Supporting Grade R teachers to integrate coding and robotics with mathematical concepts

by

Kayla Willemse

Submitted in fulfilment of the requirements for the degree

PHILOSOPHIAE DOCTOR

Computer-integrated Education

in the

Department of Science, Mathematics and Technology Education

FACULTY OF EDUCATION

at the

UNIVERSITY OF PRETORIA

South Africa

Supervisor: Prof Ronel Callaghan

2023

DECLARATION OF AUTHENTICITY

I, Kayla Willemse, hereby declare that this thesis, **Supporting Grade R teachers to integrate coding and robotics with mathematical concepts**, is submitted in accordance with the requirements for the degree Philosophiae Doctor at the University of Pretoria. This thesis is my own original work and has not previously been submitted by me for a degree at this or any other tertiary institution. All sources cited or quoted in this thesis are indicated and acknowledged with a comprehensive list of references.

1. I understand what plagiarism is and am aware of the University's policy in this regard.
2. I declare that this thesis is my own original work. Where other people's work has been used (either from a printed source, internet or any other source), this has been properly acknowledged and referenced in accordance with the requirements as stated in the University's plagiarism prevention policy.
3. I have not used another student's past written work to hand in as my own.
4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.
5. All icons in this thesis have been designed by myself.

Kayla Willemse

July 2023

ETHICAL CLEARANCE CERTIFICATE

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Make today matter
www.up.ac.za

FACULTY OF EDUCATION
Ethics Committee

RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE	CLEARANCE NUMBER: **EDU166/21**
DEGREE AND PROJECT	PhD Supporting Grade R teachers to integrate coding and robotics with mathematical concepts
INVESTIGATOR	Mrs Kayla Willemse
DEPARTMENT	Science Mathematics and Technology Education
APPROVAL TO COMMENCE STUDY	20 May 2022
DATE OF CLEARANCE CERTIFICATE	05 July 2023

CHAIRPERSON OF ETHICS COMMITTEE: Prof Funke Omidire

CC Mr Simon Jiane
Prof Ronel Callaghan

This Ethics Clearance Certificate should be read in conjunction with the Integrated Declaration Form (D08) which specifies details regarding:

- Compliance with approved research protocol,
- No significant changes,
- Informed consent/assent,
- Adverse experience or undue risk,
- Registered title, and
- Data storage requirements.

Fakuiteit Opvoedkunde
Lefapha la Thuto

ETHICAL DECLARATION

The author, whose name appears on the title page of this thesis, has obtained the applicable research approval for the research described in this work. The author declares that she has observed the ethical requirements in terms of the University of Pretoria's code of ethics for researchers and the policy guidelines for responsible research.

Kayla Willemse
July 2023

ABSTRACT

The increasing dependence on technology has influenced the field of education, and there is a growing interest in introducing coding and robotics to young learners in South African schools. In order to understand how teachers can be supported to integrate coding and robotics with mathematical concepts, relevant literature was structured according to the Technological, Pedagogical, and Content Knowledge framework. Participatory action research was conducted in four cycles by involving ten Grade R teachers and one external participant specialising in the field of early childhood technology and mathematics. Data generation consisted of semi-structured individual interviews, collaborative discussion groups and guided observations with the teachers, and photovoice as well as a researcher journal that was maintained to reflect on observations and experiences. The data were analysed using both deductive and inductive data analysis and data interpretation, resulting in the development of a preliminary framework and four guidelines. An external was invited to review the guidelines in a systematising expert interview during the final cycle of the research to provide a final framework.

The study found that the integration of coding and robotics with mathematical concepts in Grade R can occur in a playful and informal way. The study recommends the use of a framework to support teachers in integrating these tools into their teaching practices, with an emphasis on meeting teachers' needs (guideline 1), addressing external factors (guideline 2), carefully planning the learning process (guideline 3), and achieving positive outcomes (guideline 4). The study emphasises that teaching is a skill that can be learned and improved, and encourages teachers to use kinaesthetic, concrete, representational, and abstract experiences, to plan informal, play-based learning experiences. Overall, the study emphasises the potential of integrating coding and robotics with using mathematical concepts teaching in Grade R learning environments and offers practical guidance for supporting teachers in this endeavour.

Key terms: Bee-Bot; coding and robotics; foundation phase; Grade R; integration; mathematical concepts; numbers, operations, and relationships; participatory action research; play-based teaching and learning; TPACK framework

PROOF OF LANGUAGE AND TECHNICAL EDITING

All-done Editing Services

editing@all-done.co.za

4 April 2023

CERTIFICATE OF EDITING

To whom it may concern,

This letter confirms that the doctoral thesis titled *Supporting Grade R teachers to integrate coding and robotics with mathematical concepts* by Kayla Willemse was proofread and edited by All-done Editing Services.

The document was edited for grammar, punctuation, spelling, overall style and consistent use of South African English spelling conventions. All amendments were tracked using Microsoft Word's "Track Changes" feature, and consequently, the author had the option to accept or reject each change. A complete edited copy was provided, but the final decisions as to which changes to implement, rested with the author. The document formatting and list of references were also edited according to the shorter Harvard reference style.

Sincerely,

M Schutte

Marietjie Schutte

DEDICATION

I dedicate this study to my mother who possesses an inquiring soul.

Always remember: there is a distinction between a road you think you know and a road you stroll yourself, and this venture proved the equal for me – and that is what I would love to leave you with, fellow traveller. The best way to give an explanation for something you appreciate is to take that quest yourself. The journey is never smooth, there are hard moments and times you will feel like you have failed – it is precisely then that you should not give up. Ensure you commence your adventure with something that sprouts delight and ardour – as it will be your companion for quite some time. My journey as a student has now come full circle, as I took the first step on this voyage as an undergraduate student in 2014, but now a new journey awaits me – and learning will remain my compass. I hope that I, and also you, can revisit my journey some day and see that it was the commencement of my contribution to support the generation of tomorrow.

ACKNOWLEDGEMENTS

At this level, studies typically rely on the participation of many people. I could not have completed this journey without the support of all of you. I would like to express my sincere gratitude to the following individuals for their various efforts in making this thesis a reality:

My Heavenly Father, who gave me the fortitude, wisdom, and perseverance necessary to finish this thesis. In the face of every challenge, You are my haven. I am in awe of Your unwavering love and the blessings You have given me.

My husband, Ruan (RC) Willemse, for your unconditional love and support. You were always a constant source of encouragement during the challenges presented in the completion of this thesis. I am truly thankful for the caring person and wonderful husband that you are.

Thank you to my mother, my family, and my friends who have always supported me. I appreciate your patience every time I had to spend time on this journey rather than being with you.

My supervisor, Professor Ronel (P) Callaghan, for her excellent advice and professional guidance. I would like to extend my utmost respect and admiration to my supervisor, an exceptional woman whose critical reasoning and advanced understanding were indispensable to the success of this venture. Without her guidance and mentorship, achieving this high level of analysis and interpretation would not have been feasible. Your compassionate dedication towards your students as people first and foremost, and as students secondly, made this journey a wonderful experience. Thank you for being a brilliant mentor and the wonderful person that you are.

Dr Judy (JC) van Heerden, who started this journey with me and continued to provide guidance and support, thank you for your love and kindness in every aspect of my personal and academic life.

Ms Marietjie Schutte, the language and technical editor of this thesis, for her excellent guidance to make this thesis a reality. Your knowledge has truly supported me to push myself further in this academic journey.

To my colleagues, I am grateful for the guidance and support you have given me along this journey. I appreciate your constant encouragement.

The University of Pretoria for financial support in the form of a postgraduate bursary.

This study would not have been possible without the participation of the teachers and the external reviewer. I have gained a lot of knowledge from each of you. Thank you for providing significant insight and expertise in order to build a teaching framework based on the context of this study.

ABBREVIATIONS AND ACRONYMS

4th IR	Fourth industrial revolution
AB	Activity booklet
ASD	Autism Spectrum Disorder
AT	Activity template
ATC21S	Assessment and Teaching of 21st Century Skills
C2005	Curriculum 2005
CAPS	Curriculum and Assessment Policy Statement
CHERP	Creative Hybrid Environment for Robotic Programming
CK	Content knowledge
CRA approach	Concrete-representational-abstract (CRA) approach
DBE	Department of Basic Education
DE	Department of Education
DEEWR	Department of Education, Employment and Workplace Relations
DL	Digital literacy
DT	Digital technology
EC	Early childhood
ECE	Early childhood education
ECEC	Early Childhood Education and Care
eCLAC	Economic Commission for Latin America and the Caribbean
ELC	Early learning centre
ELE	Early learning environment
EPB	External participant booklet
EP	External participant
FP	Foundation phase
HEI	Higher education institution
ICT	Information communication technology
KCRA approach	Kinaesthetic-concrete-representational-abstract approach
LE	Learning environment
LoLT	Language of learning and teaching
LTSM	Learning and teaching support materials
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MISTRA	Mapungubwe Institute for Strategic Reflection
NAEYC	National Association for the Education of Young Children
NCF	National Curriculum Framework
NEL framework	Nurturing early learners framework
NLESD	Newfoundland and Labrador English Schools District
OECD	Organization for Economic Co-operation and Development
PAR	Participatory action research
PBDL	Play-based digital learning
PCK	Pedagogical content knowledge
PIRLS	Progress in International Reading Literacy Study
PK	Pedagogical knowledge
PLAY	Powerful learning around you
PRQ	Primary research question
PSRIP	Primary School Reading Improvement Programme
RNCS	Revised national curriculum statement
SACE	South African Council for Educators
SMT	School management team
SRQ	Secondary research question
STEAM	Science, technology, engineering, art, and mathematics education
STEM	Science, technology, engineering, and mathematics education
STM	Science, mathematics, and technology
STREAM	Science, technology, robotics, engineering, and mathematics education
TCB	Teacher collaboration booklet

TCK	Technological content knowledge
TIMSS	Trends in International Mathematics and Science Study
TK	Technological knowledge
TPACK	Technological pedagogical and content knowledge
TPK	Technological pedagogical knowledge
UNESCO	United Nations Educational Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
ZPD	Zone of proximal development

TABLE OF CONTENTS

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

CHAPTER 4: DATA GENERATION PROCEDURES AND DEDUCTIVE DATA ANALYSIS DESCRIPTION

CHAPTER 5: DATA RESULTS AND INDUCTIVE DATA ANALYSIS OF THE FIRST THREE CYCLES

CHAPTER 6: DATA INTERPRETATION AND PRELIMINARY FRAMEWORK

CHAPTER 7: COMPARISON OF THE RESEARCH FINDINGS WITH THE LITERATURE AND THE FINAL FRAMEWORK

CHAPTER 8: CONCLUDING REMARKS

LIST OF FIGURES

Chapter 4: Data generation procedures and deductive data analysis description

Chapter 5: Data results and inductive data analysis of the first three cycles

LIST OF TABLES

APPENDICES

CHAPTER 1: OVERVIEW OF THE STUDY AND ORIENTATION

1.1 INTRODUCTION TO THE STUDY

Digital technology (DT) is an integral part of life in the 21st century, also in South Africa (Khanlari, 2014; Callaghan, Joubert & Engelbrecht, 2023). DT refers to various electronic devices, tools, and resources that are powered by digital technology and are designed to process, store, and communicate information (Santos & Aliakbari, 2020). These include computers, tablets, smartphones, software applications, social media platforms, and the internet (McPake, Plowman & Stephen, 2013). DT has revolutionised the way people interact, work, and learn (Chowdhry, Sieler & Alwis, 2014), and has become an essential part of many aspects of daily life, including education (Blin & Munro, 2008). The prevalence of DT as means of communication and knowledge acquisition has progressively increased in our learning environments (LEs) (Gömleksiz, 2004; South African Government, 2015; Nel, Marais & Bird, 2021; Strom, 2021), our communication devices (Hardell, 2017), and even in our food service industry (Fitzgerald, Kruschwitz, Bonnet & Welch, 2013). In recent years, the integration of DT into education, particularly in science, technology, engineering, art, and mathematics (STEAM[1]) subjects, has garnered increasing attention due to its potential to enhance learning outcomes and engage learners in innovative ways (Li, Schoenfeld, Disessa, Graesser, Benson, English & Duschl, 2020). DT provides opportunities for learners to engage with content through interactive and multimodal experiences that support higher-order thinking skills (ibid.). By incorporating DT in STEAM education, learners can explore complex concepts and create real-world connections through hands-on experiences that promote creativity, critical thinking, and solving problems (Sullivan & Bers, 2018; Alves-Oliveira, 2020; Angeli & Valanides, 2020; Torres & Giddie, 2020; DBE, 2023).

McPake *et al*. (2013) believe that some learners may encounter DT, such as email, online shopping, online communications technologies, and toys that simulate cellular phones even before they attend formal school. Although the term digital technology

[1] See 2.3.3.4 Science, technology, engineering, art, and mathematics education.

also refers to robots that are used to enhance human lives by designing automobiles, unloading ships, or vacuuming floors, this study did not focus on these sophisticated functions (Brown, Roehrig & Malhotra, 2015). Instead, this study focused on how coding and robotics, as one concept, can be integrated with numbers, operations and relationships through a play-based pedagogy. More specifically, it explored how coding and the robot named Bee-Bot[2] can be integrated with mathematical concepts, such as counting, addition, describing numbers, and problem-solving techniques that are needed for developing number sense.

Coding and robotics is seen as a gateway to STEAM education because of their multidisciplinary nature. In early childhood (EC), subjects are not isolated, but rather integrated to include a variety of content and abilities, and, for this reason, coding and robotics can act as curricular integrators (Bers, Ponte, Juelich, Viera & Schenker, 2002; Bers, Seddighin & Sullivan, 2013). By playing with coding and robotics, young learners may become engineers and storytellers by developing their own meaningful creations that react to their surroundings (Bers, 2008; Bers *et al.*, 2013). Furthermore, learners have the opportunity to engage in social interactions when playing with robotic manipulatives which is also an envisaged outcome of the South African Curriculum (DBE, 2011a; Bers *et al.*, 2013). This study focused on the integration of the “T” and “M” of STEAM education as the aim was to understand how coding and robotics (technology) can be integrated with numbers, operations, and relationships (mathematics).

Tham (2018) argues that knowledge and skills associated with DT are requirements to actively contribute to the future job market. Adesola and Olla (2019) are of the opinion that individuals who do not possess the necessary DT knowledge and skills will feel excluded and have fewer job prospects. When some individuals do not possess these, it will, according to Van Dijk (2017), increase the digital divide between people. This divide is defined as the gap between individuals who do and individuals who do not have access to forms of both DT and information and communications technology (ICT). ICT refers to the technologies and devices used for communication and information processing, such as computers, smartphones, the internet, and social

[2] See 1.5 Clarification of key concepts.

media (Tzur, Katz & Davidovitch, 2022). The digital divide can result in inequalities in access to education, job opportunities, healthcare, and other important resources, ultimately perpetuating social and economic disparities (Milner, 2016). Efforts to reduce the digital divide and increase access to DT and ICT have become a global priority (Piers, Williams & Sharpe, 2023).

To close this gap, Matos, Pedro and Piedade (2019) propose that guidelines should be developed that are compatible with the needs of learners that use computers, mobile technologies, video games, and other 'toys' and tools of the digital era. The Department of Basic Education (DBE, 2023) responds to learners' needs through a curriculum to implement coding and robotics in the Foundation Phase (FP). The DBE (2023) advocates that coding and robotics is critical to function in an information-driven and digitalised environment, to utilise digital skills, and to transfer these skills to address everyday challenges. The new subject was added in the hope that it will provide learners with the knowledge and exposure to the internet, machine learning, augmented reality, virtual reality, and digital literacy (DL) (ibid.). Learners will, furthermore, benefit from having this knowledge when seeking employment and support learners to be prepared for a changing environment (ibid.). In cooperation with Higher Education Institutions (HEIs), the Department of Education intends to upskill and train teachers who will teach this new subject (ibid.).

1.2 CONTEXT OF THE STUDY

The study aimed to investigate the potential of integrating coding and robotics with mathematical concepts, including numbers, operations, and the relationships between numbers in a South African Grade R learning environment. In recent years, there has been an increasing emphasis on integrating technology in learning experiences to enhance student creativity, critical thinking, and subject-matter knowledge (Clements *et al.*, 2001:103; Hoyles & Noss, 2003; Highfield, Mulligan & Hedberg, 2008; Adams *et al.*, 2010; Highfield, 2010; Chalmers *et al.*, 2012; Allen, 2013; Ardito, Mosley & Scollins, 2014; Chambers, 2015; Sullivan & Bers, 2018; Alves-Oliveira, 2020; Angeli & Valanides, 2020; Govind *et al.*, 2020; Torres & Giddie, 2020; DBE, 2023; Diago *et al.*, 2022). However, many teachers face technology anxiety due to a lack of training and resources (Adukaite, Zyl & Cantoni, 2016). To overcome this challenge, teachers need both pre-service and in-service training in DT and how these are used in teaching.

Previous research has shown that coding and robotics can be effective in teaching mathematical concepts, such as problem-solving, geometry, numbers, sizes, and shapes to Grade R learners (Faisal, Kapila & Iskander, 2012; Kazakoff, Sullivan & Bers, 2013). Additionally, it has been demonstrated that the use of LEGO™ robotics can be an effective way of teaching mathematics and science concepts, including reading graphs, modelling, and understanding decimal numbers (Rogers & Portsmore, 2004). This study centered its focus not on the teaching of mathematics or coding and robotics, but specifically on the integration of these domains. Its primary aim was to explore ways in which teachers can be supported to effectively integrate coding and robotics with mathematical concepts in the context of South African Grade R LEs.

1.3 PROBLEM STATEMENT

Every day, the general public is exposed to DT in the form of smartphones, social media and online games, and an increasing amount of DT is employed in our schools in the form of tablets, smartboards, and robots (Economic Commission for Latin America and the Caribbean [eCLAC], 2021). Nevertheless, numerous studies have revealed that despite the fact that technology is being employed in LEs at an increasing rate and is frequently considered as the solution to educational issues, it is not being utilised to its full potential (Keating, Gardiner & Rudd, 2009; Burnett, 2011; Hughes & Robertson, 2013; Prinsloo & Sasman, 2015; Campbell & Kapp, 2020). Moreover, opposing to the generalised portrayal of young individuals as "digital natives"[3] (Dingli & Seychell, 2015:9), research by Czerniewicz and Brown (2013) has shown that many South African learners begin higher education as digital strangers[4].

[3] Digital natives refer to individuals who do not perceive ongoing technological advancements as a hindrance (Dingli & Seychell, 2015).

[4] Digital strangers refer to individuals who lack both experience and opportunities to using technology (Czerniewicz & Brown, 2013).

