., 2023). These tools help children develop key skills like creativity, computational thinking and problem-solving, which are essential in today's digital world (Lee et al., 2023; Murcia et. al., 2020; Strawhacker et al., 2018).

Incorporating digital coding devices into early years classrooms can support these foundational skills. For example, the Australian Early Years Learning Framework (Australian Government Department of Education [AGDE], 2022) emphasises the importance of integrating digital tools in ways that enhance play-based learning. By doing so, a learning environment can be created where digital technologies enrich rather than replace traditional play and learning activities. However, while digital tools offer exciting opportunities, it is important to approach their integration thoughtfully. There is still much to learn about how these tools are used in practice and how they can best foster computational thinking and creativity during play (Hu et al., 2023; Maslin et al., 2023).

Computational Thinking

Computational thinking encompasses several key components that can be naturally embedded within everyday experiences. These include decomposition, pattern recognition, abstraction, algorithmic thinking, and evaluation (Lee et al., 2023; Valenzuela, 2022; Wing, 2006). Computational thinking is recognised as a significant component of school curricula (Angeli & Giannakos, 2020). However, there is relatively limited attention given to children aged three to eight (Hu et al., 2023). For example, in a systematic review, Su and Yang (2023) identified only 26 studies on computational thinking in young children between 2011 and 2022, highlighting the limited research on how computational thinking can be meaningfully integrated into early childhood settings. As such, it is increasingly important to understand what computational thinking is and how it can be a part of children's creative problem-solving. Key components of computational thinking can be naturally integrated into everyday activities and early years experiences. For example:

- Decomposition: Breaking down tasks into smaller, manageable steps. For example, when children are organising their toys or constructing a block tower, they are practicing decomposition.
- Pattern Recognition: Identifying similarities or patterns. This could be as simple as recognizing patterns in a sequence of coloured blocks or noticing the repetitive structure in a nursery rhyme.
- Abstraction: Focusing on the important details while ignoring the irrelevant ones. This skill is evident when children identify the main idea in a story or simplify a complex game to understand its basic rules.
- Algorithmic Thinking: Developing step-by-step strategies for solving problems. Whether children are getting dressed in the morning or figuring out how to build a bridge with blocks, they are applying algorithmic thinking.
- Evaluation: Assessing and improving their solutions. After completing a construction challenge, children might recognise a better way to fit the pieces together, reflecting the evaluation process.

As illustrated in these examples, computational thinking skills are not only about using technology but are also about developing ways of thinking that help children approach problems systematically (Marsh et al., 2018). Computational thinking can provide young learners with systematic approaches to solving problems, which are also closely connected to the kinds of flexible, imaginative, and original thinking that underpin creativity.

Creativity

The idea that creativity is an essential part of children's play and learning is not new. Over 70 years ago, Guilford (1950) recognised creativity as a valuable form of learning. Today, even though creativity is considered a key skill for the 21st century, it can still be a complex concept to fully understand and apply in learning and teaching (Fielding & Murcia, 2022; Puryear & Lamb, 2020). There is not one single definition that everyone agrees on, but two important aspects of creativity are widely accepted: originality and usefulness (Barron & Harrington, 1981). Originality refers to how unique an idea is, while usefulness focuses on how valuable the idea is to a group or culture.

In early childhood education, we often focus on everyday creativity, which Kaufman and Beghetto (2009) describe as little-c and mini-c creativity. Little-c refers to the creative acts we see in daily life, while mini-c involves the personal creativity that happens within an individual, especially in young children. Thinking most likely plays a big role in encouraging creativity in children, as it helps them move from "what is" to "what might be" (Craft et al., 2012). Mini-c creativity is particularly important in young children's learning processes because it refers to the personal and meaningful interpretation of new experiences and ideas and recognises that they are shaping understandings in ways unique to them (Richardson & Mishra, 2018). Another helpful concept is the Four Ps of Creativity, introduced by Rhodes (1961). This framework suggests that to support children's creativity, we need to consider:

- Product: the creative work the child produces.
- Person: the child being the person doing the thinking.
- Press: the elements in the environment that enable the child's creativity.

- Process: the ways in which the child develops ideas and products.

