



Integrating Play-Based Learning with Coding for Early Childhood Mathematics Education in Under-Resourced Schools

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ABSTRACT

Recent advancements in educational technology and mathematics curricula provide early childhood teachers with new opportunities to use coding in their teaching activities. Although the integration of play-based learning with coding holds promise, challenges such as resource availability, teacher training, and curriculum alignment must be addressed. The lens of Kolb's experiential theory supports that coding involves concrete experiences, reflection on outcomes, interactive problem-solving, and mathematical learning. Furthermore, experiential learning is adaptable to local contexts by leveraging available materials. In a case study within qualitative research, this paper explored teachers' perceptions of integrating play-based learning with coding for early childhood mathematics in under-resourced schools. Twelve foundation phase teachers teaching mathematics in under-resourced schools from Limpopo, South Africa, were sampled through homogenous purposive sampling. The data were collected using semi-structured interviews and non-participant observations to solicit teachers' perceptions of integrating play-based learning with coding for early childhood mathematics in under-resourced schools. Thematic data analysis was used to interpret the perceptions of teachers on the subject under the study. The findings indicated that teachers implement play-based learning with LEGO Six Bricks with coding. However, under-resourced schools have limited training, a lack of resources, and insufficient curriculum alignment. Based on these findings, it is recommended that teachers use available coding resources to integrate play-based learning into mathematics classrooms. These findings contribute to the growing literature on coding in teaching mathematics in early childhood.

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INTRODUCTION

The integration of coding into early childhood education (ECE) has gained increasing recognition due to its potential to develop foundational mathematical skills, problem-solving abilities and computational thinking.¹ Regionally, Kenya's Competency-Based Curriculum (CBC) encourages

¹ Marina Umaschi Bers, *Coding as a Playground: Programming and Computational Thinking in the Early Childhood Classroom* (Routledge, 2020); Angela Castro et al., "High-Capacity Robots in Early Education: Developing Computational Thinking with a Voice-Controlled Collaborative Robot," *Education Sciences* 14, no. 8 (2024): 856; Department of Basic Education, "National

teachers to incorporate coding in teaching literacy and mathematics from an early age.² On the same note, the United Nations Educational Scientific and Cultural Organization (UNESCO's) Institute for Life Long Learning promotes internationally integrating digital skills, including coding, in the 21st century (UNESCO Institute for Lifelong Learning, 2023).³ Coding, or programming, is generally defined as a basic language consisting of steps or instructions provided to a computer or a child to achieve a certain outcome.⁴ In Early Childhood Education (ECE), there are two types of coding activities: unplugged (coding without a computer, tablet, or any screen) and plugged-in coding.⁵

Several researchers, such as Lee and Junoh, Metin and Willemse emphasise the importance of beginning with unplugged coding, enabling children to engage in physical movement either by manipulating objects or using their own bodies before introducing abstract coding concepts.⁶ Play-based learning, a well-established pedagogical approach, promotes young learners' engagement, creativity and cognitive development.⁷ By combining play-based learning with coding, teachers can provide developmentally appropriate experiences that improve mathematical understanding meaningfully.⁸ However, implementing such approaches in under-resourced schools presents challenges, including limited access to technological resources and insufficient teacher training.⁹ Therefore, the authors explored teachers' perceptions of integrating play-based learning with early childhood mathematics in under-resourced schools.

While the literature has highlighted the benefits of coding in early learning, little is known about how teachers in resource-constrained environments navigate the challenges of implementation, access and pedagogical adaptation.¹⁰ This gap in the literature calls for a deeper exploration of how unplugged and plugged-in coding may be integrated into early mathematics education. By addressing this gap, the study contributes to the discourse on using coding to bridge this gap by exploring how teachers in under-resourced schools perceive the integration of play-based learning with coding in early childhood mathematics education. Thus, this paper asked the following question: *How do teachers perceive integrating play-based learning with coding for early childhood mathematics in under-resourced schools?*

THEORETICAL FRAMEWORK

Kolb's Experiential Learning Theory, as seen in Figure 1, provides a relevant theoretical framework for understanding how young learners engage with play-based learning and coding in early childhood mathematics education.¹¹ Unlike Bruner's cognitive development theory, which emphasises a progression from concrete, representational and abstract knowledge, Kolb's theory outlines four interconnected learning stages that include hands-on experiences with concrete materials, reflective

Curriculum Statement (NCS): Curriculum and Assessment Policy Statement," *Mathematics, Intermediate Phase Grades* (Author Pretoria, South Africa, 2011).

² Kenya Institute of Curriculum Development, *Facilitator's Training Manual for Early Years Education Curriculum*, 2017.

³ UNESCO, *Empowering Self-Help Groups in Kenya through ICT for Better Education and Alternative Livelihood Activities, Kenya* (Kenya: Institute for Lifelong Learning, 2023).

⁴ Merve Canbeldek and Nesrin Isikoglu, "Exploring the Effects of 'Productive Children: Coding and Robotics Education Program' in Early Childhood Education," *Education and Information Technologies* 28, no. 3 (2023): 3359–79.

⁵ Jean Greyling, "Coding Unplugged—a Guide to Introducing Coding and Robotics to South African Schools," *Transforming Entrepreneurship Education* 155 (2023); Joohi Lee and Jo Junoh, "Implementing Unplugged Coding Activities in Early Childhood Classrooms," *Early Childhood Education Journal* 47, no. 6 (November 19, 2019): 709–16, <https://doi.org/10.1007/s10643-019-00967-z>.

⁶ Lee and Junoh, "Implementing Unplugged Coding Activities in Early Childhood Classrooms"; Sermin Metin, "Activity-Based Unplugged Coding during the Preschool Period," *International Journal of Technology and Design Education* 32, no. 1 (March 18, 2022): 149–65, <https://doi.org/10.1007/s10798-020-09616-8>; Kayla R R Murphy, "Improving Educational Opportunities by Weaving Indigenous Knowledge into the Academy from an Indigenous Perspective," 2022.