Plowman *et al*. (2011) also argue that the integration of DT in early childhood (EC) has received less attention than in higher grades. This statement is echoed by the recent studies conducted by Cherniak, Lee, Cho and Jung (2019) and Uğur-Erdoğmuş (2021) who found a dearth of research on the use of robotics for educational purposes in early learning environments (ELEs). Many robots exist for educational purposes, and they are generally used to teach programming skills to learners (Uğur-Erdoğmuş, 2021). A significant amount of research (Bolstad, 2004; Parette, Quesenberry & Blum, 2010; Plowman, Stevenson, Stephen & McPake, 2012; McPake *et al.*, 2013; Dicker & Naudé, 2014) examines how young learners interact with DT at home (those that have access to it) and how it forms part of their households. Furthermore, research indicates that DT may play a significant role in learners' as well as their families' daily lives regarding their early print literacy, as well as numerical, information-gathering, and problem-solving skills (Plowman, Stevenson, McPake Stephen & Adey, 2011; Vaughan & Beers, 2017).

International evaluations, such as Trends in International Mathematics and Science Study (TIMSS), also report that when teachers were questioned about incorporating technology into education and enhancing learners' critical-thinking skills, teachers indicated a significant gap between their professional development needs and recent professional development opportunities (Mullis, Martin, Foy, Kelly & Fishbein, 2020). Of the global Grade 4 teachers surveyed, 72% indicated a need for professional development opportunities regarding integrating technology into mathematics instruction, and more specifically, 46% of South African teachers indicated this need (ibid.). In my opinion, teachers in this particular context could benefit from some form of structured guidance that can assist them to integrate technology, particularly coding and robots, with Grade R mathematical concepts.

According to Hart and Laher's (2015) study, South African teachers typically see the usage of educational technology as positive and beneficial, however, teachers might only have limited access to educational technology and have a limited level of computer literacy (Torres & Giddie, 2020). Furthermore, Nokwali, Mammen and Maphosa (2017) established that although learners were enthusiastic to have educational technology integrated into their learning, challenges, such as insufficient time, space, and resources, made it difficult for teachers to implement it successfully.

Makgato (2014) also elucidated that South African teachers frequently lack the necessary skills to use technology tools and programmes, like Microsoft PowerPoint and email, successfully. Ramorola (2013) furthermore argues that limited evidence exists that teachers are integrating technology into activities that encourage learners to engage in critical thinking and to collaborate with peers. Both teachers and learners may have a desire to include educational technology in their curriculum, however, South African schools also frequently lack the funding required to purchase and maintain these types of technological tools (Torres & Giddie, 2020).

Low mathematical competencies and poor achievement pose a serious problem globally, especially in South Africa (Engelbrecht, 2016; Fritz, Long, Herzog, Balzer, Ehlert & Henning, 2020). TIMSS and Progress in International Reading Literacy Study (PIRLS) track trends in learner achievement in mathematics, science, and reading. These assessments, which have been done at regular intervals since 1995, now include 70 countries (Mullis *et al.*, 2020). Every four years, TIMSS monitors learners' achievement in Grade 4 and Grade 8 in mathematics and science. TIMSS 2019 was the seventh such study, which also marked the start of the e-Assessment era, with countries being able to administer the survey in either electronic or hard copy format (ibid.). The TIMSS 2019 mathematics assessment for Grade 4 learners was based on a comprehensive assessment framework that was established in collaboration with participating nations to reflect their curriculum aims and included three core areas: number, measurement and geometry, as well as data (ibid.). Thirty-six countries participated in TIMSS 2019, including South Africa, and were measured according to a centre point average achievement score (ibid.). South Africa was listed as one of the countries in the bottom three of average achievement scores in mathematics (ibid.).

The problem addressed in this qualitative study is the integration of DT in ELEs in South Africa, specifically with Grade R mathematical concepts. Despite the increasing presence of DT in schools and homes, research indicates that it is not being fully utilised to enhance teaching and learning. Furthermore, there is a lack of research on the use of robotics for educational purposes in ELEs, and a significant gap exists between teachers' professional development needs and recent opportunities to incorporate technology into their teaching practices. Limited access to technology, a lack of computer literacy, and insufficient funding are some of the challenges faced by teachers and learners in integrating technology into the curriculum. The ultimate goal of this study is to provide support to teachers in integrating coding and robotics with Grade R mathematical concepts, while considering external factors that may impact successful implementation and outlining how the learning process should unfold, with the aim of achieving possible positive outcomes.

1.4 RATIONALE

Participation in the digital era has become connected with lifelong learning, affecting everything from access to information technology to its application in teaching and learning (Campbell & Kapp, 2020), therefore, it is inevitable for teachers to look at DT to assess how it affects and contributes to learning. Teachers must understand how to integrate DT, especially coding and robotics, into the learning environment (LE), not only to ensure that the aims of the Curriculum and Assessment Policy Statement (CAPS) are met, but also to prepare learners to become digital citizens in a rapidly changing environment. The study, therefore, aims to explore how to support teachers in integrating coding and robotics with mathematical concepts to Grade R learners in South Africa. As DT becomes increasingly important for future job prospects, efforts to reduce the digital divide and increase access to DT and ICT have become a global priority, and the South African Department of Basic Education (DBE) has added coding and robotics to the curriculum to prepare learners for a changing environment and upskill teachers to teach these new subjects.

The DBE (2021a, 2021b, 2021c) is eagerly anticipating the full-scale implementation of the draft coding and robotics curriculum for Grades R-3 for the 2023 academic year. Due to the COVID-19 pandemic, the DBE had to revise its initial timelines for implementation which would have started in 2020. The DBE (2021a, 2021b, 2021c) states that to prepare teachers for this new subject, collaboration with Higher Education Institutions (HEIs) will be pursued, as the country currently lacks a sufficient number of qualified teachers in coding and robotics. Universities' initial teacher development programmes will play a crucial role in training and supplying teachers for the sector (DBE, 2021a, 2021b, 2021c). Furthermore, provincial education officials have been actively engaging school principals, school management teams (SMTs), and teachers to embrace this significant change in the curriculum (DBE, 2021a, 2021b, 2021c).

Teachers' knowledge and abilities of integrating coding and robotics with mathematical concepts might be strengthened through phases of participation, action, and reflection. This is of the utmost importance because there are still significant inequities in the resources that are readily available in many South African schools (i.e. another form of digital divide) (Torres & Giddie, 2020; Parker & Conversano, 2021). Public schools often have few or non-existent technological resources that might significantly affect learners' capacity to learn crucial 21st-century technological skills (Torres & Giddie, 2020). Teachers may also have unequal access to resources and training opportunities that might help them improve their instructional practices and successfully integrate educational technology technologies (ibid.). We may lose the teachers' voices and risk them remaining digitally illiterate[5] unless teachers are given the opportunity to participate in activities that improve their understanding of DT.

1.5 RESEARCH QUESTIONS

As mentioned previously, in the near future, coding and robotics will be incorporated into our schools as subjects, including Grade R ELEs (DBE, 2021a). Teachers should be trained in the context, content, and pedagogy of this topic, according to the DBE (2023). Furthermore, since the DBE (2023) mentions that this subject has the potential to be linked with other learning areas, particularly mathematics, teachers should be given the chance not only to learn about coding and robotics but also to express their own ideas on how they may be integrated successfully. As we are in the midst of the fourth industrial revolution[6] (4th IR), learners and teachers should be given the opportunity to engage with various digital tools to develop a 21st-century LE. Numerous studies (Engelbrecht, 2016; Mapaire, 2016; Mullis *et al.*, 2020, Mabena,

[5] Digital illiteracy, according to Yu, Lin, and Liao (2017), has a variety of causes, including a lack of literacy skills and competencies, a lack of access to computers and the Internet, and a lack of technical knowledge of ICT technologies.

[6] The 4th IR is the age of digitalisation, which is now under development and covers everything from developments in "smart" industries and cities to an increase in automation in both residential and professional settings (Fazlul Hoque, 2019:1).

Mokgosi & Ramapela, 2021) have also found low mathematics performance among learners. For this reason, unique and creative ways for teachers to support learners doing mathematics are needed by considering what the learners are exposed to on a daily basis, which is technology.

Based on this background information, it is evident that there is a need for research on the integration of coding and robotics with mathematical concepts and how teachers can be supported to integrate these technologies into their teaching. Therefore, the primary research question (PRQ) of the study, "***How can Grade R teachers be supported to integrate coding and robotics with mathematical concepts?***" was based on this need for research.

The purpose of the PRQ was to investigate how teachers can be assisted in integrating coding and robotics with mathematical concepts in Grade R. The research employed various methods, such as interviews and guided observations to understand the current practices and possible challenges faced by teachers in integrating coding and robotics into the Grade R curriculum. The study aimed to develop evidence-based recommendations and guidelines for supporting teachers in integrating coding and robotics with Grade R mathematical concepts. The outcome of this research may enhance the understanding of the integration of coding and robotics with mathematical concepts.

1.5.1 Secondary research questions

The study has three secondary research questions (SRQs) that aimed to gain a deeper understanding of the integration of coding and robotics with mathematical concepts in Grade R. SRQ1 focused on the role of pedagogical knowledge in supporting Grade R teaching, SRQ2 investigated how coding and robotics can support Grade R teaching, and SRQ3 explored how mathematical concepts in Grade R can be used in play-based teaching. These SRQs provided insights into the potential benefits and challenges of integrating coding and robotics with mathematical concepts in Grade R and offered strategies for supporting teachers in integrating these technologies into their teaching practices.

1.5.1.1 SRQ1: How does pedagogical knowledge support Grade R teaching?

The primary focus of this research question was to explore how pedagogical knowledge can be applied to support effective Grade R teaching in general. By investigating this question, the aim was to identify the specific pedagogical approaches, strategies, and frameworks that can be employed to effectively support teachers in integrating coding and robotics with mathematical concepts in Grade R classrooms, focusing specifically on play-based teaching.

1.5.1.2 SRQ2: How does coding and robotics support Grade R teaching?

This research question focuses on understanding how coding and robotics can support Grade R teaching in general. It aimed to uncover the potential benefits, challenges, and instructional opportunities associated with integrating coding and robotics activities in Grade R classrooms.

1.5.1.3 SRQ3: How can Grade R mathematical concepts be used in play-based teaching?

The primary focus of this research question was to explore how mathematical concepts are used in the play-based teaching of Grade R learners. Ultimately, the research sought to provide valuable insights to support teachers in their endeavours to use Grade R mathematical concepts in play-based teaching.

The findings from each sub-question can contribute to the development of support mechanisms, including pedagogical knowledge enhancement, effective integration of coding and robotics with mathematics, and play-based teaching approaches, ultimately providing valuable guidance for supporting Grade R teachers in their integration efforts. The specific aim of this study was to develop evidence-based recommendations and guidelines for supporting Grade R teachers in integrating coding and robotics with mathematical concepts.

1.5.2 Delimitations of the study

This study was delimited in several ways to ensure that it remained focused and feasible. Firstly, although PAR can be an ongoing process, this study was limited to four cycles to ensure that the research could be completed within the allocated time frame. Secondly, the study was limited to a specific affluent area in Gauteng, which may not be representative of other provinces in South Africa. For this reason, I realise that my study does not lie within the context of most environments in South Africa. The sample size was also limited to ten teachers, which may not be representative of all Grade R teachers in South Africa.

In addition, the study aimed to investigate coding and robotics as one concept in the context of ECE, even though the majority of research in this area focuses solely on coding. Furthermore, the study only focused on the first three focus areas of coding and robotics identified by the DBE (2023), as it did not focus on the engineering design process (see 2.3.5.8 A South African perspective: Using coding and robotics in the Grade R learning environment). Moreover, the study only focused on one specific content area of mathematics, namely, numbers, operations, and relationships.

In conclusion, this study exclusively focused on grand theorists and international best practices in the realm of play-based teaching. Alternative theories, such as constructionism, were not examined within the scope of this research. Therefore, further investigations are warranted to explore the potential contributions of other theories in this context. Additional research is necessary to gain a comprehensive understanding of how these theories may influence play-based teaching approaches.

1.6 PURPOSE OF THE STUDY

The study's purpose was to fill the gap mentioned in the previous section by developing evidence-based recommendations and guidelines for Grade R teachers on how to integrate coding and robotics with mathematical concepts. To achieve the research aims and address the research questions, the study focused on the development of a teaching framework that could support Grade R teachers to integrate coding and robotics with mathematical concepts. A teaching framework is defined as an evidence-based model that assists teachers in aligning learning objectives with learning environment activities, creating stimulating and inclusive environments, and incorporating assessment into the learning process (Organization for Economic Cooperation and Development [OECD], 2009). The teaching framework developed in this study focused specifically on integrating coding and robotics with mathematical concepts of numbers, operations, and relationships in Grade R.

The framework consists of guidelines, developed by teachers and reviewed by an external participant (EP), on how coding and robotics can be integrated with numbers, operations, and/or number relationships through kinaesthetic, concrete, representational or abstract activities. The framework was designed through reflective cycles of Participatory Action Research (PAR), which enabled teachers to refine and improve their integration of coding and robotics with mathematical concepts.

The development of this teaching framework is important because the implementation of coding and robotics as a subject is planned for implementation in 2023 (DBE, 2023). As more young learners receive access to digital technologies (DTs) in a variety of contexts, it is critical for early childhood (EC) teachers to understand how they can integrate its use in teaching and learning. Additionally, teachers must rethink play in today's modern culture in order to provide a richer learning environment for learners and to recognise that today's play is drastically different from that of earlier generations (Nel *et al.*, 2021). Without the necessary support to understand what coding and robotics entail and how to integrate them with other subjects, specifically mathematics, teachers may be unable to support learners effectively. Therefore, the development of a teaching framework may help to bridge this gap and support teachers to integrate coding and robotics with mathematical concepts in Grade R classrooms.

The study's ultimate goal was to contribute to the improvement of education quality and promote the effective use of technology in ELEs. By providing valuable insights into how to better support teachers in integration coding and robotics with mathematical concepts in ELEs, the study could have a positive impact on both teachers' and learners' experiences. Additionally, the integration of coding and robotics into the teaching of mathematical concepts to Grade R learners can provide a play-based pedagogy that engages young learners and enhances their learning experience. Overall, the study has the potential to make a significant contribution to the field of ECE and to the effective use of technology in education.

1.7 CONCEPT CLARIFICATION

The following concepts and terminologies in Table 1.1 are used throughout the study and are explained according to their applicability to the study.

Table 1.1: Key concepts

Key concept	Clarification	Literature
Framework	Teaching is a complicated act, and it is beneficial for teachers to have a "road map through the territory" that is organised by a shared knowledge of novice, experienced, and skilled teachers. Furthermore, when these common understandings can be organised into a framework, teachers will be able to enhance, analyse, and improve their own teaching practices.	• Danielson (2007:1-13)
Information Communication Technology (ICT)	The use of technology to connect, process, and manage information is referred to as Information Communication Technology (ICT). From personal communication to business transactions and education, ICT has become an increasingly important aspect of everyday living. ICT in education has created new learning opportunities, such as online classes, virtual classrooms, and educational applications. The use of ICT in education can improve teaching and learning experiences, increase learner involvement, and make learning opportunities more accessible. However, there are concerns about the digital divide and the potential negative effect of technology on the well-being of learners. It is critical that ICT be used in education in an ethical and responsible way.	• World Economic Forum (2021)
Integration	When it comes to education, integration is the deliberate blending of different subject areas, abilities, and ideas to give learners a well-rounded educational experience. It entails the seamless fusion of many educational fields - including language, math, and life skills - into a coherent and interrelated curriculum. Integration enables learners to make connections between many fields of study and have a more comprehensive understanding of the world around them. Integration is essential to ECE because it fosters holistic development and encourages rich educational experiences. Integration benefits from the diverse exploration of the world that young learners engage in spontaneously. Teachers can design meaningful activities that enhance learners' cognitive, social, emotional, and physical growth by integrating numerous disciplines and concepts. This method develops learners' critical thinking and problem-solving abilities from an early age and helps learners understand the connections between many fields of study. In today's technologically advanced society, the integration of coding and robotics with mathematical concepts in ECE is extremely important. Young children are offered hands-on experience and opportunities to build computational thinking, creativity, and problem-solving skills through coding and robotics. Learners can apply mathematical concepts in a concrete and useful way by incorporating these concepts with mathematics. Learners that participate in this integration acquire the growth mindset, resilience, and adaptability that are crucial in the digital age. A holistic and inclusive learning environment that respects each learner's unique abilities, interests, and learning styles is fostered by integration in ECE. It promotes teamwork, collaboration, and communication among learnerss as they work on interdisciplinary projects and consider many viewpoints. Additionally, integration enables teachers to cover several learning objectives at once, maximising class time and encouraging a better comprehension of subjects. Learners can forge meaningful connections and get a more	• DBE (2011b) • United Nations Children's Fund (UNICEF) (2018) • Chevalier, Giang, Piatti and Mondada (2020) • Papadakis, Vaiopoulou, Sifaki, Stamovlasis and Kalogiannakis (2021)

Key concept	Clarification	Literature
	complete picture of the world by fusing information from several disciplines. In conclusion, the integration of coding and robotics with mathematical concepts strengthens learners' computational thinking skills and prepares them for a future driven by technology. By embracing integration, teachers may offer exciting and pertinent learning experiences that equip learners to be lifelong learners and contributing members of a society that is continually changing.	
Digital technology (DT)	Digital technology in education can improve the effectiveness of ICT by allowing for more efficient communication and collaboration, as well as access to a broader variety of resources and learning opportunities. Electronic tools, systems, devices, and resources that create, store, process, or transmit data are referred to as digital technology (DT). The widespread use of DT has altered people's lives, employment, and communication. It has created new learning opportunities, such as e-learning, internet collaboration, and virtual reality. Digital technology can improve access to educational resources, improve teaching and learning experiences, and promote creativity and innovation. However, there are concerns about digital technology's potential negative effect on mental health, social relationships, and privacy. It is critical to use modern technology ethically and responsibly. The use of DT in education can improve educational technology's effectiveness by providing access to a broader variety of resources and learning opportunities.	• Das (2019) • Ng, Leung, Su, Ng and Chu (2023)
Educational technology	Using technology to improve both teaching and learning is referred to as educational technology. It encompasses a wide variety of tools, including interactive whiteboards, educational apps, learning management systems, and virtual simulations. Educational technology can help with personalised and adaptive learning, learner involvement and motivation, and communication and collaboration. However, successful educational technology integration necessitates careful planning, professional development, and ongoing evaluation.	• Marienko, Nosenko, Sukhikh, Tataurov and Shyshkina (2021) • Goldin, Rauch, Pacher and Woschank (2022)
Play-based learning	In Grade R, the teaching and learning of mathematics should employ a play-based learning approach. Play-based learning has been supported by various theorists who include but are not limited to Frederich Froebel (1782-1852); John Dewey (1859-1952); Maria Montessori (1869-1952), Lev Vygotsky (1896-1934), and Jean Piaget (1896-1980). The key characteristics of play include that play is purposeful, avoids worksheets, promotes creative and open-ended expectations, promotes numeracy understanding and skills, promotes social and oral skills, and reflects learners' interests. Play-based learning has rarely been defined as maturational, where play is seen as a natural way in which learners express themselves, and essentially leans more towards a focus on how teaching occurs in ECE. Play-based learning in a	• Bruce (1997) • Brock (2009) • Fleer (2010) • McGrath (2010) • DBE (2011b) • Walker (2011)