Murcia and colleagues (Murcia et al., 2020) adapted Rhodes' concept of the 4Ps into the A-E Children's Creativity Framework, which emphasizes originality as something personal to each child. In part, this framework breaks creativity down into five processes that lead to a creative product:

1. Agency: Encouraging children to take ownership of their ideas and actions.
2. Being Curious: Fostering children's sense of inquiry and questioning.
3. Connecting: Helping children link different ideas or elements together.
4. Daring: Supporting children as they take risks and try new things.
5. Experimenting: Allowing children to develop new ideas through investigating and tinkering.

With a focus on process, early childhood educators can nurture the creativity of young children as they explore problems and use digital technologies in finding solutions. With digital technologies embedded in play and learning, computational thinking can potentially contribute to children's achievement of creative products.

Computational Thinking and Creativity

Digital technologies, particularly tangible coding devices, offer opportunities for children to engage in playful experiences where computational thinking contributes to the development of creative products (Highfield et al., 2018; Wilson et al., 2023). Such tools support creativity, imagination, and problem-solving, while also aligning with early learning frameworks that advocate for play-based and developmentally appropriate integration of technology (AGDE, 2022).

By embedding computational thinking into creative contexts, children can move fluidly between logical problem-solving and imaginative exploration. For example, coding activities can involve decomposition and algorithmic thinking while also encouraging dimensions of creativity such as experimentation, risk-taking, and originality. This alignment suggests that computational thinking does not merely serve technical skill development but also enhances children's creative capacities by supporting them to generate, test, and refine novel solutions. When brought together in early learning contexts, creativity can provide a complementary lens to computational thinking by emphasizing imagination, originality, and personal meaning-making, which suggests the two concepts may be mutually reinforcing.

Nevertheless, as recent research indicates, more systematic investigation is required to understand how computational thinking and creativity intersect in early learning environments (Maslin et al., 2023; Hu et al., 2023). Thoughtful integration of digital tools is necessary to ensure that technology enriches, rather than replaces, traditional forms of play and learning. When designed and facilitated well, computational thinking and creativity can work together to foster children's problem-solving skills, imaginative capacities, and lifelong learning dispositions.

The study

The study was conducted in the context of the 'Creative Cove', an eight week stay-and-play programme of digital play experiences, hosted at a Western Australian Science Discovery Centre. For the purposes of this article, three of the eight sessions are considered in depth. An objective of the programme was to gain insights into the design features of tangible coding devices and associated pedagogies in fostering children's creative and computational thinking. Each learning session was facilitated by two practitioner researchers, both qualified early childhood teachers with experience working in the sector. These teachers guided children's engagement and exploration, drawing from inquiry-based approaches to teaching and learning with young children. The children's parents were also invited to engage in each session, and they were encouraged to observe, co-play and extend children's ideas and interactions.

This article focuses on three tangible coding devices Cubetto, Blue-Bot and Botzee (Table 1). Each device was featured in a session that included an introduction to the device and an opportunity for play and investigation that was guided by an overarching idea and inquiry-based pedagogies.

Table 1:
'Creative Cove' - Session Overview

Tangible Coding Device	Overview of session
Cubetto: A simple wooden cubed-shaped robot designed for children aged 3 to 9 years, to build understanding of the fundamentals of coding. Children code Cubetto by placing, in a sequence of directions, coding blocks ('chiplets') onto the control board. https://www.primotoys.com	Following 'Cubetto's First Day' story, children crafted code sequences to manoeuvre Cubetto on the grid play mat, exploring pathways and destinations. The objective was to introduce foundation coding language and skills through sequencing, directionality, counting and evaluating.
Blue-Bot: A hard clear-shelled robot allowing children to see the internal hardware, with Bluetooth compatibility, and controllable through a mechanical coding interface. It introduces children to hardware components, while fostering an understanding of software and coding sequences. The mechanical interface engages children's abstract thinking and memory skills. https://www.teaching.com.au/product/TTSB485	Integrating Blue-Bot into a cross-curricula activity, exploring bees, flowers, pollen and hives, created a STEM learning experience. Coding the Blue-Bot 'bee' to collect pollen and return it to the hive, created an open-ended challenge rich with algorithmic thinking and the measurement of distance. The objective was to expand children's understanding of coding, progressing from visualisable sequences to abstract coding.
Botzee: A versatile block construction kit that encourages children to create their own robots by assembling hardware. Once constructed, these robots can be controlled through block coding using a tablet device. Leveraging augmented reality, Botzee introduces an imaginary world into the child's immediate environment. https://botzeestoys.com/products/botzees-robotics-botzees-classic	Building a robot Botzee required children to incorporate operating components, a motor and Bluetooth sensors, into their block constructions. Children could be creative or follow the design guide displayed on a tablet. The tablet touch screen was introduced as a control and coding interface. Additionally, the software includes an augmented reality view of Botzee in the play environment.