⁷ Prosper Lunga, Stef Esterhuizen, and Mariette Koen, "Play-Based Pedagogy: An Approach to Advance Young Children's Holistic Development," *South African Journal of Childhood Education* 12, no. 1 (2022): 1133.

⁸ Canbeldek and Isikoglu, "Exploring the Effects of 'Productive Children: Coding and Robotics Education Program' in Early Childhood Education."

⁹ Afikile Sikwebu and Darelle van GREUNEN, "Starting from Scratch: Introducing Primary School Learners to Programming," in *2020 IST-Africa Conference (IST-Africa)* (IEEE, 2020), 1–9.

¹⁰ Sikwebu and van Greunen, Starting from scratch: Introducing primary school learners to programming.

¹¹ Sikwebu and van GREUNEN, "Starting from Scratch: Introducing Primary School Learners to Programming."

observation, abstract conceptualisation, and active experimentation, each fostering problem-solving skills, and deeper engagement with mathematical concepts.¹²

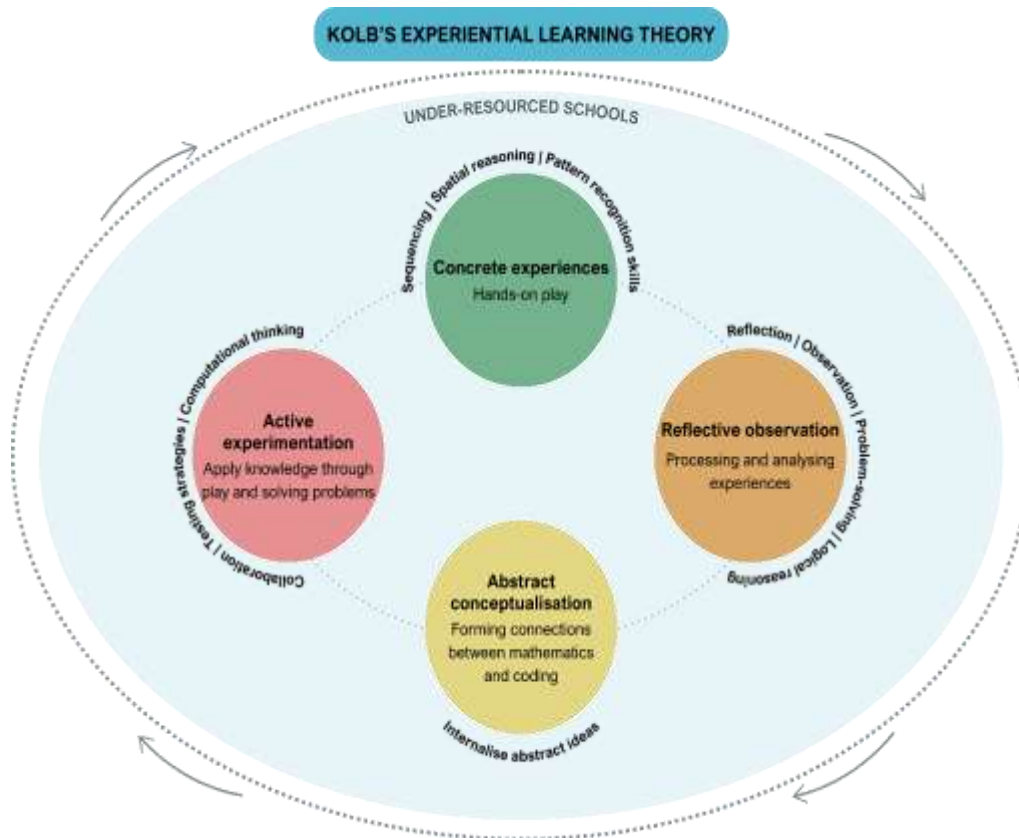


Figure 1. Kolb's experiential learning theory in the context of this study. Adapted from Pamungkas¹³

Figure 1 illustrates how Kolb's Experiential Learning Theory is the foundation for integrating play-based learning with coding in early childhood mathematics education in under-resourced schools. The framework demonstrates a cyclical learning process that aligns with Kolb's four key stages of experiential learning. Each stage is vital in supporting young learners' problem-solving skills, computational thinking and mathematical understanding through coding and play-based activities. At the top of the figure, in blue, Kolb's Experiential Learning Theory is positioned as the overarching theoretical lens. It emphasises the importance of learning through hands-on experiences, reflection, conceptual understanding and active engagement. The model then progresses to concrete experiences in green, where young learners engage in hands-on play using coding tools such as LEGO Six Bricks and ScratchJr. This stage allows children to interact directly with physical objects, developing foundational sequencing, spatial reasoning and pattern recognition skills.

Following hands-on engagement, learners transition into reflective observation, in orange, where they process and analyse their experiences. In this phase, teachers encourage children to reflect on their coding activities, make observations, and identify patterns. This reflection strengthens problem-solving abilities and logical reasoning. As learners develop insights from their experiences, they move into the abstract conceptualisation stage, in yellow, where they begin forming connections between mathematical concepts and coding principles. Children internalise abstract ideas, such as

¹² Perdoor Sreeramana Aithal and Nandita Mishra, "Integrated Framework for Experiential Learning: Approaches and Impacts," *International Journal of Case Studies in Business, IT and Education (IJCSBE)* 8, no. 1 (2024): 145–73.

¹³ Stephanus Fajar Pamungkas, Indah Widiastuti, and Suharno, "Kolb's Experiential Learning for Vocational Education in Mechanical Engineering: A Review," in *AIP Conference Proceedings*, vol. 2114 (AIP Publishing LLC, 2019), 030023.

directional sense, number operations and logical sequencing through structured play-based activities, reinforcing their understanding of early mathematical concepts.