Key concept	Clarification	Literature
	stimulating environment will provide learners with “lasting mathematical memories”. For the purposes of this study, play-based learning will be defined as any play-based activity that Grade R learners participate in to acquire new ideas and abilities and to enhance their understanding.	• Derman, Zeteroğlu and Birgül (2020) • Reikerås (2020)
Grade R	In South Africa, Grade R, often referred to as ‘kindergarten’ in an international context, is the first year of formal schooling and serves as a gateway to formal education. The grade level entails informal learning, which typically incorporates play as a component of the learning process.	• DBE (2011b) • Van Heerden (2011) • Janse van Rensburg (2015)
Early Childhood Education (ECE)	Early childhood encompasses the period from birth to 8 years old, during which a child's brain is highly responsive to the environment around them. This time of remarkable growth requires specialised educational approaches that foster the development of key skills and foundational concepts essential for later life. ECE focuses on achieving critical developmental milestones, such as social-emotional skills, and developing early literacy, numeracy, and critical-thinking skills. The development of high-quality early childhood care and education is considered a crucial economic indicator, and UNESCO has designated it as one of its sustainable development goals. Providing high-quality ECE directly contributes to better outcomes for children, which translates into national improvements in prosperity, social inclusion, and economic development.	• Organization for Economic Co-operation and Development (OECD, 2012) • National Association for the Education of Young Children (NAEYC, 2019) • United Nations Educational Scientific and Cultural Organization (UNESCO, 2015)
Foundation Phase (FP)	In South Africa, the Foundation Phase (FP) refers to the first phase of formal education, which includes Grades R to 3 (ages 5 to 9). It is a critical time for learners to acquire basic literacy, numeracy, and life skills that will lay the foundation for their future learning and success. The curriculum is designed to be developmentally appropriate, play-based, and culturally sensitive, with an emphasis on learning through practical experience, exploration, and creativity. The goal is to ensure that all children have access to quality education that meets their individual needs and prepares them for later phases of schooling.	• DBE (2011b)
Learning environment (LE)	The learning environment should comprise much more than desks, chalkboards and a writing board. Historical, economic, occupational, and other conditions should also influence the setting of a successful learning environment. Moreover, the LE consists of the physical space, time allocation for teaching and	• Dewey (1938) • Jacobs and Alcock (2017)

Key concept	Clarification	Literature
	learning, the grouping of learners, which includes virtual and classroom-based teaching, and the age of learners, as well as teaching personnel.	
Early learning environment (ELE)	A favourable and psychological space in the playroom or outside in the play area, or visited during an outing, in which teachers may teach and children can learn and interact with wonder.	• Van Heerden and Du Preez (2021)
Mathematics	A universal language that employs numbers, symbols, and images to communicate. Learners must be familiar with mathematical ideas and abilities in order to comprehend the world in which they live.	• DBE (2011b) • Naudé (2014)
Learners	The term 'pupils' refer to individuals at the primary or secondary level of education. The term 'students' is favoured when referring to individuals that are at a tertiary level of learning. Sometimes the terms 'pupils' and 'learners' are used interchangeably to refer to individuals in primary or secondary education. However, this study gives preference to the term 'learners' rather than pupils or students.	• Bjuland and Helgevold (2017) • Hapompwe, Karim and Kambikambi (2020) • Nguyen (2021)
Early numeracy	To define the term 'numeracy' it is necessary to first define the term 'numeral'. A numeral is defined as a written symbol for a number. Examples include '1', '11', '71', and '171'. While adults have reached competency in reading numerals as number sentences, learners need to first learn numerals before they can understand these sentences. An example of this is an adult's ability to read and interpret '1 + 2 = 3' whereas the young learner still needs to understand what the numeral '1' entails. Numeracy, therefore, is the ability to be literate in numerical skills, such as operations, counting and comparison abilities.	• Desoete and Grégoire (2006) • Wright (2013) • Naudé (2021)
Grade R mathematics	In Grade R, mathematics is often referred to as 'early mathematics', and according to Harris and Petersen (2017), it includes basic concepts and skills, such as counting, understanding quantity, identifying shapes, grasping spatial relationships, measuring, and recognising patterns. Mathematics is a necessary topic in the Grade R curriculum as well as all subsequent grades (Grades 1-12) of schooling and can be utilised by anybody in any scenario in life. The FP (Grade R-3) curriculum, CAPS, encompasses the teaching and learning of four subjects namely a home language, a first additional language, mathematics, and life skills. To be literate in mathematics, learners need to be competent in the language of mathematics, which involves using numbers, symbols, and pictures (Naudé, 2014).	• DBE (2011b) • Wriston (2015)
Mathematical learning environment	If we look at the development of young children from birth, we would probably be able to conclude that most children first learn to crawl, then they start to walk, and only after they can walk, they start to run, skip, and jump. Similar to these physical developments, learners also follow natural developmental progressions in learning mathematics. When teachers develop LEs based on their knowledge of learners' development, these environments are considered to be developmentally appropriate for learners.	• Clements and Sarama (2014)

Key concept	Clarification	Literature
The teaching of early mathematics	Mathematics teachers in the FP should aim to ensure that learners become numerate, that is, to comprehend how the world functions and how they (the learners) can employ mathematics to be productive. Nevertheless, this study does not focus on the teaching of mathematics but rather focuses on how already-developed mathematical concepts can be integrated in Grade R teaching.	• Naudé (2014)
Mathematical concepts	Concepts within mathematics that learners need to understand and develop. Within the context of this study, the mathematical concepts of numbers, the operations of numbers, and the relationships between numbers are explored.	• Churchman (2006) • DBE (2011b)
Numbers, operations, and relationships	The general focus in this area is to develop number sense. This encompasses the essence of numbers, what they represent, how one number relates to another, and how we manipulate numbers using the four mathematical operations to comprehend their relationships. As mentioned, this area is the main focus of Grade R and the FP in general.	• DBE (2011b)
Technological profile	The 21st-century learner has never been without technology, therefore, these learners need to experience learning opportunities keeping this reliance on technology in mind. In this study, the technological profile relates to South African Grade R teachers and learners who integrate coding and robotics with mathematics.	• Harvey, Drolet and DeVore (2014)
Digital literacy (DL)	Digital literacy (DL) is reached when an individual is literate in the use of DT, and teachers need to acquire DL in order to use new innovative methods to teach and to keep up with trends in technology.	• Marsh (2020)
Digital play (DP)	Young learners engage in digital play when they use various technologies, such as cellular phones, electronic toys, and digital media content.	• Nel *et al*. (2021)
Coding	Computer programming is the process of giving a machine[7] a set of commands or instructions, which is called coding, or to write a code or language that a robot or computer can understand.	• Kingsley-Hughes and Kingsley-Hughes (2005)
Robot	A robot is defined as a machine that can perform tasks, react to the environment, and change what it does based on certain factors.	• Katovich (2019)
Robotics	Robotics is a discipline of engineering that encompasses the idea, design, production, and operation of robots and is seen as an exceptional chance to expose learners to the world of technology. Robotics helps us to grow as a global civilisation. As an example: In ancient Egypt, the Egyptians used human labour to build extraordinary pyramids but in today's world, we use science, technology, engineering, art, and mathematics (STEAM) to build skyscrapers. Through science, we can use observations and experiments to learn about the world around us that leads to innovations in robotics. The teacher	• Bers (2010) • Ardiny, Witwicki and Mondada (2015)

[7] The term 'machine' is used to refer to a robot, for the purposes of this study.

Key concept	Clarification	Literature
	participants in this study were not asked to build or design robots but were provided with a predesigned and prebuilt robot that they integrated with specific mathematical concepts. Robotics is the science and engineering area concerned with the creation, maintenance, use, and control of robots. A robot is a machine created to do specified activities autonomously or with little to no human assistance. Robots are frequently used in ECE as teaching aids to educate kids to the fundamentals of programming and robotics.	• Bier, Cheng, Mostafavi, Anton and Bodea (2018) • Katovich (2019)
The Bee-Bot	The Bee-Bot is a robot that resembles a black and yellow bumblebee. It has up to forty commands for its directional keys that are used to move the robot right, left, forward, and backwards. Usually, the Bee-Bot is used to teach concepts, such as measurement, location, and transformation. However, if different grids[8] are used for the Bee-Bot to move on, other content areas of mathematics can also be integrated. Figure 1.1 provides a front and side view as well as a top view of the Bee-Bot. As seen in the top view, different buttons can be pressed to move the Bee-Bot.  **Figure 1.1: A front view, side profile and top view of the Bee-Bot**	• Bers (2010) • Attard (2012)

[8] These grids can be purchased or the user can make them, which provides great flexibility (Attard, 2012).

1.8 PRELUDE TO THE LITERATURE

This study focused on integrating technology and mathematics in Grade R teaching, where play-based learning is a popular approach. The Technological Pedagogical and Content Knowledge (TPACK) framework developed by Koehler and Mishra (2005) was employed to guide the study since it highlights the importance of teaching with technology. TPACK consists of three major knowledge areas: pedagogical knowledge (PK), content knowledge (CK), and technological knowledge (TK). When these three types of knowledge areas are integrated, new knowledge areas are created, namely, pedagogical content knowledge (PCK), technological content knowledge (TCK), and technological pedagogical knowledge (TPK). These six knowledge areas inform a holistic view of TPACK and are situated within the context of Grade R LEs. The different knowledge areas are explained in more detail in Chapter 2, however, Figure 1.2 represents, conceptually, the interactions between these different knowledge areas.

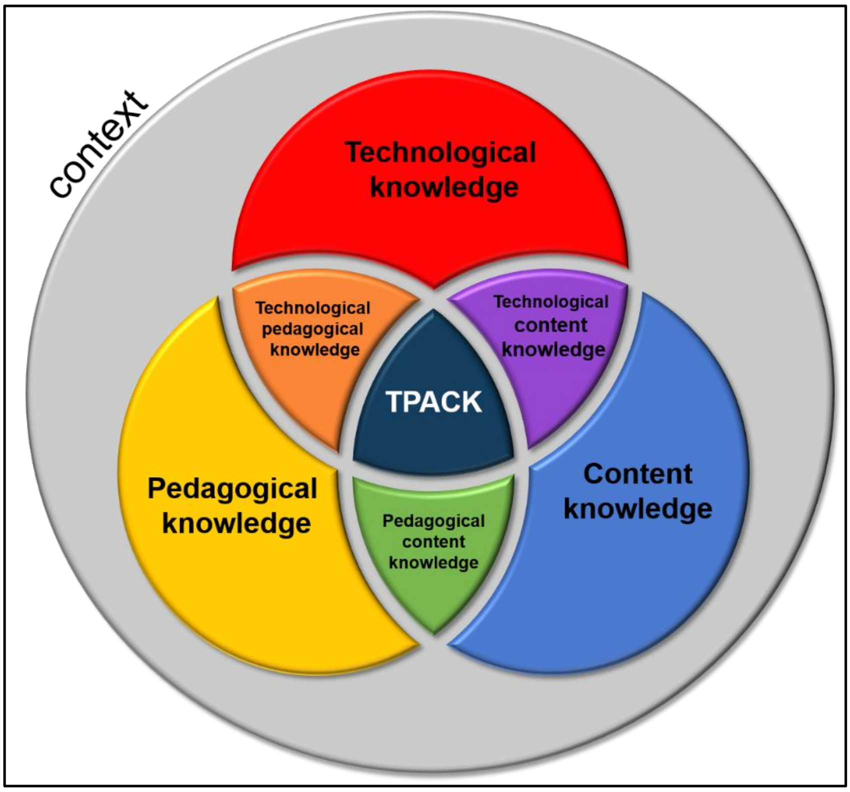


Figure 1.2: A visual representation of the TPACK framework (Adapted from Koehler & Mishra, 2009:63)

In this study, the TPACK framework served as a guide for organising and presenting the literature. Chapter 2 begins with an explanation of TPACK and how it relates to the study's focus on integrating technology and mathematics in Grade R. The importance of understanding play-based teaching as well as the pedagogical theories of Piaget, Vygotsky, Montessori, and Reggio Emilia is discussed in the context of PK. Although these theories and practices primarily focus on child development, the study emphasises the role of teachers in implementing them effectively. In the CK section, the study delved into the specific mathematical concepts of numbers, operations, and relationships, which are essential for Grade R learners. The TK section focused on the use of coding and robotics as technology tools to enhance teaching and learning. By using the TPACK framework, the study was able to connect these different knowledge areas and highlight the interplay between them in the context of Grade R LEs. This helped to provide a comprehensive understanding of how technology and mathematics can be integrated effectively, and how teachers can play a crucial role in facilitating this integration.

1.9 PRELUDE TO THE METHODOLOGY

Chapter 3 provides a full overview of the study's research design and methodology. This study used PAR, a research method that involves community members to bring about change (Creswell, 2009; Somerville, 2014; Creswell & Creswell, 2018). The study focused on integrating coding and robotics with mathematical concepts in Grade R, using an interpretivist paradigm and a qualitative approach. The PAR model was used to develop a teaching framework based on the participants' needs and experiences. The study employed several data generation instruments, including semi-structured interviews and guided observations, and conducted four cycles of PAR. A preliminary teaching framework was developed, reviewed, and refined before the final framework was developed. The purpose of the teaching framework is to provide teachers with a practice-based resource to support their teaching in integrating coding and robotics with Grade R mathematical concepts.

The teaching framework in this study was based on the connections between planning, acting, observation, reflection, and participants' learning from their own experiences (Lawson, 2015; Le Cordeur, 2016). I collaborated with the participants to bridge the gap between theory and practice, taking into account their worldview beliefs and sentiments to develop guidelines for the framework. The aim of the PAR model employed was to empower the Grade R teachers to make a difference in their teaching community. I familiarised myself with the research questions and objectives, and used deductive thematic data analysis to create a starting point through TPACK and the literature reviewed for the findings. The PAR model implemented in this study is presented in Figure 1.3, with a more detailed version discussed in Chapter 3.

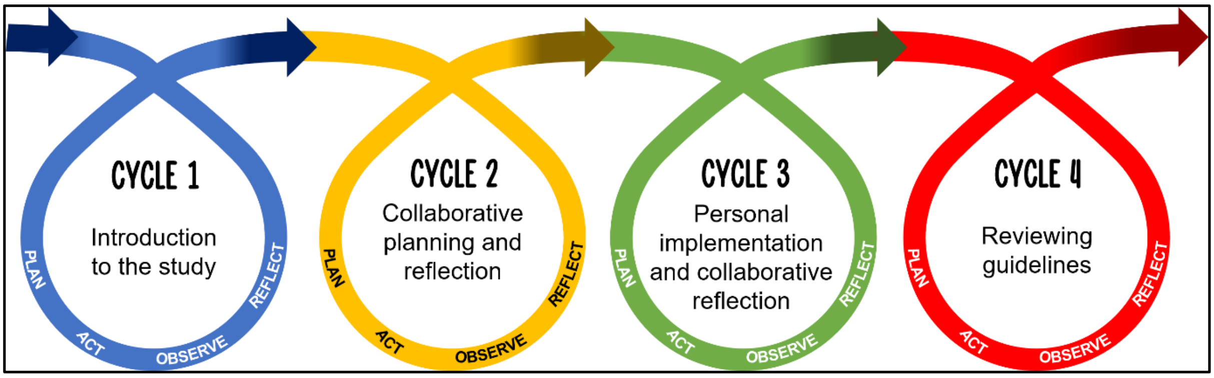


Figure 1.3: Simplified model of PAR employed in this study

In ***Cycle 1: Introduction to the study*** (blue), I conducted five introductory sessions and 10 semi-structured individual interviews to introduce participants to play-based theories, international best practices, mathematical concepts, coding activities and educational robots. The aim was to support teachers who had no prior experience with coding and robotics to integrate it in Grade R. I also discussed the nature of PAR with the participants.

Cycle 2: Collaborative planning and reflection (yellow), During the interviews, it was found that teachers were unsure of how coding and robotics could be integrated with specific mathematical concepts to enhance play-based teaching. As a result, I created an activity template (AT) to help teachers with this (see Figure 4.5). Two collaborative discussion groups and nine guided observations were held in this cycle. Photographs (see Appendix I for examples) were used to capture moments of integrating coding and robotics with specific mathematical concepts.

In ***Cycle 3: Personal implementation and collaborative reflection*** (green), the individual activities of the teachers were observed and photovoice was used. The final collaborative discussion group was held to reflect on experiences and insights in integrating coding and robotics with mathematics. The findings of all three cycles were then analysed using inductive data analysis to develop a preliminary framework before Cycle 4.

For ***Cycle 4: Reviewing guidelines*** (red), I conducted an expert interview with an EP to reflect on the preliminary framework developed from the findings of the three cycles. The EP was provided with an external participant booklet (EPB) (see Appendix L) to provide suggestions for strengthening the guidelines and establishing a teaching framework for teachers to integrate coding and robotics with mathematical concepts in Grade R.

A total of five introductory sessions, 10 semi-structured individual interview schedules, three collaborative discussion groups, 18 guided observations, and one systematising expert interview were conducted over a period of ten inconsecutive weeks.

1.10 OUTLINE OF CHAPTERS

In this section, a brief overview of each chapter in this study is provided by highlighting the main points. This supports understanding the structure of the study and to gain an insight into what each chapter explores. Table 1.2 provides an overview of the chapters of this study. The content of each chapter in this study was colour-coded according to the colours shown in Table 1.2.