Methods

An aim of the research was to understand how children's play with tangible coding devices could influence their creative and computational thinking.

Research questions

The following research questions underpinned the study's design, data collection and analysis.

- What are the affordances of tangible coding devices for fostering children's creativity and computational thinking?
- What pedagogical principles support quality digital play with and by young children?

Participants

Prior to recruitment of participants, ethics for this project was approved by the Human Research Ethics Committee of an Australian University (HRE2022-0546). Expressions of interest in participation in the research were received after advertising to the members of the hosting Science Discovery Centre. Purposeful qualitative sampling, based on provided demographic information and postcodes, was used to select five children aged 4 to 5 years, comprising two females and three males, along with a significant other (a parent or caregiver). To safeguard the privacy and identity of all involved, pseudonyms have been used in place of actual names.

Action Research

Action research methods, aligned with the cycles of planning and critical reflection outlined in the National Quality Framework (The Australian Children's Education and Care Quality Authority [ACECQA], (2020) for the Australian early childhood sector, were used in this study. The cycle of planning endorsed by ACECQA emphasises key stages, including observation, analysis, planning, implementation, reflection and follow-up activities (ACECQA, 2020; Elliot, 2007; Murcia & Cross, 2022). Importantly, the research team met both before and after each session to plan, reflect and adjust next step planning based on observations and developing understanding of the children's interests and engagement.

Data Collection & Analysis

The primary data set for this study was video recordings. Videos provided a comprehensive and contextually rich capturing of children's experiences, thus allowing for in-depth examination of children's actions and discourse with others (Jewitt & Mackley, 2018). Four high-definition cameras were strategically positioned around the room to record interactions among the children, parents, and the practitioner researchers, resulting in approximately four hours of video footage for each session.

The research team closely examined specific moments from videos where children were playing with digital devices. These key moments, or critical episodes, were chosen because they provided valuable insights into how children engaged with the devices and showed evidence of their creative and computational thinking skills. Collaborative multimodal analysis (Jewitt, 2009; Kewalramani & Veresov, 2021) was employed to consider all the different ways the children communicated and interacted during play. To synthesise, narrative-style learning stories were written for each child, describing their creativity and computational thinking. To make sure these observations were accurate and interpretations trustworthy, the research team used a 'member-checking' process. This involved having different team members independently review the video clips and then discuss their observations together. This helped to clarify any uncertainties and enabled a shared understanding and representation of the children's experiences.

Through analysis, evidence emerged of children using important computational thinking skills, such as breaking down tasks (decomposition), following steps to solve problems (algorithmic thinking), recognising patterns, focusing on important details (abstraction), and assessing their solutions (evaluation). Creativity was evident in the original and fit-for-purpose solutions achieved by the children in response to the set challenges. Narrative vignettes were written to illustrate the study's findings. These vignettes were then cross checked with the relevant video episodes and verified by the contributing researchers.