The final stage, active experimentation, in red, allows learners to apply their newfound knowledge through interactive play and problem-solving. In this phase, children engage in collaborative coding activities, test different strategies and explore computational thinking concepts such as debugging, sequencing, and algorithmic logic. This active engagement fosters deeper learning and improves the real-world application of mathematics through coding. The model also incorporates the broader context of under-resourced schools, where access to technology, teacher training and structured curriculum support remains a challenge. The framework also highlights how unplugged coding activities, namely LEGO Six Bricks, provide an alternative approach for teaching computational thinking and mathematics in environments with limited digital resources.

Similarly, Murray supports the idea that this theory highlights learning through direct experience, active experimentation, and reflective observation, which closely aligns with the principles of play-based learning and hands-on interaction with concrete learning tools.¹⁴ Kolb maintains the significance of hands-on learning, reflection, conceptual understanding, and active problem-solving in teaching and learning activities.¹⁵ The authors believe teachers can use Kolb's theory to integrate play-based learning with coding for early childhood mathematics. Washbrooke and Giacaman confirm that play-based learning and coding encourage hands-on learning, reflection, conceptual understanding, and active problem-solving.¹⁶ As a result, Kolb's theory can be applied in under-resourced schools by using play-based learning with coding to ensure that learning remains engaging, contextually relevant, and inclusive, empowering young learners to develop critical early mathematical and problem-solving skills.

Concrete experience using hands-on engagement with coding

In the first stage, Kolb's theory begins with concrete experiences, where learners interact directly with educational materials.¹⁷ Similarly, other researchers corroborate that hands-on engagement improves young children's early mathematical skills, such as sequencing, pattern recognition, spatial awareness, and problem-solving.¹⁸ In the context of this paper, the authors learn that children engage with tangible coding tools, such as LEGO Six Bricks, to explore mathematical concepts through hands-on manipulation. These physical objects allow learners to develop sequencing, spatial reasoning, and pattern recognition skills through structured play. Additionally, teachers can use locally available materials to simulate coding concepts, ensuring that experiential learning remains meaningful in under-resourced schools with limited access to advanced digital technology.

Researchers state that children transition to reflective observation after interacting with concrete materials, where they analyse and process their experiences in the second stage.¹⁹ Teachers can encourage learners to engage in playful, tangible coding activities using LEGO Six Bricks to develop problem-solving skills. Researchers further highlight that abstract conceptualisation follows reflective observation, supporting metacognition and a deeper understanding of mathematical relationships.²⁰ Through hands-on interaction with coding tools, learners internalise key mathematical concepts, such as directional sense, number operations and logical sequencing. This process bridges the gap between

¹⁴ Trudie. Murray, "The Playful Entrepreneur' Fostering Entrepreneurial Education in Early Childhood Education" (Munster Technological University, 2024), <https://doi.org/10.34719/YWOI3734>.

¹⁵ David A. Kolb, *Experiential Learning: Experience as the Source of Learning and Development* (Englewood Cliffs, New Jersey: Prentice-Hall, 1939).

¹⁶ Sarah Washbrooke and Nasser Giacaman, "Play, Code, Learn: Fostering Computational Thinking in Primary Aged Learners Through Interactive Play," in *IoT, AI, and ICT for Educational Applications: Technologies to Enable Education for All* (Springer, 2024), 135–62.

¹⁷ Kolb, *Experiential Learning: Experience as the Source of Learning and Development*.

¹⁸ Elizabeth M. Byrne et al., "Educational Interventions Involving Physical Manipulatives for Improving Children's Learning and Development: A Scoping Review," *Review of Education* 11, no. 2 (August 15, 2023), <https://doi.org/10.1002/rev3.3400>.

¹⁹ Fatini Jisma Fakaruddin, Edy Hafizan Mohd Shahali, and Rohaida Mohd Saat, "Creative Thinking Patterns in Primary School Students' Hands-on Science Activities Involving Robotic as Learning Tools," *Asia Pacific Education Review* 25, no. 1 (March 13, 2024): 171–86, <https://doi.org/10.1007/s12564-023-09825-5>.

²⁰ Mara Cotič et al., "Mathematics Education: What Was It, What Is It, and What Will It Be?," *International Electronic Journal of Mathematics Education* 19, no. 3 (2024): em0783.

concrete experiences and abstract mathematical thinking, reinforcing problem-solving skills essential for early mathematics education.

Active experimentation to enhance mathematics concepts

The final stage of Kolb's cycle, active experimentation, allows children to collaborate and apply their mathematical understanding through interactive learning experiences. Nemiro highlights that active experimentation fosters teamwork, where learners engage in small groups to explore coding principles using LEGO® Six Bricks.²¹ This collaborative approach not only enhances communication and peer learning but also encourages children to test different strategies for problem-solving in mathematics. Through structured yet playful engagement, learners begin recognising patterns in their coding activities, directly connecting to mathematical concepts such as counting, addition, subtraction and problem decomposition.²²

At this stage, play-based learning allows mathematical ideas to emerge naturally rather than through rote memorisation, reinforcing the importance of social interaction in mathematics education.²³ Teachers play a crucial role in guiding these interactions by designing hands-on exploration activities that promote creative problem-solving and cognitive development. By incorporating play-based learning and coding, learners can collaborate to design and test new sequences, fostering computational thinking and real-world application of mathematics concepts.

Against this background, integrating play-based learning with coding, specifically LEGO Six Bricks, provides innovative learning opportunities. It reinforces the adaptability and relevance of active, experiential learning in under-resourced schools, ensuring that early mathematical education remains engaging, accessible, and meaningful for all learners.

LITERATURE REVIEW

Integrating play-based learning into early childhood mathematics education has been widely recognised for enhancing engagement, creativity and cognitive development. This approach encourages exploration and problem-solving, allowing young learners to develop foundational mathematical concepts naturally and meaningfully.²⁴ Researchers indicate that play supports learners' skills, such as spatial reasoning, pattern recognition and logical sequencing, all fundamental to mathematical understanding.²⁵ Play-based learning aligns with Kolb's Experiential Learning Theory by offering hands-on engagement, reflection and iterative learning opportunities.²⁶

LEGO Six Bricks and ScratchJr in Early Mathematics Education

Unplugged coding tools such as LEGO Six Bricks promote hands-on exploration and conceptual understanding in early childhood education.²⁷ Through engaging activities, children can practise skills such as memory and problem-solving, which are essential for cognitive development. Studies have highlighted its effectiveness in supporting learner engagement, shape recognition, pattern sequencing,

²¹ Jill E. Nemiro, "Building Collaboration Skills in 4th- to 6th-Grade Students Through Robotics," *Journal of Research in Childhood Education* 35, no. 3 (July 3, 2021): 351–72, <https://doi.org/10.1080/02568543.2020.1721621>.