Table 1.2: Overview of the chapters in this study

<table>
<tr><th colspan="3">CHAPTER 1: OVERVIEW OF THE STUDY AND ORIENTATION</th></tr>
<tr><th>Primary research question</th><th colspan="2">Secondary research questions</th></tr>
<tr><td>How can Grade R teachers be supported to integrate coding and robotics with mathematical concepts?</td><td colspan="2">• How does pedagogical knowledge support Grade R teaching?
• How does coding and robotics support Grade R teaching?
• How can Grade R mathematical concepts be used in play-based teaching?</td></tr>
<tr><th colspan="3">CHAPTER 2: THEORETICAL FRAMEWORK AND INVESTIGATING THE LITERATURE</th></tr>
<tr><th colspan="3">TECHNOLOGICAL, PEDAGOGICAL, AND CONTENT KNOWLEDGE</th></tr>
<tr><th>Pedagogical knowledge</th><th>Content knowledge</th><th>Technological knowledge</th></tr>
<tr><td><u>Grand theorists</u>:
• Lev Vygotsky
• Jean Piaget
<u>International best practices</u>:
• Maria Montessori
• Reggio Emilia</td><td>Numbers, operations, and relationships</td><td>• 21st-century skills
• Digital literacy
• 21st-century teaching skills
• STEAM education
• Play-based digital teaching
• Coding
• Robotics</td></tr>
<tr><th>Pedagogical content knowledge</th><th>Technological content knowledge</th><th>Technological pedagogical knowledge</th></tr>
<tr><td>• Policy and curriculum for Grade R mathematics
• Play-based mathematics teaching
• Grade R mathematics: Perspectives from Japan, New Zealand, Singapore, and South Africa</td><td>Integrating coding and robotics with mathematics</td><td>• Play-based learning pedagogy to promote 21st-century skills
• Play-based digital learning
• Using coding in the Grade R learning environment
• Using the Bee-Bot in the Grade R learning environment
• Using coding and robotics in the Grade R learning environment: Perspectives from Japan, New Zealand, Singapore, and South Africa</td></tr>
<tr><th colspan="3">Technological, pedagogical, and content knowledge</th></tr>
<tr><td colspan="3">Teachers' understandings and perceptions of integrating coding and robotics with mathematics</td></tr>
<tr><th colspan="3">CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY</th></tr>
<tr><th>Paradigmatic assumptions</th><th>Research design and sampling</th><th>Ethical considerations</th></tr>
<tr><td>Meta-theoretical paradigm

Methodological paradigm</td><td>• Participatory action research
• Purposive sampling</td><td>• Researcher reflexivity
• Ethics committees and codes of ethics
• Informed consent and assent
• Confidentiality and anonymity
• <u>Trustworthiness</u>: reliability, credibility, transferability, dependability, and confirmability</td></tr>
</table>

Data generation	
Qualitative data generation techniques	**Qualitative data documentation techniques**
Teachers	
• Researcher reflection journal • Semi-structured individual interview schedules • Collaborative discussion groups • Guided observations • Photovoice	Verbatim transcripts Photovoice
External	
• Systematising expert interview	• Verbatim transcript
CHAPTER 4: DATA GENERATION PROCEDURES AND DEDUCTIVE DATA ANALYSIS DESCRIPTION	
Participatory action research Discussion of data generation	
CHAPTER 5: DATA RESULTS AND INDUCTIVE DATA ANALYSIS OF THE FIRST THREE CYCLES	
Findings from the different data generation methods	
CHAPTER 6: DATA INTERPRETATION AND PRELIMINARY FRAMEWORK	
Data interpretation	
Preliminary development of framework	
CHAPTER 7: COMPARISON OF THE RESEARCH FINDINGS WITH THE LITERATURE	
Supportive findings; Contradictive findings; Absences and silences in findings; New ideas from findings	
Framework	
CHAPTER 8: CONCLUDING REMARKS	
Main findings Research questions answered Purpose of the study evaluated	

Format adapted from Van Heerden (2011:14)

Chapter 1 (light green) provides an overview of the study's purpose, research questions, and methodology. Chapter 2 (orange) presents the theoretical framework and relevant literature. Chapter 3 (blue) discusses the research design and methodology, including ethical considerations. Chapter 4 (red) describes the data generation methods and analysis. Chapter 5 (orange) presents the codes, categories, sub-themes, and main themes that emerged from the data analysis. Chapter 6 (mint green) explains data interpretation and presents the preliminary framework that was reviewed. Chapter 7 (purple) compares the findings to existing literature and provides the final framework for integrating coding and robotics with specific mathematical concepts. Chapter 8 (dark green) summarises the main findings of the study and evaluates the study's purpose according to these findings.

1.11 SUMMARY OF CHAPTER 1

I outlined the goal and rationale for this study in Chapter 1. Clarification of the many terms used throughout the study was subsequented by the research questions that helped to understand how coding and robotics can be integrated with specific Grade R mathematical concepts. The study's theoretical foundation, the research methodology, and the research methods have all been briefly explained. Finally, a chapter summary of this research study was given. In Chapter 2, the study’s theoretical framework has been presented and discussed first, in order to organise the applicable literature.

CHAPTER 2: THEORETICAL FRAMEWORK AND INVESTIGATING THE LITERATURE

2.1 INTRODUCTION

This study aimed to understand how teachers can be supported to integrate coding and robotics with certain mathematical concepts in a Grade R learning environment. In this chapter, the theoretical perspectives that are relevant to this study are presented first (see 2.2 Technological, Pedagogical, and Content Knowledge (TPACK) as a theoretical framework). The TPACK framework, as a theoretical framework, was investigated to explain the relationship between coding, robotics and mathematics in Grade R. The literature was evaluated according to these knowledge areas presented in TPACK and scrutinised according to both international and local literature in order to provide an overview and identify the gaps in research (see 2.3 Exploring the literature: Teaching numbers operations, and relationships through coding and robotics in the Grade R learning environment). As previously mentioned, coding and robotics are earmarked to be implemented as a subject in our South African LEs in the near future. It is, therefore, imperative that the different concepts that underpin using coding and robotics are investigated, specifically in ELEs. Throughout the chapter, the implications of the information for the study is indicated in the following colour and/or format.

Implication for this study	Explanation of how information has an implication in the study.

2.2 TECHNOLOGICAL, PEDAGOGICAL, AND CONTENT KNOWLEDGE (TPACK) AS A THEORETICAL FRAMEWORK

This study's main topic necessitates the integration of technology and one particular discipline, mainly mathematics. Teachers take into account the relationship between the content, the pedagogy, and the technology within the learning environment when planning and preparing for technology and subject-specific integration. Therefore, play can be considered as a way to bridge technology and mathematics in Grade R, because play is employed as a means of learning and teaching in ELEs. I decided to use the TPACK framework presented by Koehler and Mishra (2005), which highlights the importance of teaching with technology. TPACK was referred to in the literature as TPCK until 2008 when researchers advised using the more readily pronounced moniker 'TPACK' (Thompson & Mishra, 2007:38). This framework was built on the rationale that educational technology has attempted for many years to uncover its theoretical foundations (Roblyer & Knezek, 2003; Roblyer, 2005; McDougall & Jones, 2006; Graham, 2011; Hannaway, 2016).

TPACK consists of three major knowledge areas, namely, PK, CK, and TK. When these three types of knowledge areas are integrated, new knowledge areas are created, namely, PCK, TCK, and TPK. These six knowledge areas inform a holistic view of TPACK and are situated within a specific context, which in this study is the Grade R learning environment and the factors that impact it.

The TPACK framework, developed by Koehler and Mishra (2005), has been visually presented in Chapter 1 (see Figure 1.2). Figure 2.1 is based on this but provides the acronym for each knowledge area. These were used as icons in the study to support understanding and to clarify which section refers to which construct of TPACK.

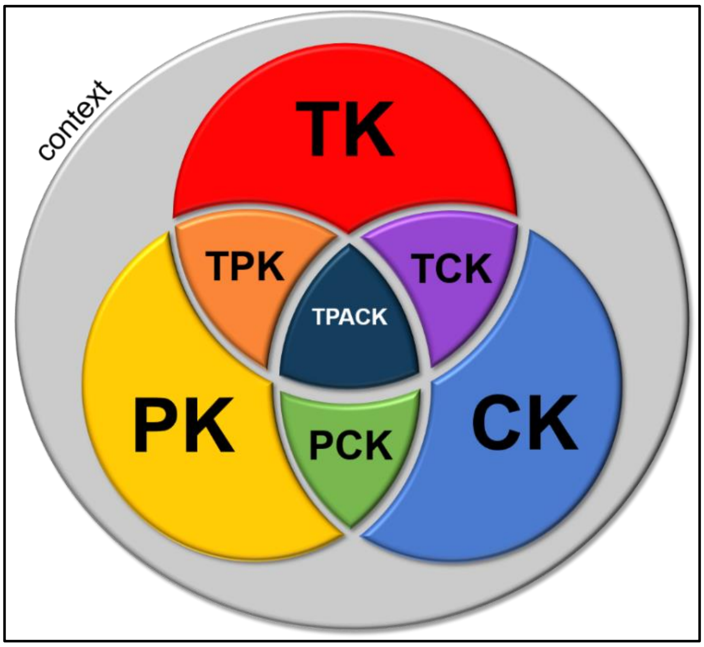


Figure 2.1: A visual representation of the TPACK framework constructs with acronyms

As shown in Figure 2.1, each TPACK knowledge area is denoted by a distinct colour, and this is also how it is explained in this study. The three primary knowledge areas of PK (yellow), CK (blue), and TK (red) are covered first in the literature review. The discussion then proceeds to PCK (green), TCK (purple), and TPK (orange). The link (TPACK – dark blue), between play-based teaching (PK), numbers, operations, and relationships (CK), as well as coding and robotics (TK), are then be explored.

2.2.1 Technological pedagogical and content knowledge areas

Koehler and Mishra (2005) characterise the specific types of knowledge that teachers need to effectively integrate technology. As mentioned previously, these knowledge areas consist of three major constructs, namely, PK, CK, and TK, and when these are integrated, PCK, TCK, and TPK are developed (ibid.). The subsequent part clarifies and expands on each of these knowledge areas.

a. **Pedagogical knowledge (PK)**: PK explicates that teachers should possess the necessary knowledge of different instructional practices, teaching methods, assessment accommodations, and classroom management (Koehler & Mishra, 2009; Mishra, Koehler & Henriksen, 2011; Hannaway, 2016).

b. **Content knowledge (CK)**: CK is concerned with the knowledge of the subject matter, the knowledge of theories and concepts, and an understanding of how knowledge can be established (Shulman, 1986; Mishra *et al.*, 2011).

c. **Technological knowledge (TK)**: TK refers to an understanding of the various technologies that exist and how we can use these tools and resources in our LEs (Koehler & Mishra, 2009; Schmidt, Baran, Thompson, Mishra, Koehler & Shin, 2009; Mishra *et al.*, 2011; Hannaway, 2016). The teacher needs to consider technology that is appropriate and effective for learning and teaching (Santos & Castro, 2021).

d. **Pedagogical Content Knowledge (PCK)**: PCK refers to how learners can be effectively engaged to learn different concepts and skills in a specific subject area (Shulman, 1986; Schmidt *et al.*, 2009, Howell, 2012). PCK varies in the content area since it combines both content and pedagogy with the purpose of improving teaching practices (Hannaway, 2016).

e. **Technological Pedagogical Knowledge (TPK)**: TPK refers to choosing and managing different technologies for learners to ensure effective learning can take place (Koehler & Mishra, 2009; Howell, 2012).

f. **Technological Content Knowledge (TCK)**: TCK alludes to how technology is used in a specific subject area for lasting learning and how to provide new ways of teaching content (Schmidt *et al.*, 2009; Howell, 2012).

g. **Technological Pedagogical Content and Knowledge (TPACK)**: TPACK is defined as the interaction between CK, PK, and TK when using technology for teaching and learning (Schmidt *et al.*, 2009; Howell, 2012).

h. Lastly, although not a knowledge area, **the context** has a direct effect on each of the knowledge areas mentioned above and is central to TPACK (Koehler & Mishra, 2009).

2.2.2 The application of technological pedagogical and content knowledge

Possible difficulties to ground research about technology in education in theoretical roots have been ascribed to the rapid pace of technological change, a lack of solid methodological design, and a focus on practical rather than theoretical issues (Roblyer & Knezek, 2003; Roblyer, 2005; McDougall & Jones, 2006; Graham, 2011; Hannaway, 2016). Graham (2011) recognises various shortcomings after analysing the theoretical considerations to comprehend TPACK according to key components for the development of a theory provided by Whetten (1989). These shortcomings are briefly examined in terms of 'what' factors should be considered when explaining TPACK, "evaluating 'how' the constructs in the framework are related", and finally, "explaining 'why' the relationships" are important in a larger context (Whetten, 1989:490-491).

Even though the individual knowledge areas of TPACK have been defined in the section above, Graham (2011) identifies a shortcoming of TPACK by arguing that much more theoretical work needs to be done in order to develop each construct's precise meaning. Furthermore, since TPACK is based on a previous framework named pedagogical content knowledge (PCK) developed by Lee Shulman (1986), it can also generate a lack of theoretical clarity (Graham, 2011). Koehler and Mishra (2005) used PCK as a point of departure to highlight the importance of teaching with technology and named it TPACK.

The second shortcoming focuses on how the constructs in TPACK are related, which asks the question of whether the constructs in TPACK are integrative or transformative (ibid.). At the one end, TPACK is viewed as integrative because of "the combination or mixture of different types of knowledge" whereas the transformative perspective sees it as a "new synthesized form of knowledge that cannot be explained by the sum of its parts" (Gess-Newsome, 2002; Graham, 2011:1956). These views are simplified by Angeli and Valanides (2009) who state that it is unclear whether TPACK represents a distinct type of knowledge or if TPACK simply refers to growth in any of the associated constructs. This explanation presented by Angeli and Valanides (2009) is criticised by Graham (2011) who claims that construct value, which includes both the theoretical and prescriptive value of all constructs in the framework, must be defined.

To begin, the construct value issue entails determining the theoretical value of all the constructs in the model as well as explaining how the TPACK constructs connect to other commonly used terms like 'technology integration' (Graham, 2011). Secondly, Graham (2011) argues that researchers must better define TPACK's prescriptive value of potential, which is echoed by Archambault and Barnett (2010) who are dissatisfied with the framework's ability to forecast or expose results or new information, thereby restricting its influence on educational technology.

Although several shortcomings exist in the implementation of the TPACK framework, various authors have outlined several reasons why it works, particularly in the current era. First off, one of the most common criticisms of educational technology is that it is more motivated by strong pedagogical principles than by actual technological necessities (Mishra & Koehler, 2006). Mishra and Koehler (2006), however, argue that TPACK provides individuals with a vocabulary to discuss the linkages that exist or do not exist in educational technology conceptualisations. Furthermore, Mishra and Koehler (2006) argue that their paradigm situates this component, the content-technology link, within the larger context of pedagogical technology use. Kilbane and Milman (2014:51) also advocate the use of TPACK by explaining that it provides a theoretical framework for teachers to visualise the intricate links between the various knowledge areas as well as to assess a teacher's expertise and to plan for professional development for "optimal use of educational technology".

2.2.3 The application of technological pedagogical and content knowledge in this study

The aforementioned seven knowledge strands, including the context, were used to identify the literature themes needed for this research study. Each knowledge area is used to represent a different topic that is discussed by using international and local literature where applicable. Firstly, PK alludes to play-based teaching as well as grand theories and best international practices in the Grade R learning environment. Secondly, CK focuses on Grade R mathematical concepts, and more specifically the content area of numbers, operations, and relationships. The literature then focuses on TK in the Grade R learning environment and includes DL, 21st-century skills and teaching skills, STEAM education, play-based digital learning and teaching, as well as coding and robotics as part of the discussion. These three main knowledge areas are then combined to discuss using mathematical concepts in Grade R (PCK), integrating coding and robotics with mathematics (TCK), and using coding and robotics in Grade R (TPK).

Implication for this study	I employed TPACK to identify relevant literature according to the study's topic and research questions. TPACK was used to gain in-depth insight into the TK of using coding and robotics; the PK of play-based teaching in the Grade R learning environment; and the specific CK of numbers, operations, and relationships. The three main strands of knowledge areas were furthermore integrated to investigate other aspects that influenced this study.

Figure 2.2 depicts these knowledge areas in the context of this study.

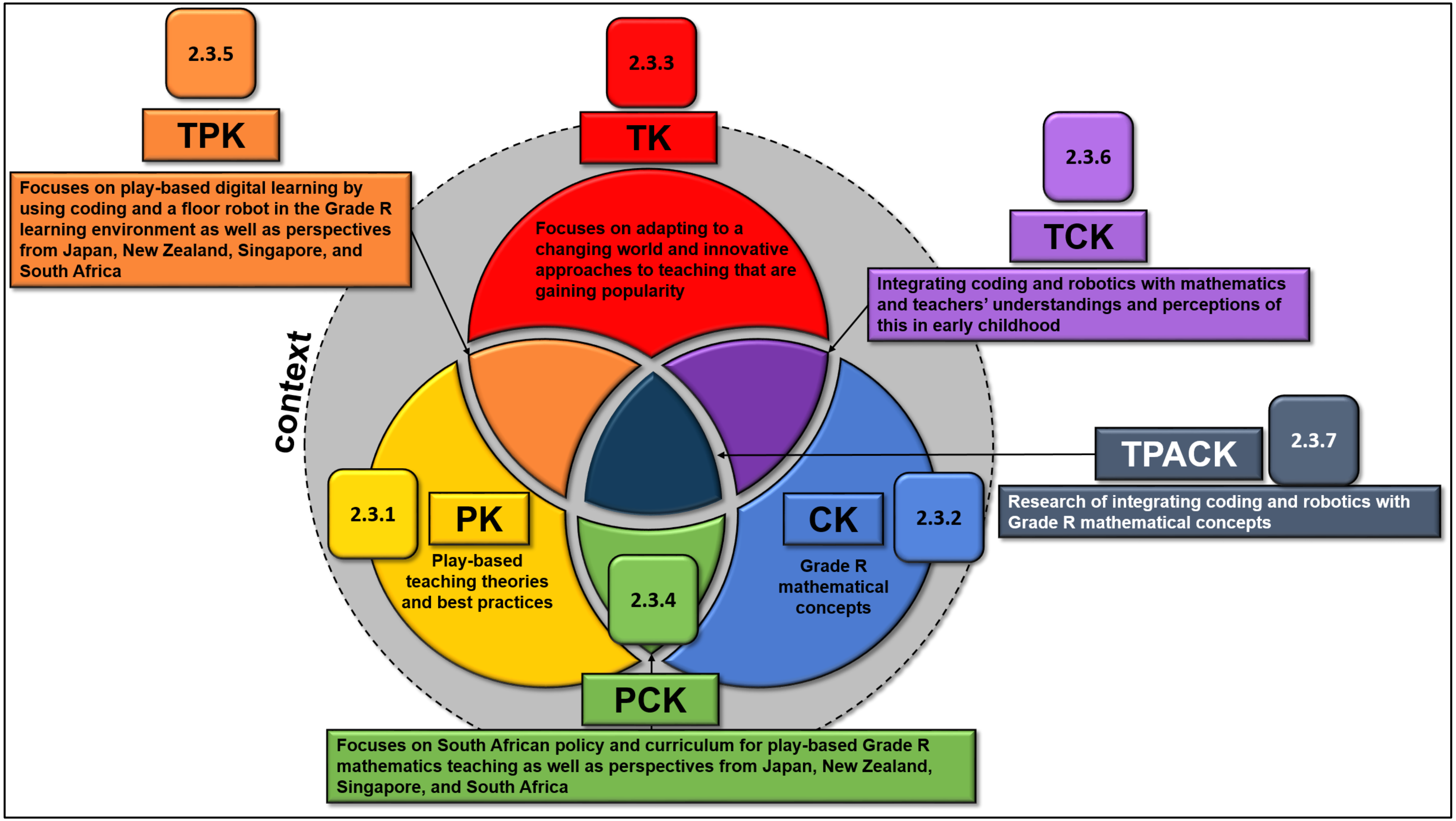


Figure 2.2: The literature in the context of TPACK

The literature review of this study commences with an overview of PK (yellow), specifically play-based learning as well as theories and international best practices. Following this, a discussion regarding the content (blue) of Grade R mathematical concepts in a South African context is explored with a specific focus on numbers, operations, and relationships. TK (red) is then explained by providing literature pertaining to 21st-century skills and 21st-century teaching skills, digital literacy, play-based digital teaching, and lastly, coding and robotics. PCK (green) follows after this discussion, where I discuss the policy and curriculum for Grade R mathematics as well as how mathematics is used both in South Africa and internationally in Japan, New Zealand and Singapore. TCK (purple) focuses specifically on integrating coding and robotics with mathematical concepts. Next, TPK (orange) elucidates how coding and robotics is used in ELEs. The application of these constructs to this study guided the implementation of Boolean searches for retrieving pertinent literature.