Narrative Vignettes

Vignette 1: Cubetto

Sarah (teacher 1) introduced the story, 'Cubetto's First Day' and set the challenge for the children to code the little robot on the described journey. She suggested that the children use coloured chiplets to show the directions taken by the little robot in the story. She asked, "Why do we need to put the chiplets onto the board?" Sally (child 1) excitedly answered, "So that Cubetto knows!" As the children explored the story and developed coding sequences, Wendy asked, "What does the blue (coding chiplet) mean?" and Sally answered, "The blue means a code." Aaron (child 2) began the experience by having the first turn coding Cubetto. Aaron said, "What? He's turning!" Sarah replied, "he is turning because what did we leave on the board?" Aaron was prompted through questioning to check the coding sequence. Without talking, and obviously thinking as he looked at the chiplets, he reached over and corrected, removing the unnecessary yellow (left turn) coding chiplet from the board. Aaron had multiple consecutive turns at coding Cubetto, while Wendy (child 3) drew nearby, and Sally patiently watched and waited. Sally, realising it was her turn, excitedly exclaimed, "Me?!" before picking up Cubetto and putting the device in the correct starting place for the story. Sally began by re-telling the pathway from the story that Cubetto needs to follow. She confidently told the group a sequence of code, "two green, then a red to go there (pointing)", and then placed each chiplet onto the coding board. Sally visually checked the floor map, pausing after inserting chiplets to consider what came next in the sequence. Sally celebrated with Sarah as she set Cubetto off on its coded journey, successfully achieving the task of crossing the river. Then Wendy shyly re-joined the group as it was her turn. Sarah encouraged and scaffolded the coding experience for Wendy through questioning and asking, "How many spaces does he need to go forward? Can you count them?" Wendy counted, "one, two" out loud, pointing and touching the floor map and comparing the coding sequence to the coding blocks inserted into the control board. She immediately saw an error in the code, which was quickly debugged by replacing a coding chiplet.

Vignette 2: Blue-Bot

The experience began with the children sitting together, highly focused, watching a 'Sci-Show Kids' video about bees. Emily (teacher 2) asked clarifying questions at the conclusion of the video before encouraging the children to look around the room and use their imagination. She asked, "Who can see a hive?" Sally exclaimed excitedly, "The boxes!" The coding challenge was introduced with Emily saying, "Blue-Bots need to collect pollen from the flowers and take it to their hives." Emily then demonstrated the function of each coding button on the Blue-Bot and told the children they must clear the coding sequence by pushing the X button, before entering new code. Emily modelled the coding, without clearing the sequence before starting. Sally said, "That shouldn't happen" with a look of confusion. Emily reminded the children that the cross button clears the coding sequence. Sally, took the Blue-Bot and said, "Now forward!" Emily asked, "what do you need to do first?" "Clear it," Sally said excitedly. She continued her experimentation, pressing coding buttons and clearing them. Emily asked the group, "How do you know how many times to press the forward arrow to get the bee to the flower? Aaron casually replied, "Three" and pushed the forward arrow three times and then X - 'go'. His Blue-Bot moved towards the flower but stopped short of reaching it. Aaron cleared the code and repeated, but it still stopped short. He again cleared the code, but this time pressed the forward arrow only once. He repeated this one-step coding sequence until the Blue-Bot reached the flower. He did achieve the goal, but without counting the total number of single-coded moves forward or understanding coding as a sequence of moves. Nearby, Sally looked around the room and approached Jack (child 5) who was sitting quietly with his mother and said, "I need some help to get my Bot to the hive." Emily encouraged collaboration between the playing children by saying, "I think you're asking the same question as Aaron. Aaron is trying to find out how far one move is." Sally then chose to use a tape measure to show the distance between the Blue-Bot and her imaginary hive stating, "That's how far I want it to go." Sally was not yet considering the distance that Blue-Bot travelled in a single coded move.

Vignette 3: Botzee

Ethan (child 4) was excited by the robot's construction blocks and said, "I like Botzee." Sarah asked, "What do you like about Botzee?" Ethan replied, "I like making a Botzee that is not even in the picture." The children were asked to think about how they could build their robot. Sarah showed the children the hardware components, explaining what each component was and what it did. "I'm going to use three pieces of hardware to make Botzee and I'm going to make my own design," said Ethan. Aaron agreed and moved with Ethan to another part of the room with Emily. She placed the box of construction pieces down and said, "Aaron is excited to share, what about you Ethan?" "Yeah," said Ethan. Emily showed the boys the tablet displaying the Botzee build screen. Ethan and Aaron then looked through the construction pieces in the container. Ethan picked up the first piece needed to build Botzee, the main control block and exclaimed, "it's the brain". Aaron replied, "I've got the block and he can plug it in." Ethan passed the block to Aaron saying. "Aaron, we are making our own one, remember," he said to Aaron. "We found our own way to do it." Emily then prompted Aaron to read the tablet directions and he said aloud, "Point the camera at the character and hold still." Ethan held Botzee with Emily's help and Botzee made a noise to indicate it was connected with the tablet. "How do we control it?" Ethan asked. Aaron read the tablet screen and said, "Build, Code, Control." He pressed the control icon on the screen and Botzee chimed a noise in response. Ethan took the tablet and started to control Botzee, watching as it moved forward. Pointing with his finger he asked, "how does he turn that way?" Aaron pointed to the controller on the screen and Ethan tapped, moving Botzee in short, jolted movements and then in circles. With confidence, Ethan stood up, moving behind Botzee as he controlled the robot to the picture of a pond on the floor. When Botzee arrived at the pond, everyone clapped, and Ethan looked up from the tablet with a big smile.