²² Camilo Vieira, J. Chiu, and B. Velasquez, "Towards a Learning Progression of Sequencing and Algorithm Design for Five- and Six-Years-Old Children Engaging with an Educational Robot," *Computer Science Education* 34, no. 4 (October 12, 2024): 596–616, <https://doi.org/10.1080/08993408.2023.2255058>.

²³ Nazmin Sultana, "Teaching Mathematics through Play Pedagogy in Government Pre-Primary Classes: An Exploratory Study" (Bracs University, 2023).

²⁴ Canbeldek and Isikoglu, "Exploring the Effects of 'Productive Children: Coding and Robotics Education Program' in Early Childhood Education"; J Chambers, "Inside Singapore's Plans for Robots in Pre-Schools. How a Bold New Scheme Is Teaching Tech Skills to 6 Year Olds. GovInsider," 2015; Murphy, "Improving Educational Opportunities by Weaving Indigenous Knowledge into the Academy from an Indigenous Perspective."

²⁵ Elizabeth Kazakoff and Marina Bers, "Programming in a Robotics Context in the Kindergarten Classroom: The Impact on Sequencing Skills," *Journal of Educational Multimedia and Hypermedia* 21, no. 4 (2012): 371–91; Annie Savard and Kate Highfield, "Teachers' Talk about Robotics: Where Is the Mathematics?," *Mathematics Education Research Group of Australasia*, 2015.

²⁶ Kolb, *Experiential Learning: Experience as the Source of Learning and Development*.

²⁷ The LEGO Foundation, *Six Bricks Guide: Learning through Play with LEGO Bricks*, 2017.

number sense and recall.²⁸ Children who actively manipulate tangible objects like LEGO bricks develop a stronger grasp of mathematical relationships.

Plugged-in coding has also become a powerful tool for supporting mathematical learning in early childhood education. Platforms like ScratchJr enable young learners to engage with movement, sequences and directions through digital interactions.²⁹ Integrating coding into early mathematics can enhance problem-solving abilities, logical sequencing and spatial awareness.³⁰ While coding can be introduced through both unplugged and digital activities, Lee and Junho, and Willemse emphasise the benefits of starting with tangible, hands-on methods before progressing to screen-based tools.³¹ Using coding platforms such as ScratchJr provides a meaningful bridge between play-based learning and foundational mathematics.

Challenges in under-resourced educational settings

Implementing play-based coding activities in under-resourced schools presents significant challenges. Primary barriers include limited access to technological resources like computers, tablets and internet connectivity.³² Unplugged coding can be a viable alternative, leveraging everyday materials and movement-based learning to teach computational thinking. Teacher training and professional development are critical to successfully integrating coding and play-based learning into mathematics education. Research has highlighted that many early childhood teachers feel unprepared to incorporate coding into their teaching due to a lack of formal training and exposure.³³ Although many teachers have attended workshops on coding (and robotics), they often report that the training is insufficient or lacks practical implementation strategies.³⁴ Professional development programmes that introduce teachers to hands-on methodologies and structured lesson plans have increased teachers' confidence and competence.³⁵ Providing teachers with structured lesson plans, hands-on workshops, and ongoing mentorship opportunities can help bridge the gap between theory and practice.

Another pressing issue in under-resourced schools is the need for systematic curriculum support. Teachers require clear frameworks that outline how coding activities can be integrated into existing mathematics curricula, ensuring that these activities align with learning objectives and developmental milestones.³⁶ Research suggests that interdisciplinary approaches, where coding is embedded within broader learning themes, can improve its effectiveness and sustainability in classroom settings.³⁷

²⁸ Gerald Ardito, "We, Robot: Using Robotics to Promote Collaborative and Mathematics Learning in a Middle School Classroom," 2014; Marina Bers, Safoura Seddighin, and Amanda Sullivan, "Ready for Robotics: Bringing Together the T and E of STEM in Early Childhood Teacher Education," *Journal of Technology and Teacher Education* 21, no. 3 (2013): 355–77; Ann S Masten et al., "Resilience in Development and Psychopathology: Multisystem Perspectives," *Annual Review of Clinical Psychology* 17, no. 1 (2021): 521–49.

²⁹ Madhu Govind, Emily Relkin, and Marina Umaschi Bers, "Engaging Children and Parents to Code Together Using the ScratchJr App," *Visitor Studies* 23, no. 1 (January 2, 2020): 46–65, <https://doi.org/10.1080/10645578.2020.1732184>.

³⁰ Mark Gura, "Lego Robotics: STEM Sport of the Mind.," *Learning & Leading with Technology* 40, no. 1 (2012): 12–16.

³¹ Lee and Junho, "Implementing Unplugged Coding Activities in Early Childhood Classrooms"; Isabelle C. de Vink et al., "Supporting Creative Problem Solving in Primary Geometry Education," *Thinking Skills and Creativity* 48 (June 2023): 101307, <https://doi.org/10.1016/j.tsc.2023.101307>.

³² Tai-Kuei Yu, Mei-Lan Lin, and Ying-Kai Liao, "Understanding Factors Influencing Information Communication Technology Adoption Behavior: The Moderators of Information Literacy and Digital Skills," *Computers in Human Behavior* 71 (June 2017): 196–208, <https://doi.org/10.1016/j.chb.2017.02.005>.