2.3 EXPLORING THE LITERATURE: INTEGRATING CODING AND ROBOTICS WITH NUMBERS OPERATIONS, AND RELATIONSHIPS IN THE GRADE R LEARNING ENVIRONMENT

In the next section, relevant literature is organised according to the knowledge areas presented in TPACK. As mentioned previously, the icons indicate which construct of TPACK is discussed to serve as guides to the literature review sections.

2.3.1 Pedagogical knowledge: Play-based teaching

PK

The word pedagogy comes from the Greek word ‘paidagōgos’, which means ‘to lead the child’ or to ‘tend the child’. Individuals who teach and work with young learners frequently use the words ‘practice’ and ‘approach’ to describe the strategies they employ to implement play-based learning (Stach & Veldsman, 2021). The following section explains what play-based learning entails and then provides an in-depth overview of the theories and international practices applicable to this study.

Smith and Vollstedt's (1985) definition of play has been used in this specific study. They define play as a joyous, flexible, imaginative, creative and spontaneous activity that is not focused on the results and is imperative to the learners’ development and learning. Joyfulness is a play-based learning characteristic that is typically connected with most types of play (Stach & Veldsman, 2021). Play-based learning encompasses feelings of excitement, surprise, and learning from the unexpected (ibid.). Table 2.1 organises the play-based learning characteristics and situates them within the context of this study.

Table 2.1: Play-based learning characteristics

Play-based learning characteristic		Explanation	Implication for this study
Joyful	• Groos (1889) • Smith and Vollstedt (1985) • Bodrova and Leong (2007) • The LEGO Foundation (2017) • Stach and Veldsman (2021)	The activities should not be focused on a result but should be joyful and flexible.	The Grade R teachers created enjoyable activities to pique the learners' interest.
Actively engaging	• Rubin, Fein and Vandenberg (1983) • The LEGO Foundation (2017) • Stach and Veldsman (2021) • Clements (2022)	Learners are actively engaged and focused when learning through play.	The Grade R teachers engaged the learners in activities that encouraged their involvement.
Meaningful	• The LEGO Foundation (2017) • Stach and Veldsman (2021)	Play activities intended at enhancing learners' learning must be meaningful, as learners are attempting to make sense of their surroundings and relate new knowledge to previous knowledge.	The Grade R teachers ensured that the activities were meaningful in terms of developing the learners' skills in numbers, operations, and relationships, and based the activities on the learners' prior knowledge.
Iterative	• Smith and Vollstedt (1985) • Whitebread and Basilio (2013) • The LEGO Foundation (2017) • Stach and Veldsman (2021) • Clements (2022)	Learners must have the opportunity to solve problems, test new ideas, and be creative.	The Grade R teachers designed activities that allowed learners to develop problem-solving skills; yet, in certain instances, learners were required to meet a predetermined learning objective, leaving little space for creativity.
Socially interactive	• Groos (1889) • Bodrova and Leong (2007) • Golinkoff and Hirsh-Pasek (2017)	Learners must have the opportunity to communicate ideas, enjoy each other's	All of the activities developed by the Grade R teachers encouraged the learners to interact with one

Play-based learning characteristic		Explanation	Implication for this study
	• The LEGO Foundation (2017) • Stach and Veldsman (2021) • Clements (2022)	company, and build relationships.	another as well as with the respective teacher.

Henricks (2015:5) provides a valuable view of play, stating that play is either "an exercising or refining of the familiar" or that it "celebrates the unpredictable and surprising". Moyles (2012), in turn, asserts that learners need to play as it is essential to their neurological development and promotes the mind's flexibility. In South Africa, "play" refers to "powerful learning around you" to promote the concept that play is linked to learning (DBE, 2017:1). Although Mardell, Wilson, Ryan, Ertel, Krechevsky and Baker (2016), and Stach and Veldsman (2021) recognise that not all play is learning and that not all learning must be playful, play does have the potential to increase learning in most situations.

A high inter-observer agreement exists in defining play (Ellis, 2017), therefore, it is recommended by Smith and Vollstedt (1985) that instead of examining and analysing literature to find the perfect definition, the characteristics of play should rather be combined to define it. Some foundational authors (Krasnor & Pepler, 1980; Rubin *et al*., 1983; Sutton-Smith & Kelly-Byrne, 1984) have provided certain sets of play criteria, however, for this study, a broader set of criteria proposed by Irvin (2017) was used. The author states that play should: 1) be motivated by a personal interest in the activity and not driven by basic needs or social demands; 2) be driven by the activity itself more than specific goals; 3) occur with familiar objects or in exploring unfamiliar objects; 4) be considered to be nonliteral; 5) exist without rules from the outside, however, rules can be modified by the learners that play; and 6) require the active engagement of the learners. The above-mentioned criteria can help us to understand play.

Thus, play can be described as the most natural way for learners to learn and develop, which includes the learning of mathematics (Bruce, 1997; Brock, 2009; Fleer, 2010; McGrath, 2010; DBE, 2011b; Walker, 2011; Derman *et al.*, 2020; Reikerås, 2020). Play is the process by which learners explore, recreate, and comprehend their surroundings (Derman *et al.*, 2020). Özdoğan (2011) postulates that learners develop daily life knowledge through play and that this includes mathematical experiences. De Holton, Ahmed, Williams, and Hill (2001) believe that learners who use prior knowledge in mathematical play develop a link to new knowledge and skills of mathematics. Learners come across different problems that need solutions in mathematical play and, therefore, mathematics creates “powerful learning environments” where learners can build logical thinking (Özdoğan, 2011:3119).

Play-based teaching is a crucial element of ECE because it promotes the development of various skills, such as cognitive, social, and emotional skills (UNICEF, 2018). However, there is a substantial gap in the literature regarding the integration of coding and robotics with mathematical concepts in South African ELEs. This disparity is especially concerning in light of the increasing significance of DL and technological skills in today's society. According to one research study by Ching, Hsu and Baldwin (2018), incorporating coding and robotics into play-based teaching can enhance learners’ creativity, critical thinking, and problem-solving skills. The research also discovered that learners who engage in play-based robotics and coding activities may outperform their peers in terms of mathematical success. To better understand the specific ways that coding and robotics can be incorporated into play-based teaching to encourage the development of mathematical concepts, more study is required (ibid.). Another study by Papadakis (2020) found that incorporating coding and robotics into play-based teaching can also help learners’ spatial awareness and spatial reasoning skills, which are crucial for the development of mathematical concepts. However, the research also made clear that in order to successfully incorporate coding and robotics tools into play-based teaching, teachers must receive training in the use of coding and robotics (ibid.).

Jensen, Pyle, Zosh, Ebrahim, Zaragoza Scherman, Reunamo and Hamre (2019) and Stach and Veldsman (2021) argue that individuals working in ECE settings cannot follow a single play-based learning practice, since teachers require a range of methods that represents the dynamic character of play. Furthermore, if children are to learn through play, it must connect to real-life events, make use of what is readily accessible, and promote holistic development (Awopegba, Oduolowu & Nsamenang, 2013). For this reason, this study explored the work of two foundational theorists and two international practices as explained in the following section.

Theories are shaped over time as well as the environment in which they are developed and emerge as a result of asking questions and watching behavioural patterns (Schunk, 2012). We consider the impact of theories and concepts on the quality and care offered to young learners in the early years when interpreting them (Conkbayir & Pascal, 2016). Theories, according to Fleer (2013), not only affect our perspectives but also give direction and structure to our activities. Furthermore, Johnson (2015) postulates that play theories have been covered extensively as well as intensively and serve as a lens to pursue the meaning of play and to guide research as well as practice, from different perspectives on play. Grand theorists of play include Fredrich Froebel, Jean Piaget, Lev Vygotsky, Erik Erikson, and Jerome Bruner, to name a few. This study only focused on two grand theorists of play and their beliefs of play pedagogy namely, Lev Semyonovitch Vygotsky and Jean William Fritz Piaget. Vygotsky (1896-1934) regarded play as a fundamental aspect of learning, but also as a basis for creating a zone of potential growth in which young learners can perform at their best (Vygotsky, 1978). Piaget's (1896-1980) theory of play, cited in Bruce (2004), involves the senses and movement, as well as the development of the imagination and the regulation of human behaviour.

This section also investigates two international best practices. Firstly, the pedagogy of Montessori schools is explored, founded on Maria Tecla Artemisia Montessori's (1870-1952) notion that a child's intellect should be developed after their senses have been stimulated through multisensory experiences (Seldin, 2017). Secondly, the practices of Reggio Emilia are considered, which is mainly built on the idea that young learners should be playfully engaged in natural settings, with the support of individuals who are interested and adequately trained (Smidt, 2013).

Montessori and Reggio Emilia approaches have gained recognition globally due to their innovative methods of teaching (Aljabreen, 2020). In the South African context, these approaches are particularly relevant for integrating coding and robotics in Grade R teaching. The Montessori approach emphasises self-directed learning and hands-on exploration, which aligns well with integrating coding and robotics, and provides a framework for individualised learning (ibid.). Similarly, the Reggio Emilia approach emphasises inquiry-based learning, collaboration and communication, which is aligned with South Africa's commitment to fostering social cohesion (Mapungubwe Institute for Strategic Reflection [MISTRA], 2015; Aljabreen, 2020). The reason why I focused on Montessori and Reggio Emilia approaches in my thesis is that they are among the most widely recognised and researched approaches in the field of ECE. Additionally, both approaches have been successfully implemented in various contexts globally, which suggests that they are adaptable and can be modified to suit the unique needs of the South African context (Aljabreen, 2020).

While other approaches such as Waldorf, the African approach, or any of the US approaches have a following in South Africa, I chose to limit myself to these two theories and best international practices for two reasons. One reason is that a thesis' scope and length are typically limited, and trying to cover all pertinent theories and practices in a specific area may be too broad for a single thesis. Focusing only on these also allowed a more in-depth examination of these theories and practices, which led to a more nuanced and comprehensive knowledge of the topic at hand.

2.3.1.1 Grand theorist of play: Lev Vygotsky

Vygotsky's sociocultural theory, which entails that "*mental functions are given in the form of social relationships, which serve as the source of the emergence and development of these very functions in man*", has made a significant impact in the field of ECE (Elkonin, 1989:473; Doherty & Hughes, 2014; Fleer & Veresov, 2018; Vasileva & Balyasnikova, 2019). This theory highlights the role of teachers in progressing learning beyond what learners currently understand but within reach of what the learner could understand if supported by a more knowledgeable other (Doherty & Hughes, 2014), highlighting one of the most important concepts of Vygotsky's theory, namely, the zone of proximal development (ZPD) (Mooney, 2013). The ZPD is defined by Vygotsky (1978:86) as "*the distance between the actual developmental level as determined by independent problem solving, and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers*". Vygotsky's notion of the ZPD is, therefore, founded on the premise that development is characterised by what a learner can do independently as well as what the learner can achieve with the help of an adult or more competent peer (Daniels, 2014). Knowing both levels of Vygotsky's ZPD is beneficial for teachers since they reveal where a learner is at any given time as well as where the learner is heading (Slavin, 2006). The ZPD has numerous implications for teaching. The teacher must design activities that combine both what learners are capable of doing on their own and what they are not capable of doing on their own, according to Vygotsky's theory, for the curriculum to be developmentally appropriate (ibid.).

Slavin (2006) states that teachers can implement three strategies for arranging learning opportunities, based on Vygotsky's theory. Firstly, teaching can be designed to offer practice in the ZPD for individual learners or groups of learners (ibid.). Secondly, cooperative learning opportunities with groups of learners at different levels can be organised to ensure learners can support each other to learn (ibid.). Lastly, the teacher can use a method, referred to as "scaffolding"[9] (Wood, Bruner, & Ross, 1976:90) or "guided participation" (Rogoff, 2003:282-289), which assists a learner in their ZPD by providing the learner with hints and prompts at different levels. Berk (2018) also states that a Vygotskian learning environment emphasises active participation through assisted discovery, which takes place when teachers direct learning by tailoring activities to each learner's ZPD. Peer collaboration aids assisted discovery, as learners of various abilities engage in groups, teaching and supporting one another (ibid.). In the context of this study, teachers should pursue experiences that allow for open-ended usage, investigation, and collaboration of technology in a Vygotskian learning environment (Couse & Chen, 2010).

Implication for this study	The implication of using Vygotsky's pedagogical theory in this study is imperative when describing how coding and robotics can be integrated with specific mathematical concepts. The integration of these needs to be substantiated by evidence of theories of how learners learn and, most importantly, how teachers support learners' learning.

Vygotsky (1978) focuses on the learner-in-context. Vygotsky (1978) explains 'context' as the culture of a young learner and how they represent their culture. According to

[9] Scaffolding occurs when a teacher determines what a learner knows and can accomplish, and then gives the necessary assistance so that the learner can attain the learning objective (Stach & Veldsman, 2021).

Vygotsky (1978), seeing child development in isolation from cultural context distorts our understanding of development and frequently leads us to attribute the origins of a learner's behaviour to the child rather than to their culture (Falikman, 2021).

Kirova and Jamison (2018) used Vygotsky's sociocultural theory lens to study young learners' use of iPads. In their study, the learning of these learners was investigated as it took place through interactions with others, as well as the use of iPads and other technology in the learning environment. The learners received iPads and instructions on how to take photographs and videos, and then produced digital literacy texts. The teachers and more knowledgeable peers offered scaffolding. The study's findings highlight the value of scaffolding and allowing learners to work within their own ZPDs (ibid.).

2.3.1.2 Grand theorist of play: Jean Piaget

Doherty and Hughes (2014) posit that Jean Piaget is, without a doubt, the theorist who has had the most impact on child development research and, as a result, has significantly influenced many of the current teaching methods in early learning centres (ELCs). The cognitive developmental theory of Piaget focuses on how children adapt to their surroundings (Piaget, 1951). Piaget's career started when he noticed that learners of certain ages would provide similar wrong answers in intelligence tests and this became the research question that grounded his life's work (Mooney, 2013).

Berk (2001 cited in Slavin, 2006) outlines Piaget's cognitive development theory in four imperative stances.

First of all, the process of learners' thinking is highlighted rather than just the outcomes (Piaget, 1951). Together with evaluating the accuracy of the responses, teachers must be aware of the processes learners received to arrive at their conclusions. A teacher can only provide appropriate learning experiences if they are aware of how their learners learn and how to develop on their current level of cognitive functioning.

Secondly, the importance of learners' self-initiated, active engagement in learning activities should also be acknowledged by teachers. In a Piagetian learning environment, the presentation of pre-made knowledge is minimised, and learners are urged to learn on their own through spontaneous engagement with their surroundings (Piaget, 1951). Owing to this, teachers offer a wide range of activities that let learners take direct action in the real world rather than instructing in a didactic manner.

Thirdly, learners should be taught through practices that enhance true cognitive comprehension according to their level of development, rather than to expect learners to perform based on levels determined by adults who wish to speed up a child's development (Piaget, 1951; May & Kundert, 1997).

Last but not least, while at various paces, all learners experience the same developing process (Piaget, 1951; Berk, 2018). As a result, teachers must put out extra effort to develop activities for individuals and small groups of learners rather than the entire class. Furthermore, rather than using normative standards established by peers' performance, assessments of learners' educational progress should be made in terms of each learner's unique prior developmental route because individual variations are to be expected.

The adaptation and variation of teaching to the learner's stage of development is a critical implication of Piaget's theory (Kilag, Ignacio, Lumando, Alvez, Abendan, Quiñanola & Sasan, 2022). The instructional topic must be consistent and relevant to the learner's developmental stage (ibid.). Teachers in science, mathematics, and technology (STM) LEs must optimise learning by enabling learners to learn from a range of situations, including discovery learning. When learners are given opportunities to explore and experiment, they develop new understandings that make learning real and permanent (Awofala, Akinoso, Olabiyi & Ojo, 2022; Kilag *et al.*, 2022). STM teachers should also foster cooperative learning among learners (Awofala *et al.*, 2022). Allowing learners of different cognitive levels to create a team and work together frequently motivates and inspires learners who are less mature in their knowledge to progress to a more advanced level of learning and comprehension (Kilag *et al.*, 2022). Another key aspect of Piaget's theory is the use of concrete hands-on experiences to help learners understand basic concepts (Awofala, Akinoso, Olabiyi & Ojo, 2022; Kilag *et al.*, 2022). An unwavering premise is that in STM LEs, teachers should assist learners in progressively transitioning from the physical and concrete to more abstract and nonfigurative modes of mind (Awofala *et al.*, 2022). As a result, Piaget's theory of intellectual advancement assists STM teachers in appreciating learners' intellectual growth as they construct phase-appropriate activities to boost learners' learning of STM (Awofala *et al.*, 2022).

2.3.1.3 International best practices: Maria Montessori

Maria Montessori's opportunity to work with children came in 1907 when she opened her first children's home, called *Casa dei Bambini*, to which children of working parents were invited (Mooney, 2013). She provided these learners with child-sized furniture and tools that she mostly made herself, and she encouraged the learners to work independently (ibid.). Montessori's beliefs on child development are unique and well-established, and they are frequently used as a foundation to enrich other educational approaches (Aljabreen, 2020). According to the philosophical foundation of the Montessori approach, teachers must provide learning opportunities that are learner-centred (Isaacs, 2018) and that advance learners' developmental potential to higher levels (Aljabreen, 2020), which necessitates Montessori teachers taking on a guidance role (Atli, Korkmaz, Tastepe & Koksal Akyol, 2016). Furthermore, Isaacs (2018) emphasises that Montessori teachers should have detailed knowledge of learners' interests and learning styles and should use a wide range of resources.

In all Montessori LEs, observation is the primary tool of the teacher's assessment, and it is critical in ensuring that each learner has a variety of learning experiences (Isaacs, 2018). Teachers must adhere to basic principles in order for a school to be considered Montessori-inspired (Montessori, 2012). These principles are that the teacher or other role player should have respect for the learner, be aware that learners can acquire knowledge independently, and that the resources and materials must be child-centred (Morrison, 2010; Van Heerden & Du Preez, 2021). In light of the context of this study, it is also important to discuss how Montessori ELEs use technology. Powell (2016) and Jones (2017) suggest that since technology has become so pervasive in our lives, some academics and teachers are advocating for its inclusion in Montessori ELEs as a means of providing more real and meaningful learning experiences. Nevertheless, despite this endeavour, little research has been done on how technology is used in the Montessori ELE (Jones, 2017). Powell (2016:156) emphasises that Maria

Montessori encourages individuals to “give the world to the young child” and that technology, when used in ways that are compatible with a learner's developmental needs, can assist in bringing the world to the young child.