Discussion

During the digital coding experiences with toy robots, the children not only demonstrated technical skills but also displayed effective collaboration and communication abilities, leading to creative products and ideas. By working together, children shared ideas, solved problems, and supported one another, while demonstrating principles of computational thinking (ISTE, 2021). These elements of computational thinking were key to their problem-solving and emerged as they navigated challenges in play. Thematic analysis of the activities provided valuable insights into how the children engaged in computational thinking while problem-solving and co-playing with peers, educators, and even parents. One theme that stood out was how children learned from their social interactions within the digital play environment, reinforcing the idea that social networks support learning in collaborative digital spaces (Budiyanto et al., 2021). The vignettes from the study illustrated critical episodes where digital play with tangible coding devices offered rich teaching and opportunities for children's learning.

The three coding robots used, Cubetto, Blue-Bot, and Botzee, were chosen for their user-friendly interfaces designed to be intuitive for young learners. Features like large buttons, coloured coding chiplets, simple icons, and straightforward navigation systems made it easy for the children to code the robots without requiring advanced technical knowledge. These tangible elements encouraged hands-on, constructive play and creative thinking, particularly when combined with other materials and environmental elements (Lavigne et al., 2020).

By physically engaging with the robots through coding, children not only deepened their understanding of computational concepts but also exercised their creative thinking skills. The teachers' design of the learning and setting of coding challenges was intentional and required the children to approach tasks creatively, as they were open in nature and encouraged agency, curiosity and experimentation (Murcia et al., 2020). The children's actions provided an insight into their creative thinking as they were learning from failed attempts, such as when Aaron adjusted his approach to coding the Blue-Bot and explored the distance it travelled, he was persisting and trying different approaches. Processes that are characteristic of creative thinking became evident as the children used their imagination to plan the robot's movements. They were observed making connections, putting ideas into action and finding alternate routes or strategies when a robot didn't follow the expected path, exemplified by play with Botzee and the children's joy when it arrived at the pond.

The children were also experimenting with different commands, adjusting and refining their coding strategies based on the robots' actions. Similar to findings from Lee et al. (2023), the children broke the tasks into smaller parts demonstrating the decomposition element of computational thinking, while linking coding symbols, patterns and algorithms to the robots' actions. Additionally, by counting and trialling the number of forward codes needed for the Blue-Bot's journey, the children demonstrated their commitment to testing, evaluating and refining coded sequences. Sally and Aaron's selection of a tape measure and his subsequent experimentation with pressing the forward arrow as a single action while adding one more move to his calculation of distance, showcased computational thinking underpinning his problem-solving approach.

The children were also observed identifying errors and making adjustments to reach their desired outcomes evidenced by Aaron's surprised response to Cubetto's movement, saying, "What? He's turning!" He responded by checking the coding sequence and removing the unnecessary yellow (left turn) coding chiplet from the control board. This process of trial and error allowed them to refine their approach to tasks, fostering both computational and creative thinking. As they coded robots to complete different tasks—such as guiding their Blue-Bot carrying pollen back to the hive and programming Cubetto to navigate the journey described in the storybook—the children engaged in problem identification and abstraction, as described by Wing (2006), by focusing on the essential details in each task necessary for successfully achieving goals.