³³ Amy MacDonald et al., "Effective Early Childhood STEM Education: Findings from the Little Scientists Evaluation," *Early Childhood Education Journal* 48, no. 3 (May 21, 2020): 353–63, <https://doi.org/10.1007/s10643-019-01004-9>; Stamatios Papadakis et al., "Attitudes towards the Use of Educational Robotics: Exploring Pre-Service and In-Service Early Childhood Teacher Profiles," *Education Sciences* 11, no. 5 (April 27, 2021): 204, <https://doi.org/10.3390/educsci11050204>.

³⁴ Papadakis et al., "Attitudes towards the Use of Educational Robotics: Exploring Pre-Service and In-Service Early Childhood Teacher Profiles."

³⁵ Tugba Boz and Martha Allexsaht-Snider, "How Do Elementary School Teachers Learn Coding and Robotics? A Case Study of Mediations and Conflicts," *Education and Information Technologies* 27, no. 3 (April 11, 2022): 3935–63, <https://doi.org/10.1007/s10639-021-10736-4>.

³⁶ MacDonald et al., "Effective Early Childhood STEM Education: Findings from the Little Scientists Evaluation."

³⁷ Amanda Sullivan and Marina Umaschi Bers, "Dancing Robots: Integrating Art, Music, and Robotics in Singapore's Early Childhood Centers," *International Journal of Technology and Design Education* 28, no. 2 (June 23, 2018): 325–46, <https://doi.org/10.1007/s10798-017-9397-0>.

Addressing these challenges requires a multifaceted approach, including investment in teacher training, development of resource-efficient coding activities, and alignment of curriculum with play-based methodologies. Integrating coding into early childhood mathematics education holds great promise for improving problem-solving skills and fostering a deeper understanding of mathematical concepts.

Teachers can create meaningful learning experiences that support young children's cognitive and mathematical development by using play-based learning and experiential engagement principles. Future research should continue to explore innovative strategies for overcoming barriers to implementation, particularly in under-resourced contexts, ensuring that all children have equitable access to coding and mathematical learning opportunities.

METHODOLOGY

Research Design

An interpretivism research paradigm supported by Paudel and Vosotros explored teachers' perceptions of integrating play-based learning with coding for early childhood mathematics in under-resourced schools.³⁸ Paudel noted that interpretivism recognises reality as socially constructed, implying that teachers' specific contexts shape their perceptions, experiences, and beliefs.³⁹ Similarly, Vosotros emphasised that interpretivism enables a deeper exploration of how these contextual factors impact teachers' attitudes and approaches to implementing play-based pedagogy.⁴⁰ Since integrating play-based learning and coding is relatively new in many under-resourced schools, teachers' interpretations will vary based on their backgrounds, training, and classroom realities.

A qualitative research approach was used to engage teachers in real-world settings; the research uncovers nuanced understandings of how they navigate play-based mathematics learning with coding. William states that qualitative methods align with interpretivism, allowing for rich and descriptive accounts of how participants make sense of their real-world settings.⁴¹ Using a qualitative research approach, rich, in-depth, contextualised, and nuanced insights data were collected to understand how teachers make sense of and implement these strategies in their classroom settings.

Since the study was aimed at exploring teachers' subjective experiences and perspectives, a multiple case study approach was used, as it aligns well with an interpretive paradigm and a qualitative research approach.⁴² As such, multiple schools (four) were compared in terms of how different teachers navigate play-based learning and coding in varying under-resourced contexts. A multiple case study (four cases) from three schools allowed for a comprehensive and in-depth investigation. It enabled a holistic examination of how teachers engage with their perceptions and teaching practices and implement play-based learning with coding in early childhood mathematics education.

Homogeneous purposive sampling was used as it involves the selection of participants with shared characteristics relevant to the research.⁴³ Furthermore, Akkaş and Meydan explain that the typical characteristics of the participants make the findings coherent and contextually relevant.⁴⁴ For the context of this paper, teachers from four different schools teaching mathematics in Grades 1 to 3

³⁸ P Paudel, "Examining Paradigmatic Shifts: Unveiling the Philosophical Foundations Shaping Social Research Methodologies," *Journal of the University of Ruhuna* 12, no. 1 (2024); Rouie Christine T Bustillo, Rouie Christine T Bustillo, and Jay Ann Vie Sayson, "Navigating the Dual Roles: Understanding the Unique Challenges of Student-Mothers in Pursuit of Higher Education," *Ignatian International Journal for Multidisciplinary Research* 2, no. 2 (2024): 58–69; Mareike Kunter et al., "Professional Competence of Teachers: Effects on Instructional Quality and Student Development.," *Journal of Educational Psychology* 105, no. 3 (2013): 805.

³⁹ Paudel, "Examining Paradigmatic Shifts: Unveiling the Philosophical Foundations Shaping Social Research Methodologies."

⁴⁰ Ann Jay Vosotros, "Exploring Play-Based Learning Strategies: Elementary Teachers in Focus," *Innovative Approaches in Education: Strategies for Effective Teaching and Learning* 1, no. 1 (2024): 1–20.

⁴¹ Fodouop Kouam Arthur William, "Interpretivism or Constructivism: Navigating Research Paradigms in Social Science Research," *Interpretivism or Constructivism: Navigating Research Paradigms in Social Science Research* 143, no.1 (2024): 5.

⁴² Daphne Halkias et al., *The Multiple Case Study Design: Methodology and Application for Management Education* (Routledge, 2022).

⁴³ Friday Nyimbili and Leah Nyimbili, "Types of Purposive Sampling Techniques with Their Examples and Application in Qualitative Research Studies," *British Journal of Multidisciplinary and Advanced Studies* 5, no. 1 (February 16, 2024): 90–99, <https://doi.org/10.37745/bjmas.2022.0419>.

⁴⁴ Handan Akkaş and Cem Harun Meydan, "Sampling Methods in Qualitative Sampling in Multicultural Settings," in *Principles of Conducting Qualitative Research in Multicultural Settings* (IGI Global, 2024), 32–54.

were selected to participate in the research. Thus, twelve teachers participated based on at least three years of teaching experience in the foundation phase; they were required to teach coding (and robotics), implement play-based learning activities, and were based in under-resourced schools. This inclusion criterion ensured that participants were information-rich cases, contributing to deep and contextualised insights into the research-related issues.