2.3.1.4 International best practices: Reggio Emilia

The Reggio Emilia approach is an extension of Loris Malaguzzi’s theory (Malaguzzi, 1998) but it has also integrated the perspectives of theorists, such as Lev Vygotsky and Jean Piaget (Edwards, Gandini & Nimmo, 2015; Aljabreen, 2020). Reggio Emilia's high-quality experiences for young learners are founded on a set of core ideals that have evolved through time to represent what the Reggio Emilia community believes is vital for young learners and their families (Murris, Reynolds & Peers, 2018). The Reggio approach emphasises the importance of the environment in supporting learners’ development, play, and learning by referring to the environment as “the third teacher” (Aljabreen, 2020:345; Gantt, 2021:2). The approach also values a powerful image of the child since learners are seen as strong, confident, and competent (McNally & Slutsky, 2017). The relationships between the learners, the teachers and the parents are all equally important, with an emphasis on parents and families becoming part of the learning process (ibid.). Lastly, the approach understands how learners acquire knowledge individually as well as in groups by providing adequate time for projects and reflective teacher practices (ibid.).

Reggio Emilia teachers collaborate in pairs to plan and assist the learners while they play and work in groups (ibid.). The teacher stays with the learner from the moment they enter the Reggio school until they leave, which enables the teacher to form deep bonds with the learners and their families (Thornton & Brunton, 2010). Reggio has the belief that the teacher's role is not just teaching but also learning. Personnel take responsibility for their own professional progress and learn with colleagues, workshop workers, pedagogues, and parents through conversations and debates (McNally & Slutsky, 2017). During the day, the teachers discuss observations with each other, look at the documentation and begin to understand what they saw (ibid.). Thinking about these observations and interpretations enables them to determine what possibilities and resources they will provide to the learners the next day (ibid.).

Outside interests of learners and the introduction of new technology are included rather than overlooked or avoided in the Reggio approach's emergent curricula since learners need to “participate in constructing a new culture of education” (Gandini, 2015:7). As Malaguzzi advocated in Gandini (2015), ELCs is constantly in need of new equipment, proper architecture, and larger rooms; it cannot risk falling behind.

In addition to the aforementioned characteristics, Reggio Emilia teachers believe that learners have the right to express themselves in whatever way they see fit (ibid.). Multimodality is regarded as an essential aspect of learning and communication in Reggio Emilia. Learners are acknowledged as capable and competent communicators who use multiple languages, including verbal, nonverbal, and artistic forms of expression, in this method (Brandao & Theodotou, 2020). Multimodal communication acknowledges that various modes of communication can convey different meanings and that each learner has their own unique method of expressing themselves. Reggio Emilia teachers endeavour to create LEs that support and encourage learners' diverse modes of expression, allowing them to explore and experiment with various materials and media (ibid.). Reggio Emilia teachers can support learners’ development of multiple literacies and create rich, engaging learning experiences that enable learners to express themselves in meaningful ways by embracing multimodality (ibid.). Multimodality is referred to as ‘learners’ 100 languages’ in the Reggio Emilia context, and as a result, DT is seen as just another means for young learners to express themselves. Some of the DT included in the Reggio Emilia ELE comprises smart boards, digital cameras, scanners, and networked computers, which are used to explore and widen the range of interactions between the traditional materials and DT (Schwall, 2015).

I did my best to identify literature that supports the use of playful coding and robotics in Reggio Emilia LEs. Despite my attempts, I noticed a dearth of literature in this field. While some studies address the use of technology in Reggio Emilia classrooms, very few explicitly address the use of playful coding and robots. As a result, drawing definitive conclusions about the efficacy of using these technologies in Reggio Emilia LEs is difficult. To better understand how these technologies can be used to improve ECE, more research is needed to investigate the potential benefits and drawbacks of integrating playful coding and robotics into Reggio Emilia LEs.

2.3.1.5 Using the pedagogical theories and international best practices as a foundation in this study

Since teachers play a key role as catalysts for learning, they need to have deep knowledge and an awareness of how to encourage learning in their LEs (Pritchard, 2009). This means that teachers need to be aware of the current and most significant teaching theories and how these may be implemented (ibid.). Table 2.2 provides a summary of the theoretical stances and pedagogical practices mentioned above by explaining the relevance and implication thereof to this study.

While acknowledging the existence of numerous other theories yet to be explored and understood, this study deliberately concentrated on a select group of grand theorists and best practices that pertain specifically to play-based teaching. Within this particular context, play was viewed as a means to establish a connection between coding and robotics as well as mathematical concepts. Consequently, the study aimed to gain insights into the role of teachers in ECE concerning the implementation and facilitation of play-based activities with specific focus on the integration of coding and robotics with mathematical concepts. To put this in simple terms, the focus was on supporting teachers to effectively harness the power of play to support the integration of coding and robotics with mathematical concepts in ECE settings.

Table 2.2: Theoretical underpinning of this study

Categories of theories	Theorist and theory	Relevance to the study	Integrating coding and robotics with numbers, operations and relationships
Grand theories			
The sociocultural theory emphasises a learner's social engagement with individuals, such as parents, teachers, or peers, to acquire key values and skills (Doherty & Hughes, 2014).	**Vygotsky's ZPD** (Vygotsky, 1978)	The teacher extends learners' learning by presenting a task that is slightly more challenging than the current task. The area between what the learner can do and what the learner still needs to master is referred to as the ZPD (Vygotsky, 1978).	By presenting activities that lie within the ZPD, teachers encourage learners to actively engage in problem-solving, critical thinking, and the integration of mathematical concepts with coding and robotics. This approach promotes meaningful learning experiences, as learners are motivated to stretch their abilities and bridge the gap between their existing knowledge and the skills they need to master. Teachers can employ strategies such as providing scaffolding support, offering relevant resources and materials, , and encouraging reflection.
Cognitive development theories seek to explain how learners develop intellectually.	**Piaget's stages of cognitive development**	The emphasis is on the process of learners' thinking rather than the outcomes. Teachers encourage learners to initiate activities as well as actively participate in them. Furthermore, the teacher facilitates learning according to the developmental levels of the learners and provides support to individual learners.	Piaget's theory focuses on the environment that teachers need to set up when integrating coding and robotics with specific mathematical concepts. Teachers should encourage learners to explore and discover by providing them with various resources. Teachers also take on the role to support learners according to their developmental levels.
Best practices			
Combines aspects of different theories regarding child development.	**Maria Montessori**	The Montessori method is characterised by: individualised teaching, child-directed activities, activities based on learners' developmental levels, and the importance of kinaesthetic learning (Doherty & Hughes, 2014; Van Heerden & Du Preez, 2021).	Teachers must provide learning opportunities that are learner-centred, using a wide range of resources, and encouraging kinaesthetic learning opportunities. Furthermore, technology should be used to complement teaching and learning.
Constructivism (Aljabreen, 2020)	**Reggio Emilia**	This practice focuses on a learner-centred self-guided curriculum that emphasises learners' self-directed and experiential learning in natural settings (Van Heerden & Du Preez, 2021).	The teacher should organise points of learning by integrating coding and robotics with mathematical concepts. Furthermore, the teacher should use a variety of resources, observe learners' learning and encourage learners to learn from one another.

As indicated in Table 2.2, in a Vygotskian ELE, the teacher must plan learning opportunities that incorporate not just what learners can do on their own, but also what they cannot do independently. The teacher can successfully implement this by planning play-based activities within learners' ZPD. In a Piagetian ELE, teachers should offer the learners activities that allow learners to interact directly with the physical environment and should be based on the developmental level of the learner. Montessori practices require teachers to provide learning opportunities that are learner-centred and should advance learners' developmental potential to higher levels. According to the Montessori approach, the teacher should prepare, as well as direct, learning opportunities and use a wide range of resources. Lastly, the Reggio Emilio approach indicates that it is the teacher's responsibility to organise the starting points for learning opportunities and to provide open-ended resources for learners to explore and build their own thinking and learning experiences (Thornton & Brunton, 2010). This practice states that teachers should observe learners' learning and encourage learners to learn from one another.

Implication for this study

These theoretical stances and practices were summarised and provided to the participants of this study in the TCB. Teachers were urged to become acquainted with the material offered in order to identify which theories and/or practises had influenced their instruction. Nevertheless, the objective of this study was not to equip teachers with an in-depth understanding of the constructs of these theories and enable them to directly implement them. Instead, the aim was to emphasise the fundamental notion that all play-based teaching practices are grounded in theory.

CK

2.3.2 Content knowledge

The next section discusses different domains of content knowledge required by teachers as indicated by Ball, Thames and Phelps (2008).

1. The first domain is called **common content knowledge** (CCK), which refers to the mathematical knowledge and skills used in various settings other than teaching. Teachers need to be familiar with the material they teach, recognise incorrect answers from learners, and use appropriate terminology and notation. As an example, Grade R teachers need to be familiar with the CCK of numbers, operations and relationships.

2. The concept of "**horizon knowledge**" refers to the awareness of how mathematical topics relate across different grade levels. It involves understanding the progression of mathematical ideas in the curriculum, allowing teachers to build a solid foundation for future learning and recognise connections between concepts. For example, Grade R teachers should know how and why there is a need to lay the foundation for counting in Grade R in order to prepare for formal schooling.
3. The third domain is **specialised content knowledge** (SCK), which is unique to teaching. It involves a deeper understanding of mathematics that is specifically needed for teaching tasks, such as analysing learners' errors and determining effective teaching approaches. Teachers must possess unpacked mathematical knowledge that allows them to make the content visible and learnable for learners. For example, teachers should know and be able to implement specific steps for teaching learners counting.
4. **Knowledge of content and students** (KCS) is a combination of understanding learners' thinking and mathematical content. Teachers need to anticipate learners' misconceptions, predict their interests and motivations, and interpret their incomplete thoughts. This knowledge involves familiarity with common learner conceptions and misconceptions about specific mathematical concepts. As an example, Grade R teachers should understand how and why learners might not be able to count to 10.
5. **Knowledge of content and teaching** (KCT) combines knowledge of teaching strategies with mathematical understanding. Teachers need to make instructional decisions, sequence content, select appropriate examples, and evaluate different instructional methods. This domain requires an interaction between mathematical knowledge and pedagogical expertise. For example, Grade R teachers should be able to teach learners how to count when they need support.
6. **Knowledge of content and curriculum** encapsulates subject matter knowledge (SMK) and curriculum. SMK encompasses understanding mathematical concepts, facts, and syntactic aspects. It emphasises the influence of SMK on learners' mathematical understanding and achievement. As an example, Grade R teachers should know why and how certain Grade R mathematical content areas are included in CAPS.

The domain used in this study is KCS. This domain includes a comprehensive understanding of learners' specific mathematical competencies. The study focused on the integration of coding and robotics with mathematical concepts, specifically targeting pre-developed concepts. To effectively accomplish this integration, teachers were required to possess an understanding of learners' competencies in relation to mathematical concepts, therefore, teachers in this study were not expected to use CK related to teaching.

The Curriculum and Assessment Policy Statement (CAPS) is South Africa's current curriculum framework for education. It establishes a comprehensive and consistent strategy for what learners should learn and how they should be assessed (DBE, 2011b). CAPS emphasises the value of learner-centred education, in which learners actively participate in the learning process and teachers facilitate learning through a range of methods (DBE, 2011b). The policy statement contains guidelines for teaching and learning, assessment, and progression in each subject area, which includes language, mathematics, social sciences, natural sciences, technology, and the arts (DBE, 2011b; Ajani, 2021). Furthermore, CAPS stresses the significance of incorporating 21st-century skills into the curriculum, such as critical thinking, problem-solving, creativity, and collaboration. CAPS emphasises the importance of ongoing assessment, which enables teachers to monitor learner development and to adjust their teaching accordingly (DBE, 2011b; Ajani, 2021). CAPS, in general, offers a framework for quality education that promotes learners' holistic growth and prepares them for lifelong learning and active citizenship (DBE, 2011b; Ajani, 2021).

2.3.2.1 Grade R mathematical concepts

CAPS explains mathematics as a way to describe numerical, geometric and pictorial relationships using symbols and notations (DBE, 2011b). Furthermore, it is defined as an activity in which patterns and quality relationships are seen, represented, and examined (ibid.). In the Grade R context, mathematics is divided into five content areas namely numbers, operations, and relationships; patterns, functions, and algebra; space and shape; measurement; and data handling. In the next section, each of these content areas is briefly elucidated as described by the DBE (2011b) and Naudé (2021).

1. **Numbers, operations, and relationships**: Learners further develop the specific content focus of this area when they work with physical items to count collections of objects, solve contextual challenges, and build up and break down numbers.
2. **Patterns, functions, and algebra**: The learner's ability to attain effective manipulative abilities in the usage of algebra is one key component of this content area. It also emphasises the use of symbolic expressions, graphs, and tables to describe patterns and relationships, as well as the detection and analysis of regularities and changes in patterns and relationships that allow learners to make predictions and solve issues.
3. **Space and shape**: The study of space and shape increases one's awareness and enjoyment of natural and cultural patterns, accuracy, achievement, and beauty. It focuses on two-dimensional forms and three-dimensional objects' attributes, relationships, orientations, locations, and transformations.
4. **Measurement**: The selection and use of suitable units, tools, and equations to quantify properties of events, forms, objects, and the environment is the focus of measurement. It is directly related to the learner's scientific, technological, and economic worlds, allowing learners to make reasonable estimations and be aware of measurement and outcome reasonableness.
5. **Data handling**: The learner gains the ability to gather, organise, present, analyse, and understand data through the study of data handling.

Each of the aforementioned content areas contributes to the development of specific knowledge and skills in mathematics, however, it is essential that the content area of numbers, operations, and relationships is the "main focus of mathematics" in Grades R–3 as advocated by the DBE (2011b:10). This is the reason I opted to conduct my research in this content area. Learners must complete the FP with a solid understanding of numbers and operational fluency. As a result, the amount of notational time assigned to this content area is proportionally the greatest (ibid.).

In this content area, the main focus is on developing learners' number concept. Number concept development encompasses the fundamental logical foundations that underpin learners' quantitative reasoning abilities and their overall understanding of numbers (DBE, 2009; DBE, 2011b; Nunes, Bryant, Barros & Sylva, 2012; Mayes & Myers, 2014; Mntunjani, 2015; Van den Heuwel-Panhuizen & Elia, 2020). These foundations can be categorised into three key aspects: correspondence, additive reasoning, and inverse relations between operations (DBE, 2009; Nunes *et al*., 2012; Van den Heuwel-Panhuizen & Elia, 2020). These aspects play crucial roles in shaping learners' conceptual understanding of numbers and their ability to reason with quantities (DBE, 2009; DBE, 2011b; Nunes *et al*., 2012; Mntunjani, 2015; Van den Heuwel-Panhuizen & Elia, 2020).

CAPS provides a detailed overview of the progression of concepts and skills that Grade R learners need to master in each term of the year. According to this progression, Grade R learners are expected to count concrete objects; recognise, identify, and read numbers; describe, compare, and order a collection of objects up to ten; use ordinal numbers to show order, place or position; and solve problems in context (DBE, 2011b). To emphasise once again, it is important to note that the teaching of skills in this specific content area encompasses a distinct realm that pertains to how learners acquire these skills. However, it is crucial to clarify that this present study solely concentrated on the using pre-existing skills in this content area with coding and robotics. The knowledge and skills are presented in detail in Table 2.3 and are imperative in the context of this study since it provides an overview of all the topics in this mathematical content area.

Table 2.3: Numbers, operations, and relationships content area

TOPIC	ACTIVITIES
Counting objects	Estimate and count to at least ten.
Counting forwards and backwards	Count forwards and backwards in ones from one to ten. Use number rhymes and songs. Say and use number names in a familiar context.
Number symbols and number names	Recognise, identify, and read number symbols and names from one to ten.
Describe, compare, and order numbers	Describe whole numbers up to ten. Compare two objects by using mathematical vocabulary: big, small, smaller than, greater than, more than, less than, equal to, most, least, and fewer. [up to ten] Order more than two given collections of objects from smallest to greatest up to ten. Develop an awareness of ordinal numbers, such as first, second, third, up to sixth as well as last.
Problem-solving techniques	Compare apparatus, such as counters, up to ten.
Addition and subtraction	Solve word problems (story sums) in context and explain own solutions to problems involving addition and subtraction with answers up to ten. Solve verbally-stated addition and subtraction problems with solutions up to ten.
Grouping and sharing leading to division	Solve and explain solutions to word problems in a context that involve equal sharing, grouping with whole numbers up to ten and answers that may include remainders.
Money	Develop an awareness of South African coins and banknotes.
Mental mathematics	Counting everyday objects. Counting forwards and backwards. Ordinal counting.

Adapted from the DBE (2011b)

TK

2.3.3 Technological knowledge

We live in a social environment where the digital age has changed communication and literacy habits (Marsh, 2020). With this in mind, the following section reviews the literature pertaining to the skills necessary for citizens in the 21st century, as well as aspects of DL. It also explores 21st-century teaching, particularly the use of coding and robotics in ELEs.

2.3.3.1 21st-century skills

Many initiatives have provided definitions and frameworks for 21st-century skills over the past few years. These definitions highlight the significance of 21st-century skills for both individuals and for society as a whole (Siddiq, Gochyyev & Wilson, 2017). This section views the plethora of definitions by also identifying the components that constitute them. The OECD (2009) defines 21st-century skills as the abilities and competencies that young individuals have to acquire in order to be productive employees and citizens in the 21st century (Ananiadou & Claro, 2009). Siddiq *et al*. (2017) and Van Laar, Van Deursen, Van Dijk and De Haan (2017) adopt the same definition by describing 21st-century skills as the competencies that young individuals need to function effectively in the 21st century. Nevertheless, The American Association of Colleges of Teacher Education and the Partnership for 21st Century Skills (2010) uses somewhat different terminology, defining 21st-century skills as a combination of information, knowledge, particular skills, expertise, and literacies that learners must master to excel in work and life. The Assessment and Teaching of 21st Century Skills (ATC21S) initiative adopts the same stance and suggests that 21st-century skills are grounded by knowledge, skills, attitudes, values, and ethics (Binkley, Erstad, Herman, Raizen, Ripley, Miller-Ricci & Rumble, 2012).

Despite the fact that definitions of 21st-century skills vary slightly, Voogt and Roblin's (2012) review of eight 21st century skills frameworks revealed that collaboration, communication, DL, citizenship, problem-solving, critical thinking, creativity, and productivity are mentioned in most of the frameworks. The authors also argue that, in general, most 21st-century skills frameworks are consistent with one another (ibid.). The study adopts this definition of Voogt and Roblin (2012) of 21st-century skills. Another important 21st-century skill is computational thinking skills, which are discussed in the next section.