Their algorithmic thinking was evident as they measured distances and aimed for precise movements in the robots. Similar to observations made by Highfield et al. (2018), each step in this process, coding, testing, adjusting, and retesting, highlighted the children's ability to think both computationally and creatively. The coding challenges also fostered a reflective learning process, evident as the children discussed their ideas, collaborated with peers, and sought help from adults. The children learned from each other's successes and mistakes, while demonstrating persistence that is essential not only in computational thinking but also in creative problem-solving. Through these interactions, the children worked together to achieve shared goals, combining logical thinking with imaginative approaches, which are both essential for fostering creative and computational thinking.

Limitations

The action research approach used to design, facilitate, and critically reflect on the digital play experiences was a strength of this study, providing valuable insights into the teachers' pedagogy and children's interactions with coding robots. However, there are some limitations that are important to consider. Firstly, the programme was short, and children were only observed for a limited time. Additionally, the study involved a small group of children, all from the same region in Australia and within a specific age range (4 to 5 years old). This lack of diversity in the sample may mean that the findings might not fully apply to children from different backgrounds, regions, or age groups. Another consideration is that the two early childhood education teachers who designed and facilitated the sessions also participated in reflective discussions and video analysis. While they were aware of the need to remain objective, their dual role as both practitioners and researchers might have unintentionally influenced how the video data was interpreted.

Implications for Practice and Recommendations

Integrating digital technologies in early childhood education requires a balance between digital and non-digital play to ensure that digital tools complement rather than overshadow traditional play and learning activities. By providing a diverse range of experiences, teachers can support children's exploration of the intersections and connections between digital and physical materials. It is also recommended that teachers carefully consider the design features of digital devices and other digital tools, considering the age-suitability and potential for provoking children's creativity. For example, setting coding challenges and linking storytelling exercises where children can craft their own digital narratives. This approach not only enhances their technical skills but also nurtures their imaginative abilities. Drawing from this study, intentionally designing digital experiences that encourage playful learning and problem-solving provides a foundation for introducing computational thinking concepts in the early years of education. For instance, simple coding games can teach children algorithmic thinking, while traditional building blocks can help them grasp decomposition. Encouraging exploration is another key principle, where children are allowed to experiment with different ways of solving problems. Educators can guide this process by asking reflective questions such as, "What do you think will happen if we try it this way?" to promote evaluation and deeper thinking. Moreover, designing integrated learning experiences that blend computational thinking with other subjects, such as mathematics, art, and science, may assist children in understanding the broader applications of their learning.

The Australian Early Years Learning Framework (AGDE, 2022) highlights the expectation that young children are provided with opportunities to engage with digital tools in early childhood settings. With quality practices in place, educators engage in continuous observation and adaptation. By paying close attention to how children interact with digital tools during play, teachers can adjust their strategies to ensure that play remains a central aspect of learning. This observation-driven approach allows for responsive teaching that meets the needs of each child, ensuring that digital technologies enhance rather than detract from the learning experience. Additionally, ongoing professional development is essential for educators to stay informed about the latest research and innovations in digital play. By participating in professional learning opportunities, teachers can acquire new strategies and techniques for integrating digital tools effectively, ensuring they remain at the forefront of educational practices. This commitment to continuous improvement not only benefits the educators but also enriches the learning experiences of the children in their care.

In conclusion, the hands-on nature of coding with robots provided a rich context for fostering children's creative and computational thinking. As the children navigated coding challenges, co-playing with their parents and peers, they experimented with different approaches, learned from trial and error, and adopted collaborative behaviours. These digital experiences provide children with the opportunity to develop a foundational understanding of both computational and creative problem-solving processes. The experiences from this programme suggest that by thoughtfully integrating digital technologies into the early years of education, teachers can support children’s learning and development while keeping play at the heart of their educational experience.

References

Australian Children’s Education & Care Quality Authority [ACECQA]. (2020). *Guide to the National Quality Framework*. https://www.acecqa.gov.au/sites/default/files/2020-01/Guide-to-the-NQF_2.pdf

Australian Government Department of Education [AGDE]. (2022). *Belonging, being and becoming: The early years learning framework for Australia (V2.0).* AGDE for the Ministerial Council.