Semi-structured interviews and non-participant observations as data generation instruments were used since qualitative case studies require in-depth, rich data and triangulated insights. Semi-structured interviews allowed teachers to express their perceptions, experiences, thoughts, concerns, and beliefs while enabling the researcher to probe deeper into emerging themes.⁴⁵ A semi-structured interview schedule with open-ended questions was used to ask the teachers questions individually. An audio recorder was used to capture the conversations during the interviews. Non-participant observation was used to triangulate the interview responses with their teaching practices because teachers may describe their integration of play-based activities in coding in one way, but implement it differently in their mathematics classrooms. An observation schedule with questions was used to record the observation data during the mathematics lessons. The observation was made for forty-five minutes for two mathematics lessons. Triangulating semi-structured interviews with non-participant observations strengthens the case study's depth, accuracy, and credibility.⁴⁶ This approach ensures a comprehensive understanding of teachers' perspectives and classroom practices. This leads to a rich, nuanced understanding of how play-based learning and coding are integrated into early childhood mathematics education in under-resourced schools.

Data Analysis

Taking into account the subjective experiences, thematic data analysis was used to interpret the data from the participants to explore teachers' perceptions of integrating play-based learning with coding for early childhood mathematics in under-resourced schools. Thematic analysis researchers systematically identify, analyse, and interpret common themes in the data.⁴⁷ Therefore, data from the interviews and observations were compared to identify rich patterns, similarities, and differences, making it an ideal choice for multiple case study research. To do this, the data was coded using the keywords from the research question. An independent coder assisted in co-coding the same data until an agreement was reached on the number of codes. This flexibility ensured that the analysis remained open to new insights rather than being constrained by predefined categories. This aligns with the findings of Wiltshire and Ronkainen, who state that thematic analysis provides a structured yet intuitive approach to organising data into meaningful categories.⁴⁸ The final codes were grouped to create categories guided by the reviewed literature. Furthermore, categories were grouped to create themes supported by the lens of Kolb's theory. The results and findings are presented according to themes that offer deep insights into teachers' perspectives.

To protect trustworthiness measures, an audio recording during the interviews increased the validity of the data. Method triangulation (semi-structured interviews and non-participant observations) was used to ensure the findings' credibility.⁴⁹ Homogeneous purposive sampling increases the validity of these comparisons by ensuring that response differences are due to individual experiences rather than irrelevant variables.⁵⁰ Lastly, Thematic analysis supports in-depth, flexible, and rigorous analysis.

⁴⁵ Nuzhat Naz, Fozia Gulab, and Mahnaz Aslam, "Development of Qualitative Semi-Structured Interview Guide for Case Study Research," 2022.

⁴⁶ Michelle Striepe, "Combining Concept Mapping with Semi-Structured Interviews: Adding Another Dimension to the Research Process," *International Journal of Research & Method in Education* 44, no. 5 (October 20, 2021): 519–32, <https://doi.org/10.1080/1743727X.2020.1841746>.

⁴⁷ Simon Finkelstein, Umesh Sharma, and Brett Furlonger, "The Inclusive Practices of Classroom Teachers: A Scoping Review and Thematic Analysis," *International Journal of Inclusive Education* 25, no. 6 (May 12, 2021): 735–62, <https://doi.org/10.1080/13603116.2019.1572232>.

⁴⁸ Gareth Wiltshire and Noora Ronkainen, "A Realist Approach to Thematic Analysis: Making Sense of Qualitative Data through Experiential, Inferential and Dispositional Themes," *Journal of Critical Realism* 20, no. 2 (March 15, 2021): 159–80, <https://doi.org/10.1080/14767430.2021.1894909>.

⁴⁹ Striepe, "Combining Concept Mapping with Semi-Structured Interviews: Adding Another Dimension to the Research Process."

⁵⁰ Rebecca S Robinson, "Purposive Sampling," in *Encyclopedia of Quality of Life and Well-Being Research* (Springer, 2024), 5645–47.

Ethical clearance for this research was obtained from the University of South Africa (UNISA) Ethics Committee under reference number 2023/10/11/64019209/38/AM. Additional approval was granted by the Limpopo Provincial Research Ethics Committee (LPREC) through the Office of the Premier, with the project number LPREC/144/2023: PG. Informed consent was obtained from parents and participants, granting the researcher permission to access data from the lesson observations. Learners also provided assent to participate in the study. To ensure anonymity and confidentiality, the researchers assigned pseudonyms to all schools and participants. Schools were labelled S1 to S4, and participants were referred to as School 1 Foundation Phase Educator 1 (S1FPE1) to School 4 Foundation Phase Educator 3 (S4FPE3) during data analysis, results, and discussions.

PRESENTATION OF FINDINGS

The findings from the semi-structured interviews and non-participant observations are presented across multiple cases. The analysis indicates key emerging themes reflecting teachers' perceptions of integrating play-based learning with coding in early childhood mathematics. Triangulating semi-structured interviews with non-participant observations strengthens the case study's depth, accuracy, and credibility.⁵¹ This approach ensures a comprehensive understanding of teachers' perspectives and classroom practices. The participants understand that play is a natural way for young children to learn, as it allows them to explore, experiment, and make sense of abstract mathematical ideas through hands-on experiences.⁵² The participants' perceptions of integrating play activities utilising LEGO Six Bricks provide tangible learning experiences that help children grasp abstract mathematical concepts more effectively. Participant S4FPE3 described how play-based learning and games, mainly using LEGO Six Bricks, enhance learners' discipline, concentration, and attention:

I found it rather intriguing. It aids in classroom management and child discipline, helps learners to concentrate and even recall material, and maintains their attention on what you have to say. When you utilise LEGO® bricks to engage learners, you can say, 'Red, red,' and they will respond, 'On my toes.' Due to their strong sense of competition, children naturally want to get involved. (S4FPE3)

Participant S3FPE1 commented,

"We could use games; they did not address how we might use them online" (S1FPE1).