2.3.3.2 Computational thinking skills

The development of computational thinking in young learners has become an essential requirement in education (Ching & Hsu, 2023). Papert (1980:6), a pioneer in advocating for involving young children in computer programming, suggested that "learning to communicate with a computer may change the way other learning takes place". Papert (1980) envisioned the creation of computing devices that would allow young learners to command and communicate using their mathematical knowledge and skills. He believed that when children could use mathematics to communicate with a computer, they would find mathematics learning more tangible and natural.

In recent years, computational thinking has been recognised not only as a crucial skill for thriving in the 21st-century (National Research Council, 2010), but also as an essential analytical ability that should be developed in every child from a young age (Wing, 2006). Computational thinking involves skills such as problem decomposition, pattern recognition, abstraction, algorithmic thinking, solution testing and debugging (Bocconi, Chioccariello, Dettori, Ferrari & Engelhardt, 2016; Bers, 2018; Hunsaker, 2018; Varela, Rebollar, García, Bravo & Bilbao, 2019; Jaiswal, Arun & Varma, 2022; Ching & Hsu, 2023).

Various computational thinking frameworks have been developed for different purposes and learning contexts. Two frameworks are particularly relevant for Grade R learners (Ching & Hsu, 2023).

The first framework, created by the International Society for Technology in Education and the Computer Science Teachers Association (2011), provides an operational definition of computational thinking as a problem-solving process that includes formulating problems, organising and analysing data, representing data through abstractions, automating solutions through algorithmic thinking, implementing possible solutions, and generalising and transferring the problem-solving process.

The second framework, developed by Brennan and Resnick (2012), defines three critical dimensions of computational thinking and their elements: concepts, practices, and perspectives. These frameworks complement each other, with the ISTE/CSTA (2011) framework focusing on the macro level of the problem-solving process and Brennan and Resnick's (2012) framework specifying the concepts, practices, and perspectives used in problem-solving with programming.

As research on computational thinking has advanced, several literature reviews have been conducted (Hsu, Chang & Hung, 2018; Merino-Armero, González-Calero & Cózar-Gutiérrez, 2022; Ching & Hsu, 2023) and have found that computational thinking has primarily been developed through on-screen programming activities using computers. However, programming on-screen can be challenging for younger learners who may lack reading, writing, typing skills, or fine-motor abilities to operate a computer mouse or trackpad (Kazakoff & Bers, 2012).

Educational robotics is a promising approach for computational thinking development, particularly for young learners from early childhood to Grade 6 (Bers, González-González & Armas-Torres, 2019). Research has demonstrated that educational robotics supports learners in various aspects of their learning. It enhances their cognitive understanding of STEM knowledge and problem-solving skills, fosters soft skills such as teamwork and social interaction, and influences their attitudes and interests in STEM subjects and careers (Hunsaker, 2018; Varela *et al.*, 2019). The presence of robots in educational robotics activities serves as manipulatives that offer immediate feedback, enabling learners to grasp abstract concepts and problem-solving processes more effectively (Ching & Hsu, 2023). As a result, learning becomes more hands-on, tangible, and interactive (Bers *et al*., 2019; Chevalier *et al*., 2020).

The increasing availability of robotics kits that are appropriate for different ages and developmental stages has made computational thinking development through programming robots more accessible to young learners who may lack the necessary reading, writing, and typing skills to create codes for commanding robot movements (Kazakoff & Bers, 2012). However, it remains unclear which computational thinking skills can be effectively developed through robotics activities in diverse learning settings (Ching & Hsu, 2023). Additionally, there is a need to understand how robotics kits with varying features can cater to the diverse developmental abilities of young learners (ibid.).

The adoption of educational robotics has gained momentum in creating collaborative, interactive, and engaging learning environments for Grades R-12 learners to develop their computational thinking skills (Ching & Hsu, 2023). It is crucial to select developmentally appropriate robotics kits for young learners to ensure successful learning experiences (Bers *et al*., 2019). Some reviewed studies have highlighted the challenges associated with the hardware and software of robotics kits, which have caused frustration and consumed valuable time that could have been spent on collaborative and interactive computational thinking tasks (Bers *et al*., 2019). Based on this review, it is recommended that very young learners, ranging from pre-Grade R to Grade 2, use robotics kits with simple robots that offer limited functionality and feature screen-free programming environments (Ching & Hsu, 2023). These kits should employ methods such as pushing buttons or arranging physical programming manipulatives to create codes (Ching & Hsu, 2023). For this reason, this study included the use of the Bee-Bot.

2.3.3.3 Digital literacy

The term 'digital literacy' (DL) is at the centre of 21st-century skills (Hannaway, 2016). Gilster (1997:1) defines DL as the ability to comprehend and utilise information delivered through computers in a variety of formats from a variety of sources. Since this definition was constructed when the internet was still at a novel stage, the original *Digital Literacy* released by Gilster (1997) has since become a widely studied and debated work. DL, according to the Department of eLearning of Malta (2015) and Spires, Medlock Paul and Kerkhoff (2018), refers to when an individual is literate in the use of technology in order to consume and create digital compositions in the same manner that literate humans may negotiate print material through the processes of reading and writing.

In his thesis, '*What is digital literacy'?*, Belshaw (2012) disputed the term DL in particular. As a result, in the author's study, DL refers to the qualities that an individual possesses in order to teach and/or learn in the digital age. The author (Belshaw, 2012), furthermore, believes that concerns surrounding digital literacies (DLs) are real-world, everyday difficulties that affect individuals, organisations, and communities all around the world. Hannaway (2016) concurs with the previous and argues that in order to function literately, individuals must change their mindset and accept DL as a new language including novel mental processes, novel media, and innovative technology.

When considering the integration of coding and robotics with numbers, operations, and relationships in Grade R, the characteristics of DL outlined by Belshaw (2012) become relevant. These eight fundamental characteristics of DL are cultural, cognitive, constructive, communicative, confident, creative, critical, and civic, which are addressed and briefly specifically in relation to the integration of coding and robotics in Grade R education.

Cultural: In Grade R, learners are exposed to a variety of digital contexts (Hannaway, 2016), including coding and robotics. These technological advancements redefine literacy in society, and it is crucial to immerse learners in a diverse range of digital tools and experiences to develop their cultural understanding of coding and robotics (Hannon, 2000; Belshaw, 2012).

Cognitive: Johnson (2008:42) notes that DL is "the ability to use a set of cognitive tools" rather than a capacity to use a collection of technical tools. For this reason, in Grade R, learners should be encouraged to develop their thinking skills and engage with digital spaces to enhance their cognitive understanding of coding and robotics with mathematical concepts (Belshaw, 2012).

Constructive: In the digital age, the constructive component of DL is focused on creating something unique (Hannaway, 2016) by understanding how and for what purposes content may be appropriated, repurposed, and altered (Belshaw, 2012). In the context of coding and robotics in Grade R, learners are encouraged to explore how numbers, operations, and relationships can be used creatively in their coding projects, fostering their constructive abilities.

Communicative: The communicative part of DL, according to Belshaw (2012) and Hannaway (2016), is the foundation of how to communicate in digitally-networked contexts. In Grade R, learners develop their communication skills by using the correct terminology related to coding, robotics, numbers, operations, and relationships. This allows them to effectively express their ideas and collaborate with others.

Confident: The confident part of DL, according to Belshaw (2012) and Hannaway (2016), comprises confidence based on the notion that, in contrast to our physical surroundings, the digital world can be more forgiving in terms of experimenting. In the context of coding and robotics in Grade R, learners are encouraged to take risks, explore different approaches to problem-solving, and adapt their coding and robotics projects based on the use of numbers, operations, and relationships.

Creative: Performing new things in new ways is a creative aspect of DL (Hannaway, 2016). According to Conlon and Simpson (2003), the existing culture of rigid curriculum, repetitive routines, and strict outcomes should be substituted with teachers who are ready to take chances and use technology in a creative manner. In Grade R, teachers play a vital role in fostering creativity by embracing technology and using coding and robotics as tools for creative expression with mathematical concepts.

Critical: The critical part of DL is reflecting critically on diverse literacy practices, which, therefore, entails the reflection upon literacy practices in multiple “semiotic domains" within the digital world (Belshaw, 2012:213). In Grade R, learners are encouraged to critically analyse their coding and robotics activities, evaluate the effectiveness of their solutions, and reflect on the use of numbers, operations, and relationships in their coding and robotics endeavours.

Civic: The civic component of DL is discovered as a consequence of new technology and tools as a result of literacy practices (Hannaway, 2016). In the context of coding and robotics in Grade R, both teachers and learners develop an understanding of the civic implications of technology and its impact on society, fostering responsible and ethical use of technology.

By considering these DL characteristics, Grade R teachers can effectively support the integration of coding and robotics with numbers, operations, and relationships, creating a rich learning environment that promotes digital literacy and mathematical understanding.

Regarding the integration of the previous eight elements for DL, Belshaw (2012:90) states the following:

"Literacies involve the mastery of simple cognitive and practical skills. To be 'literate' is only meaningful within a social context and involves having access to the cultural, economic and political structures of a society. In addition to providing the means and skills to deal with written texts, literacies bring about a transformation in human thinking capacities. This intellectual empowerment happens as a result of new cognitive tools (e.g. writing) or technical instruments (e.g. digital technologies)."

Although there is no universally agreed-upon definition or demarcation of DL, the previous section attempts to clarify and account for the knowledge and abilities necessary to perform as a digitally literate individual. This study adopted the definition of DL by Hannaway (2016) to explain it as the knowledge, skills, and values that should be used to communicate, produce, and create in digital spaces within a range of scenarios. Although this study did not explore how coding and robotics develop DL, it still provides an overview of the skills and competencies needed.

2.3.3.4 21st-century teaching skills

No nation advances beyond the quality of its educational system, which is highly dependent on the quality of its teachers (Boaduo FRC, Milondzo & Gumbi, 2011). These authors believe that during their training, teachers should be provided with the most suitable tools, including CK and abilities, so that they can perform to the best of their abilities. Teachers are expected to grasp and comprehend the characteristics of the 21st-century learner, including features of PK and CK of subjects that they would teach the learners, under the new teacher education and training programme for the 21st-century (ibid.). Language, culture, and tradition would be included in community settings, as would technology in the broadest sense (Darling-Hammond, 2006). Furthermore, the teacher of the 21st-century must understand learners and discover a method to foster their skills (Boaduo FRC *et al.*, 2011). Teachers would also need the knowledge and abilities to build and manage their teaching and learning activities, communicate effectively, use technology efficiently, and reflect on their practices in order to stay current on educational innovations (ibid.).

Implication for this study

The literature reviewed reveals that the development of participating teachers' 21st-century teaching skills is also promoted in the setting of this study, where technology, and more especially coding and robots, play a major role. The nature of the PAR designed for this study endeavoured to support teachers in this development process through their sharing of insights from their own practices and experiences with other teachers. This supported the development of the teaching framework in the study.

2.3.3.5 Coding

The process of 'assigning codes' that allows a machine or a person to act or move is referred to as coding (McLennan, 2017; Lee & Junho, 2019). Due to the quick development of technology, learners are exposed to more automated systems based on code in their daily lives, which naturally piques their interest in how things function or operate automatically (Lee & Junho, 2019). In a digital society, coding is a relatively new literacy that has become a crucial tool for reading, analysing data, and connecting with others (Bers, 2018; Lee & Junho, 2019). To adapt to a changing world, EC teachers in the 21st century must be able to teach this new literacy of coding in the early years (Campbell & Walsh, 2017) and, therefore, it is the role of the teacher to make an informed judgement about how to use technology in a developmentally-appropriate way (Lee & Junho, 2019). Young learners learn efficiently through play in engaging learning contexts by interacting with resources and with others, as has been widely theorised and verified (Fleer, 2013; Johnson, 2015; Conkbayir & Pascal, 2016). Coding helps learners to communicate, debate, argue, solve problems, move, make decisions, and follow rules in the same manner as when they play (Bers, 2018; Lee & Junho, 2019).

For learners, and especially teachers, it is imperative to use and understand different coding terms during activities that develop coding skills. Lee and Junho (2019) mention eight important terms, namely, coding, algorithm, loop, ordinal words, directional words, directional arrows, debugging, and a coding sheet. The above-mentioned terms are briefly elucidated in the following section.

Coding is the process of identifying and labelling each step that is needed to complete a task (Gadzikowski, 2018; Lee & Junho, 2019). For example, the learners can be asked to indicate each step of brushing their teeth.

Algorithms are steps that are provided in sequence to complete a task (Gadzikowski, 2018; Lee & Junho, 2019). For example, each step in the process of brushing teeth can be given in the correct sequence.

A loop occurs when the algorithm is repeated continuously or when the task has been completed (Gadzikowski, 2018; Lee & Junho, 2019). For example, learners can be asked to brush their teeth a certain number of times.

Ordinal words present the position or rank of a step in a sequence. For example, learners can be asked to use ordinal words to explain which step is first, second, and so forth. This early coding term can be combined with numbers, operations, and relationships because one of the skills that Grade R learners should acquire is to develop an awareness of ordinal numbers (DBE, 2011b).

Directional words indicate the direction in which an action takes place. For example, learners can be asked how they brush their teeth: they brush left, right, front, back, and so forth.

Directional arrows are arrows that indicate direction. For example, learners can be asked to indicate the way to go to the bathroom.

Debugging involves removing unnecessary steps to complete a task (Gadzikowski, 2018; Lee & Junho, 2019). For example, learners can be asked to indicate the quickest way to go to the restroom.

A coding sheet is a square grid that is used to place codes. For example, the learners can be asked to indicate on a square grid the path to go to the bathroom.
What is notable about these coding terminologies is that they may be utilised in everyday tasks and do not have to be used only in conjunction with advanced tasks.

McLennan (2017) and Lee and Junho (2019) advocate the use of books to develop learners' coding skills and competencies. Books, such as *The Very Hungry Caterpillar* by Eric Carle and *Three Little Pigs* by Joseph Jacobs are suitable for this since these stories depict events in sequence; this can be used to teach coding to young learners by using pictures and a coding sheet.

Another way to introduce learners to coding is to make use of educational applications. There are various educational applications that can be used to teach learners how to code. In this regard, ScratchJr is noteworthy. ScratchJr focuses on younger learners between the ages of five and seven on mobile platforms (Govind, Relkin & Bers, 2020). In the coding language, visual blocks are employed or bricks are used to form particular logical sequences by dragging and dropping into a workspace, which enables the learner to understand the most important coding principles (ibid.). Another educational application that could be used is Kodable. Kodable is suitable for learners of all ages and each lesson is accompanied by teaching materials, a list of related words and further content (Pila, Aladé, Sheehan, Lauricella & Wartella, 2019). The opportunities for teaching learners coding through daily tasks, books and educational applications are virtually endless and could be investigated by future research in more detail.

Campbell and Walsh (2017), McLennan (2017) and Lee and Junho (2019:714-716) also support the use of "coding stations" to teach coding. These coding stations include coding sheets; directional arrow cards; concrete, representational, and abstract representations; and lastly, writing and drawing materials (Lee & Junho, 2019). In order to assist learners choose a coding sheet based on the difficulty of their tales, Lee and Junho (2019:714) first advise that the teacher should provide multiple sizes and dimensions of coding sheets and directional arrow cards. A learner will select a coding sheet with more dimensions if their tale is more complex. A floor-sized coding mat allows young learners to code kinaesthetically while they walk or crawl over it (ibid.).

Secondly, having appropriate resources in a coding station encourages young learners to develop and code their own stories (ibid.). Resources can be concrete, representational, and/or abstract. The DBE (2011b) mentions that concrete resources include different types of toys and 3D objects, representational resources are photographs of these concrete objects, and abstract representations are letters or symbols as indicated by Wolf (2017). Teachers should choose resources that will pique learners' interests and provide learners with writing and drawing supplies, as well as blank coding sheets, as it is essential to allow learners to develop their own coding stories (ibid.). After the learner has had the opportunity to explore these coding stations, commercialised coding toys can be introduced. These commercialised coding toys provide the learners with opportunities to code and watch the coding toys or robots move in accordance with the algorithm they formulated (ibid.). One of these toys, Cubroid Coding Blocks, is an educational smart toy for building robots out of blocks and for coding programming using a smartphone application (Jung, 2020). The coding application makes it simple to learn the fundamentals of coding using different conditional statements, such as repeated and sequential statements (ibid.). Figure 2.3 is a visual presentation of Cubroid Coding Blocks. The packaging and coding blocks are depicted on the left side of Figure 2.3. In the image on the right, the learners are constructing a flashlight out of these blocks, which also include a light block that they had to code to turn on according to the application.

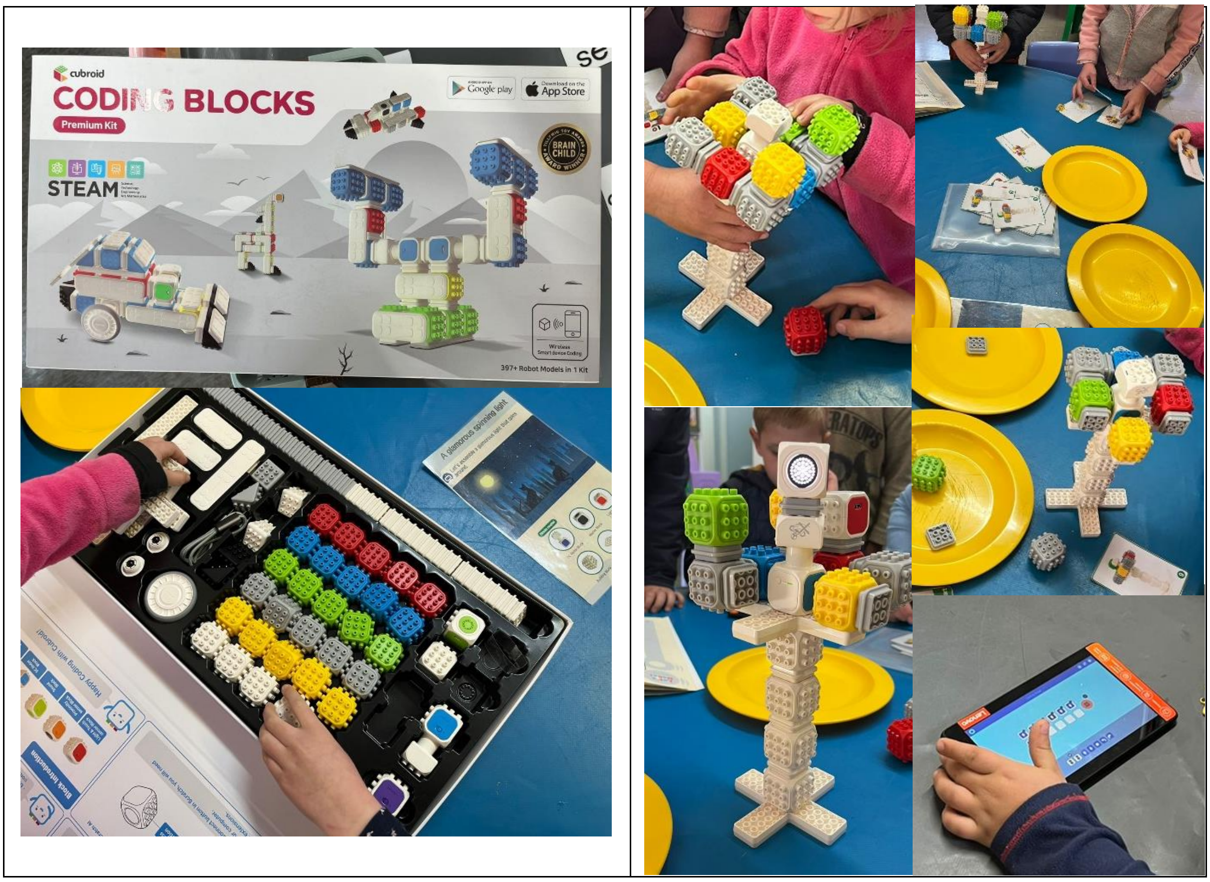


Figure 2.3: Cubroid Coding Blocks

2.3.3.6 Robotics

Robotics, or machines that are programmed by computer code, are everywhere around us. If an individual had to look around, he or she would most likely see a programmable electronic device, such as a laptop, a tablet, or a smartphone (Gadzikowski, 2018) in their near vicinity. We teach young South African learners topics, such as the weather, plants, animals, domestic pets, numbers, and life skills (DBE, 2011a), but until now we have rarely included topics, such as robotics. With the introduction of a curriculum that focuses on the implementation of both coding and robotics (DBE, 2023), the opportunity to discuss these topics has become increasingly important. The topic of robotics involves two types of fields, firstly, building robots, and secondly, programming robots. Building robots necessitates a solid understanding of design engineering, as well as mechanical and electrical engineering whereas programming robots requires a solid understanding of coding and computer science (Gadzikowski, 2018).