Angeli, C., & Giannakos, M. (2020). Computational thinking education: Issues and challenges. *Computers in Human Behavior*, *105*, 1–13. https://doi.org/10.1016/j.chb.2019.106185

Barron, F., & Harrington, D. (1981). Creativity, intelligence, and personality. *Annual Review of Psychology, 32,* 439 – 476. https://doi.org/10.1146/annurev.ps.32.020181.002255

Bers, M. (2018). *Coding as a playground: Computational thinking and programming in early childhood.* Routledge.

Budiyanto, C., Shahbodin, F., Umam, M., Isnaini, R., Rahmawati, A., & Widiastuti, I. (2021). Developing computational thinking ability in early childhood education: The influence of programming-toy on parent-children engagement. *International Journal of Pedagogy and Teacher Education, 5*(1), 19–25. https://doi.org/10.20961/ijpte.v5i1.44397

Ching, Y. H., Hsu, Y. C., & Baldwin, S. (2018). Developing computational thinking with educational technologies for young learners. *TechTrends, 62*(6), 563–573. https://doi.org/10.1007/s11528-018-0292-7

Craft, A., Cremin, T., Burnard, P., Dragovic, T., Chappell, K. (2012) Possibility thinking: An evidence-based concept driving creativity? *Education*, *3*(13), 1–19. https://www.researchgate.net/publication/284039696_Creativity_in_the_curriculum

Edwards, S., & Bird, J. (2017). Observing and assessing young children’s digital play in the early years: Using the digital play framework*. Journal of Early Childhood Research, 15*(2), 158–173. https://doi.org/10.1177/1476718X15579746

Elliot, A. (2007). Improving early childhood quality through standards, accreditation and registration. In E. Hill, B. Pocock, & A. Elliot (Eds.), *Kids count: Better early childhood education and care in Australia* (pp. 199–219). Sydney University Press.

Fielding, K., & Murcia, K. (2022). Research linking digital technologies to young children's creativity: An interpretive framework and systematic review. *Issues in Educational Research*, *32*(1), 105–125. http://www.iier.org.au/iier32/fielding.pdf

Fourtane, S. (2019). *Augmented Reality: The future of education*. https://interestingengineering.com/augmented-reality-the-future-of-education

García-Peñalvo, F. J., Reimann, D., Tuul, M., Rees, A., & Jormanainen, I. (2016). *An overview of the most relevant literature on coding and computational thinking with emphasis on the relevant issues for teachers*. TACCLE 3 Consortium. https://doi.org/10.5281/zenodo.165123

Guilford, J. P. (1950). Creativity. *American Psychologist, 5*(9), 444–454. http://dx.doi.org/10.1037/h0063487

Highfield, K., Paciga, K., & Donohue, C. (2018). Supporting whole child development in the digital age. In: S. Danby, M. Fleer, C. Davidson, & M. Hatzigianni (Eds.), *Digital childhoods: Technologies and children's everyday lives* (pp. 165–182). Springer.

Hu, W., Huang, R., & Li, Y. (2023). Young children's experience in unplugged activities about CT: From an embodied cognition perspective, *Early Childhood Education Journal*, *52*(4), 769–782. https://doi.org/10.1007/s10643-023-01475-x

International Society for Technology in Education [ISTE]. (2021). *Computational thinking competencies*. https://www.iste.org/standards/iste-standards-for-computational-thinking

Jewitt, C. (2009). An introduction to multimodality. In C. Jewitt (Ed.), *The Routledge Handbook of Multimodal Analysis* (pp. 14 - 27). Routledge.

Jewitt, C. & Mackley, K. (2018). Methodological dialogues across multimodality and sensory ethnography: Digital touch communication. *Qualitative Research, 19*(1), 90–110. https://doi.org/10.1177/1468794118796992

Kaufman, J., & Beghetto, R. (2009). Beyond big and little: The Four C Model of Creativity. *Review of General Psychology*, *13*(1), 1-12. https://doi.org/10.1037/a0013688

Kewalramani, S. & Veresov, N. (2021). Multimodal creative inquiry: Theorising a new approach for children's science meaning-making in early childhood education. *Research in Science Education, 52*, 977–947. https://doi.org/10.1007/s11165-021-10029-3

Lavigne, H., Presser, A., Rosenfeld, D., Wolsky, M., & Andrews. J. (2020). Creating a preschool computational thinking learning blueprint to guide the development of learning resources for young children. *Connected Science Learning, 2* (2). https://www.nsta.org/connected-science-learning/connected-science-learning-april-june-2020/creating-preschool