Participant S3FPE1 also discussed how technological tools like ScratchJR facilitated active learning by linking abstract mathematical concepts to tangible experiences. ScratchJR is a tablet-based application that allows learners (ages five to seven) to create simple interactive stories, animations, and games using a drag-and-drop interface with colourful coding blocks.⁵³ It supports the development of early mathematical concepts through play-based coding activities, and learners develop foundational numeracy, spatial awareness, and problem-solving skills. The participant stated:

We start from Scratch Junior. It is a cartoon cat. It shows the home and a question mark. The educator's role is to instruct learners on moving a Scratch Junior. There are question marks that show that learners can ask for answers. Let us say a Scratch Junior is going to farm animals. A learner needs to select his/her favourite animals. Whatever animal he/she would choose would appear on the screen. Even a square shape would appear if they were visiting different shapes. (S3FPE1)

Inadequate exposure to coding in early childhood education

Despite several benefits of play-based learning and coding in early childhood mathematics, many participants expressed some exposure to play-based learning and coding through seminars, training

⁵¹ Striepe, "Combining Concept Mapping with Semi-Structured Interviews: Adding Another Dimension to the Research Process."

⁵² Gabriel M. Kennedy, "Challenges of ICT Integration in Teachers' Education: A Case Study of the College of Education, University of Liberia," *International Journal of Social Science and Education Research Studies* 03, no. 05 (May 13, 2023): 860–70, <https://doi.org/10.55677/ijssers/V03I5Y2023-15>.

⁵³ Amare Misganaw Mihret, Galata Sitota Dilgasa, and Tsigereda Hailu Mamo, "Parenting Style as Correlates of Adolescents' Academic Achievement Motivation of Bate Secondary School, Haramaya, Ethiopia," *International Journal of Education and Literacy Studies* 7, no. 2 (April 30, 2019): 172, <https://doi.org/10.7575/aiac.ijels.v.7n.2p.172>.

programmes and workshops. However, their engagement was often limited to an overview rather than a comprehensive, practical implementation framework. Teachers also highlighted that these interventions were not part of a structured government initiative but were driven by non-governmental organisations (NGOs) or independent organisations. Teachers struggled to retain knowledge even when training was provided due to the long gaps between sessions. Participant S2FPE3 said:

Yes. I have been to the Six Bricks workshop. They gave us lessons in coding, robotics, and online teaching. It was merely an overview of how to apply them in the educational setting. They provided teachers' manuals and learners with LEGO® bricks. The department did not organise it, but an NGO did. They chose a few schools in our cluster. (S2FPE3)

Participant S3FPE2 added,

"Yes. We do attend training even though it is rare. I just need to remember some of the strategies that we can use. This could be caused by not attending them regularly" (S3FPE2).

Similarly, another teacher (S1FPE1) highlighted that although they attended coding (and robotics) seminars, the sessions lacked depth. The teacher said:

Indeed, we have participated in coding and robotics seminars. It was SADTU that organised the workshop. Educators were only being introduced to it. The workshop did not fully fulfil our understanding of incorporating robotics and coding into teaching and learning activities. (S1FPE1)

Even though the background indicates exposure to play-based learning and coding in early childhood, many teachers expressed concern about the infrequency of training and the difficulty in retaining strategies due to long gaps between workshops. Participant S3FPE2 commented:

"Yes. We do attend training even though it is not more frequent. I just forget some of the strategies that we can use. This could be caused by not attending them regularly" (S3FPE2).

Some teachers indicated that the training they received did not provide enough guidance on integrating coding into daily teaching and learning. Participant S4FPE3 stated:

They handed us booklets about coding and robotics, but I recall that day, we did not do that. Most of us are still uninformed about integrating coding and robotics in the foundation phase. That was not included in the training. (S4FPE3)

Triangulation of semi-structured interviews and non-participant observations

The responses from the interviews collated with classroom observations, key consistencies and discrepancies were identified, offering a more complete understanding of how teachers integrate coding into mathematics teaching. During the interviews, teachers from S1 highlighted the importance of LEGO Six Bricks in promoting learner engagement, hands-on exploration, and conceptual understanding in mathematics. Classroom observations confirmed that teachers actively used LEGO Six Bricks in teaching mathematics, particularly in activities related to shape recognition, patterns and sequence, number sense and recognition. Classroom observations revealed that teachers' interview descriptions corresponded with their use of LEGO Six Bricks, affirming their effectiveness in fostering engagement, recall, and interactive learning.

Although teachers reported attending coding (and robotics) workshops, many expressed concerns about inadequate or infrequent training for effective implementation. Despite teachers' challenges and observations, they highlighted limited yet encouraging efforts to integrate coding, mainly through Scratch Junior, to teach movement, sequences, and directions. Despite teachers' reported challenges in training, observations showed limited but promising attempts at integrating coding by using ScratchJr to understand movement, sequences, and directions. Teachers said that training often lacked practical strategies for integrating coding into early childhood mathematics. In Teacher 4's classroom, LEGO Six Bricks were used primarily for free play rather than structured

mathematics lessons. Some teachers relied more on traditional teaching methods, using LEGO bricks as supplementary tools rather than core teaching and learning materials.