Lee, J., Joswick, C., & Pole, K. (2023). Classroom play and activities to support computational thinking development in early childhood. *Early Childhood Education Journal, 51*, 457–468. https://doi.org/10.1007/s10643-022-01319-0

Marsh, J., Plowman, L., Yamada-Rice, D., Bishop, J., Lahmar, J., & Scott, F. (2018). Play and creativity in young children's use of apps. *British Journal of Educational Technology*, *49*(5), 870–882. https://doi.org/10.1111/bjet.12622

Maslin, K., Murcia, K., Blackley, S., & Lowe, G. (2023). Fostering young children's creativity in online learning environments: A systematic literature review. *Thinking Skills and Creativity*, *47*, 1–10. https://doi.org/10.1016/j.tsc.2023.101249

Merrill, S. (2017). *The future of coding in schools*. Edutopia. https://www.edutopia.org/article/future-coding-schools

Murcia, K. (2022). Children's creativity and STEM inquiry projects. *Asia Research Network Journal of Education, 2*(3), 118–126. https://so05.tci-thaijo.org/index.php/arnje/article/view/262694

Murcia, K., & Cross, E. (2022). Empowering early childhood teachers to develop digital technology pedagogies: An Australian action research case study. In: S. Papadakis, M. Kalogiannakis (Eds.), *STEM, robotics, mobile apps in early childhood and primary education* (pp.33–53). Springer. https://doi.org/10.1007/978-981-19-0568-1_3

Murcia, K., Pepper, C., Joubert, M., Cross., E. & Wilson, S. (2020). A framework for identifying and developing children's creative thinking while coding with digital technologies. *Issues in Educational Research, 30*(4), 1395–1417. http://www.iier.org.au/iier30/murcia2.pdf

Murcia, K., & Tang, K. S. (2019). Exploring the multimodality of young children's coding. *Australian Educational Computing, 34*(1), 1–15. http://journal.acce.edu.au/index.php/AEC/article/view/208

Murcia, K., Campbell, K., & Aranda, G. (2018). Trends in early childhood education practice and professional learning with digital technologies. *Pedagogika, 68*(3), 235–250. https://doi.org/10.14712/23362189.2018.858

Plowman, L. (2015). Rethinking context: Digital technologies and children's everyday lives. *Children's Geographies, 14*(2), 190–202. https://doi.org/10.1080/14733285.2015.1127326

Puryear, J., & Lamb, K. (2020). Defining creativity: How far have we come since Plucker, Beghetto, and Dow? *Creativity Research Journal, 32*(3), 206–214. https://doi.org/10.1080/10400419.2020.1821552

Rhodes, M. (1961). An analysis of creativity. *The Phi Delta Kappan, 42*(7), 305–310. https://www.jstor.org/stable/i20342591

Richardson, C., & Mishra, P. (2018). Learning environments that support student creativity: Developing the SCALE. *Thinking Skills and Creativity, 27,* 45–54. https://doi.org/10.1016/j.tsc.2017.11.004

Strawhacker, A., Lee, M., & Bers, M. (2018). Teaching tools, teachers' rules: Exploring the impact of teaching styles on young children's programming knowledge in ScratchJr. *International Journal of Technology and Design Education, 28*(2), 347–376. https://doi.org/10.1007/s10798-017-9400-9

Su, J., & Yang, W. (2023). A systematic review of integrating computational thinking in early childhood education. *Computers and Education Open, 4*, 1–12. https://doi.org/10.1016/j.caeo.2023.100122

Valenzuela, J. (2022, November 17). *How to develop computational thinkers.* ISTE. https://iste.org/blog/how-to-develop-computational-thinkers

Wing, J. M. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33–35. https://www.cs.cmu.edu/afs/cs/Web/People/15110-s13/Wing06-ct.pdf

Wilson, S., Murcia, K., Cross, E., & Lowe, G. (2023). Digital technologies and the early childhood sector: Are we fostering digital capabilities and agency in young children? *The Australian Educational Researcher*, *51*, 1425–1443. https://doi.org/10.1007/s13384-023-00647-3