DISCUSSION

Theme 1: Teachers' Perceptions of Integrating Play-Based Learning and Coding in Early Childhood Mathematics

The findings highlight that participants understand the significance of integrating play-based learning in early childhood mathematics teaching. The literature corroborates that teachers acknowledge that play-based learning enhances learners' holistic skills.⁵⁴ The findings further reveal that participants intentionally incorporated hands-on activities, such as using LEGO Six Bricks in play-based learning, to develop children's mathematical skills. The semi-structured interviews gathered that participants perceived play activities as promoting learners' understanding of abstract mathematical concepts through tangible experiences.⁵⁵ In addition, the observations from Participant S4FPE3 validate these perceptions as the participant used LEG Six Bricks to stimulate interactive activities and problem-solving skills during mathematics lessons. As mentioned in the theoretical framework, Kolb's Experiential Learning Theory respect hands-on activities, active learning, reflection, and iterative engagement in early childhood.⁵⁶

Expanding on these findings, coding tools such as ScratchJr were acknowledged for connecting tangible experiences and the development of shapes and abstract mathematical concepts in early childhood. Participant S3FPE1's verbal responses during the interviews regarding using ScratchJr for teaching sequences and directions support the literature findings, which indicate that coding improves problem-solving skills, logical sequencing, and spatial awareness.⁵⁷ On the other hand, participants expressed the need for structured guidelines to integrate play-based learning with coding into their daily mathematics lessons because coding activities frequently served as additional rather than fundamental teaching approaches from the LEGO Six Bricks strategies.

Theme 2: Challenges in Implementing Play-Based Learning and Coding in Under-Resourced Schools

Interestingly, in all three cases of this paper, the participants reported a few challenges in implementing coding, particularly in under-resourced schools. This is in addition to the understanding of the use of play-based learning in early childhood. This finding corroborates the literature that one of the major challenges was the limited access to technological resources, including computers, tablets, and internet connectivity.⁵⁸ Hence, participants depended on unplugged coding activities, such as LEGO Six Bricks, to teach learners numbers and colours while engaging in active experiences and hands-on activities linked to Kolb's theory.⁵⁹ Secondly, the findings revealed the challenge of inadequate training and professional development. During the interviews, the participants indicated that their acquaintance with play-based learning and coding was often limited to one-off workshops or initiatives led by NGOs rather than being systematically integrated into government curricula.⁶⁰ Moreover, the participants indicated that the training sessions did not adequately focus on integrating coding into their teaching and learning activities. As a result, these findings reveal a gap between theoretical training and practice, as there was a disconnect between training content and classroom application. The findings reveal a

⁵⁴ Cathy MacDonald, "Understanding Participatory Action Research: A Qualitative Research Methodology Option," *The Canadian Journal of Action Research* 13, no. 2 (September 13, 2012): 34–50, <https://doi.org/10.33524/cjar.v13i2.37>; Canbeldek and Isikoglu, "Exploring the Effects of 'Productive Children: Coding and Robotics Education Program' in Early Childhood Education."

⁵⁵ Teresa J Kennedy and Sue Dale Tunnicliffe, "Introduction: The Role of Play and STEM in the Early Years," in *Play and STEM Education in the Early Years: International Policies and Practices* (Springer, 2022), 3–37.

⁵⁶ Alice Y. Kolb and David A. Kolb, "Learning Styles and Learning Spaces: Enhancing Experiential Learning in Higher Education," *Academy of Management Learning & Education* 4, no. 2 (June 2005): 193–212, <https://doi.org/10.5465/amle.2005.17268566>.

⁵⁷ Govind, Relkin, and Bers, "Engaging Children and Parents to Code Together Using the ScratchJr App."

⁵⁸ Yu, Lin, and Liao, "Understanding Factors Influencing Information Communication Technology Adoption Behavior: The Moderators of Information Literacy and Digital Skills."

⁵⁹ Kolb and Kolb, "Learning Styles and Learning Spaces: Enhancing Experiential Learning in Higher Education."

⁶⁰ Papadakis et al., "Attitudes towards the Use of Educational Robotics: Exploring Pre-Service and In-Service Early Childhood Teacher Profiles."

gap between theoretical training and practical application, as teachers struggled to retain knowledge due to the infrequency of training sessions. These findings are consistent with those suggesting the fundamental role of training teachers about interdisciplinary approaches to improve the sustainability of coding activities in early childhood education.⁶¹

The final challenge explored from classroom observations was the inconsistencies in integrating play-based learning and coding in teaching mathematics. While other schools actively incorporated LEG Six Bricks for mathematics teaching, other schools used these approaches for free-play activities during mental mathematics rather than structured learning activities. Participants such as S2FPE3 and S3FPE2 highlighted the lack of structured implementation strategies of the curriculum, which affected their confidence in integrating coding into their teaching practices. Supporting the literature, it is encouraging to suggest the need for professional development and clear guidelines bothering on how coding and play-based learning can be systematically integrated into the mathematics curriculum in early childhood.⁶²

RECOMMENDATIONS

Considering these findings, this paper recommends that educators need professional development, structured guidelines, and resource-efficient coding activities to ensure that all children have equitable access to play-based mathematics education and implement the recommendations stemming from Kolb's theory in their classrooms. Future researchers can focus on innovative strategies to bridge these gaps in under-resourced from a large scope. These practical and policy recommendations could assist educators.

1. Educators in under-resourced schools can use un-plugged coding resources, LEGO® Six Bricks and ScratchJr, to integrate coding and mathematical playful activities in hands-on approaches. These resources support mathematical concepts, including patterns, number sense skills, sequencing and spatial orientation.
2. Policymakers should develop CAPS-aligned professional development programmes and practical lesson planning guides to help educators effectively implement coding activities within the early childhood mathematics curriculum. This will help bridge the gap between theory and classroom practice.

CONCLUSION

This paper explored teachers' perceptions of integrating play-based learning with coding for early childhood mathematics in under-resourced schools. The findings highlight teachers' positive perceptions regarding play-based learning but indicate the challenges of implementing it with coding in teaching mathematics in early childhood. Challenges, such as limited training, lack of resources, and insufficient curriculum alignment, impede their effective use in their classrooms in under-resourced schools. Triangulation of data confirmed a disconnect between teacher beliefs and actual classroom practices. While teachers valued and attempted to implement play-based and coding strategies, many lacked the confidence and support to integrate them meaningfully into structured mathematics lessons.

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⁶¹ Sullivan and Bers, "Dancing Robots: Integrating Art, Music, and Robotics in Singapore's Early Childhood Centers."

⁶² MacDonald, "Understanding Participatory Action Research: A Qualitative Research Methodology Option."

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