Implication for this study

The teacher participants in this study were not required to build robots because the Bee-Bot is a commercially available pre-programmed coding toy. Nonetheless, T3 and T4 chose to use Cubroid Coding Blocks since they were provided with these by the DBE, which required them to comprehend how to assemble and program the robots they chose to build, as well as to support the learners to do so.

2.3.3.6.1 How robotics is used in early childhood education

Science, technology, engineering, and mathematics (STEM) is an integration of different content domains that has recently been adjusted to include art (STEAM) (Sanders, 2009). This educational initiative intends to instill in all learners the capacity for critical thought, which will enable them to solve problems creatively and, as a result, increase their marketability in the workforce (White, 2014). Any learner who participates in STEAM education is thought to have an advantage if they do not pursue tertiary education or, an even greater advantage if they do attend a tertiary institution, especially in a STEAM subject area (Butz, Kelly, Adamson, Bloom, Fossum, & Gross, 2004). STEAM education prioritises the teaching of science and mathematics instruction while also including art, technology, and the engineering design process (West Virginia Board of Education, 2020). STEAM education allows learners to work collaboratively to solve interesting and relevant challenges through innovation and creativity (ibid.). Different parts of STEAM may be more or less important at different stages when presenting a lesson, therefore, the key to STEAM education is to develop connections among the five primary subjects (ibid.). In recent years, educational innovation, such as coding instruction for young learners, has become prevalent in the United States of America, Japan, Korea, Singapore, Canada, and a number of other European nations (Badmus & Omosewo, 2020). However, Badmus and Omosewo (2020) acknowledge that the integration of robotics into STEAM education might be difficult, especially in regions, such as Africa.

Owing to the rapid change in technology, researchers and policymakers have pushed for a greater emphasis on STEAM education in ELEs (Barron, Cayton-Hodges, Bofferding, Copple, Darling-Hammond & Levine, 2011; NAEYC & Fred Rogers Center for Early Learning and Children's Media, 2012). According to research, learners who are exposed to STEAM and coding at a young age have fewer gender-based prejudices when choosing STEAM careers (Metz, 2007) and face fewer barriers to entering into these academic subjects (Madill, Campbell, Cullen, Armour, Einsiedel, Ciccocioppo & Coffin, 2007) because all learners, regardless of their gender, have an opportunity to engage in these activities. Robotics is one way to introduce young learners to STEAM in a developmentally-appropriate way (Elkin, Sullivan & Bers, 2014).

Many authors advocate for the use of robotics to develop skills and competencies in EC. Bers (2008) argues that robotics provides an interesting means to develop multidisciplinary discoveries and personal connections. Furthermore, robotics enables young learners to engage in creative explorations, develop fine motor skills and hand-eye coordination, and collaborate and work as a team (Bers, 2008; Lee, Sullivan, & Bers, 2013). While the majority of robotics programmes have focused on older learners, new research has demonstrated that the discipline of robotics has great potential for young learners (Bers, 2008; Bers & Horn, 2010; Kazakoff & Bers, 2012). Teachers may successfully integrate robotics with other disciplines, and learners as young as four years old can build and programme simple robotics projects while learning a variety of engineering and computer science principles (Cejka, Rogers & Portsmore, 2006; Sullivan, Kazakoff & Bers, 2012).

A case study by Elkin *et al*. (2014) is an example of how a robotics programme can be introduced into a well-established EC curriculum and details the incorporation of robotics in a Montessori ELE. The study shows how the teacher was able to incorporate robotics and robot construction into her learning environment “based on a pedagogical tradition that places manipulation, experimentation, and collaboration at the centre of the curriculum” (Marsh, 2020:56).

2.3.3.6.2 Examples of robots used in early childhood education

The floor robot that was used in this research study, namely, the Bee-Bot, has already been introduced in Chapter 1, however, before a thorough explanation is given of the Bee-Bot, the following section also looks at a few other popular commercialised coding toys.

KIBO is a tangible robot; as seen in Figure 2.4, which is a robot kit intended primarily for learners aged four to seven (Bers, 2018; 2021). Young learners learn by doing, and KIBO provides an opportunity for them to do so. The learners can construct their own robot, program it to do whatever they desire, and embellish it with art supplies (Bers, 2018; 2021). KIBO gives young learners the opportunity to make their ideas solid and tangible without needing any support from screen time (Bers, 2018; 2021). The hardware of KIBO's kit comprises the robot body, wheels, motors, and a light output, as well as software in the form of a tangible programming language composed of interconnecting wooden blocks (Bers, 2018; Elkin *et al.*, 2014; Bers, 2021). There are no electronic or digital components in these wooden blocks, instead, an embedded scanner allows users to scan the barcodes on the wooden blocks and instantly send a program to their robot (Bers, 2018; Elkin *et al.*, 2014; Bers, 2021). Since its first release in 2014, KIBO has found its way into international LEs (Bers, 2018; 2021) and has been used to teach within a wide range of curriculum areas, including science, reading, geography, and religion, as well as to involve young learners in the development of social-emotional skills (Bers, 2018).

Figure 2.4: The KIBO robot
(Sullivan & Bers, 2016:331)

Ozobots, as seen in Figure 2.5, are small programmable robots that travel on two wheels (Tengler, 2021). Ozobots employ sensors to scan colour codes and follow lines, and because of its basic programming, the Ozobot is ideal for primary school learners (Leoste, Pastor, López, Garre, Seitlinger, Martino & Peribáñez, 2021; Tengler, 2021). The colours red, blue, green, and black can be programmed into the Ozobot in order for the robot to change speed and direction by using these colour codes (Leoste *et al.*, 2021; Tengler, 2021).

Figure 2.5: The Ozobot robot
(Tengler, 2021:123)

The Code & Go robot mouse activity set, as seen in Figure 2.6, is a mouse-like educational floor robot that includes an activity kit that contains coding sheets, maze walls, tunnels, coding cards, and activity cards (Rossou & Rangoussi, 2020). It resembles both the Bee-Bot in appearance as well as how it is used to teach certain topics (ibid.).

Figure 2.6: The Code & Go mouse robot
(Rossou & Rangoussi, 2020:34)

Another robot, namely Dash & Dot, (see Figure 2.7) consists of three-wheeled balls and a head with an eye on top (Sarma, 2018) and is defined as a "screen-based robot" (Hamilton, Clarke-Midura, Shumway & Lee, 2020:218). The robot can only roll in the direction it is pushed, but it can travel in a variety of directions on its own. In addition, the robot can spin, dance, sing, create noises, and speak (Sarma, 2018). The robot helps learners to understand essential processes that are important to all 21st-century abilities and aims to teach creative problem-solving and computational thinking (ibid.).

Figure 2.7: The Dash & Dot robot
(Sarma, 2018:6)

As seen in the preceding paragraphs, all of the educational robots mentioned hold valuable opportunities for developing diverse skills, knowledge, and values. Each robot has a different way in which it works. However, there is one thing that all of these educational robots have in common: they develop learners' understanding of concepts and skills regarding coding and also introduce learners to robotics. I acknowledge the value of each of these educational robots and I do not dismiss the importance and benefits of each of them by focusing on one educational robot. It is my opinion that more studies should be conducted regarding each specific robot as well as how they compare to one another.

2.3.3.6.3 The Bee-Bot

As mentioned previously, the Bee-Bot is a black and yellow bumblebee-like robot as seen in Figure 2.8.

Figure 2.8: The Bee-Bot
(**Diago, González-Calero & Yáñez, 2022:4)**

In ELEs, the Bee-Bot is one of the most well-known floor robots (Schina, Esteve-Gonzalez & Usart, 2021). It has been classified as a "button-operated robot" because it includes physical buttons on the device that the user may push in a precise order to instruct the robot to travel in a specific direction (Hamilton *et al.*, 2020; Diago, González-Calero & Yáñez, 2022). This robot is commonly used in educational interventions to develop coding skills (Stoeckelmayr, Tesar, & Hofmann, 2011; Kazakoff, Sullivan, & Bers, 2013), cognitive skills related to problem-solving, as well as cognitive flexibility (Diago *et al.,* 2022). However, it can also be used to teach topics, such as measuring, positioning and transformation, moreover, additional mathematical subject areas can also be incorporated if other coding sheets are used (Attard, 2012). Although the Bee-Bot's flexibility is limited by its simple interface, it has demonstrated its appeal in a variety of open-ended activities (Janka, 2008).

The Bee-Bot responds to simple movement orders supplied by means of physical buttons, as seen in the centre picture of Figure 2.7, which is a simpler form of its early predecessor, the Logo Turtle (Papert, 1980). The Bee-Bot can turn right or left while remaining in the same location, turn 90 degrees clockwise or anti-clockwise, and move forwards or backwards in a 15cm straight line. Albeit important to understand the functions of the Bee-Bot; learners were not required to understand how far the Bee-Bot moves. The robot can be programmed to move with up to 40 commands (Bers, 2021). The other buttons, as seen in the centre picture of Figure 2.7, are named '*GO*', '*Pause* (II)', and '*Clear* (X)'. The GO button executes the sequenced instructions; the pause button stops the movement for 1 second; and finally, the clear button eliminates all previously sequenced commands. The Bee-Bot is used with a coding sheet that consists of 15cm grids, as seen in the picture on the right in Figure 2.8. Lastly, the Bee-Bot can also be used with structured coding cards to teach learners the necessary skills related to coding the robot. These coding cards are visually presented in Figure 2.9. In the top row, the picture on the left indicates that the Bee-Bot should move right, the second picture indicates that the robot should move left, and the third picture shows that the Bee-Bot should move forwards. The second row includes a coding card for the Bee-Bot to move backwards, to go and to stop. The last picture, situated at the end between the two rows, indicates a coding card for the Bee-Bot to pause. These coding cards include both directional words as well as directional arrows to minimise confusion for young learners. These coding cards were created by myself, although the Bee-Bot may be purchased with its own set of coding cards.

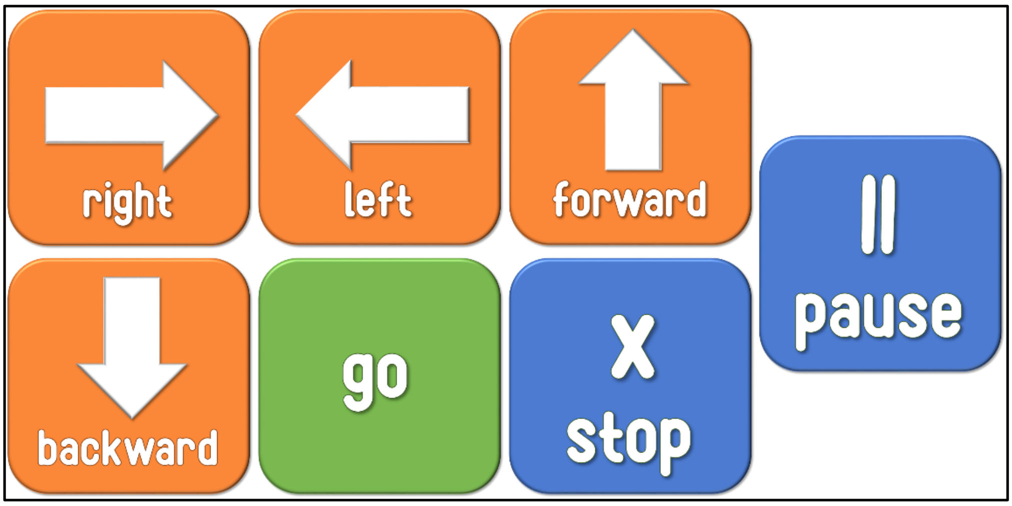


Figure 2.9: Directional words and arrows for the Bee-Bot

In the previous paragraphs, various aspects of robotics were investigated. These aspects include how robotics have been used for skill, value, and knowledge development; the different types of robotics that exist and that can be used in ELEs; as well as the Bee-Bot and its functions.

Implication for this study

The teachers were introduced to the functions of the Bee-Bot before developing learning opportunities for Grade R learners to use the robot. These functions were not only conveyed to the teachers through the teacher collaboration booklet (TCB), but the robot was also introduced to them during our first meeting so that they could become acquainted with it.

Lydon (2007) presents a few aspects for teachers to consider when using the Bee-Bot, however, only two of these are explored in this study. The first of these is that teachers should carefully consider the learning objective of the activity. If the teacher wants to develop learning objectives in another subject, such as mathematics in this study, the teacher should make the level of control technology less complex to allow learners to concentrate on the desired goal (ibid.). This is of extreme importance because the question "*What if the learner is more focused on the Bee-Bot than on mathematics*?" might arise during the implementation of this study. By reducing the emphasis on the number of directions required to navigate a path or delving into the intricacies of the Bee-Bot's functions, the complexity of controlling the technology can be mitigated. For this reason, this study aimed to investigate the integration of the Bee-Bot with learners' existing understanding of mathematical skills. The overarching goal was to explore how the Bee-Bot could be seamlessly incorporated into the learners' knowledge base of mathematical concepts, thereby facilitating a seamless and more meaningful integration of technology into their learning experiences.

Secondly, the teacher also needs to set developmentally-appropriate challenges for learners that are to use the Bee-Bot (ibid.). An example of such a challenge is for the teacher to use a coding sheet and ask the learners to choose certain directional arrows to move the robot to a specific place on the grid (ibid.). After the learners explore how the robot works and solve problems by using the coding sheets, the teacher has to present the learners with opportunities to plan solutions for the Bee-Bot by recording their commands (ibid.). This process of learning has also been elucidated by Angeli and Valanides (2020) through their scaffolded use of the Bee-Bot by providing the Grade R learners with only a few steps to ensure that the complexity does not exceed their developmental level.

The Bee-Bot was selected for this study based on its ability to support mathematical comprehension, as previously mentioned. Its interactive and user-friendly features are particularly suited to the play-based Grade R teaching context that was the focus of this study. Additionally, the availability of the Bee-Bot made it a convenient and accessible option for use in the research.

2.3.4 Pedagogical content knowledge

Teachers' PCK is a form of knowledge that combines subject matter knowledge with knowledge of how to teach that subject matter to their learners (Shing, Saat & Loke, 2015). To put it another way, it is the meeting point of content understanding and pedagogy. PCK enables teachers to comprehend not only what to teach, but also how to teach it effectively to a variety of learners in a variety of settings (ibid.). Understanding learners' prior knowledge and misconceptions, identifying suitable teaching strategies, and creating assessments to evaluate learning are all components of PCK (Bayram-Jacobs, Henze, Evagorou, Shwartz, Aschim, Alcaraz-Dominques, Barajas & Dagan, 2019).

As stated earlier, this study did not specifically address the teaching methodologies of mathematics or coding and robotics. However, it is crucial to underscore the significance of understanding the intricacies involved in the 'how' of teaching. In-depth research and exploration are required to elucidate the precise meaning of this aspect. While this section briefly touches upon approaching mathematics education in ECE, it does not comprehensively investigate the actual theories and methodologies pertaining to the teaching of mathematics. It is important to note that this study focused on learners who had already acquired the necessary mathematical skills prior to the integration with coding and robotics. The specific steps and practices employed to impart these foundational skills to the learners remain unknown within the scope of this study.

In the context of ECE and the importance of mathematics in the foundational years, it is important to consider the new movements in ECE that focus on technology from a young age. Additionally, theories of early mathematics learning and the stages of early mathematics learning can provide insight into how best to approach mathematics education in the early years. Two sources, Jansen van Vuuren, Herzog and Fritz (2018) and Sapire and Herholdt (2023), offer valuable information on these topics.

Meerkat Maths is a training programme designed for Grade R teachers to introduce numbers and fundamental number concepts to young learners (Jansen van Vuuren *et* *al*., 2018). The programme consists of several training units, each covering different cognitive skills, including the ability to detect and recognise patterns. The first chapter focuses on teaching learners to recognise and compare characteristics of objects such as shape and colour. In the second chapter, learners learn to identify differences in characteristics and find the "odd one out" (Jansen van Vuuren *et al*. 2018:4). The third chapter teaches learners how to find, describe, and continue a given pattern, while the fourth chapter introduces the principle of order within patterns and teaches learners how to sort a set of objects by size. Meerkat Maths has implications for mathematical education, and it is important to consider both learning outcomes and implementation conditions when implementing the programme (Jansen van Vuuren *et al*., 2018).

Furthermore, the Marko-D test is an individually administered oral test designed to assess learners' number concept development (Sapire & Herholdt, 2023). The test is based on an empirically validated model of learners' progressive understanding of numerical concepts and was developed in Germany. The model views number concept as a requirement for the construction of arithmetical skills and considers these concepts to be built upon each other, creating a continuum of increasing complexity (ibid.). The South African school curriculum for the FP requires the development of basic number concepts, and the Marko-D test can provide diagnostic information regarding a learner's number concept development, which in turn can be used to inform interventions and learner support (ibid.).

The content presented by Jansen van Vuuren *et al*. (2018) as well as Sapire and Herholdt (2023) can inform kinaesthetic, concrete, representational, and abstract learning. For instance, the Meerkat Maths training units are designed to introduce learners to important first number concepts through concrete and representational learning by recognising and comparing characteristics of objects, identifying differences in characteristics, and finding, describing, and continuing patterns. This approach supports concrete and semi-concrete learning by providing opportunities to manipulate and physically interact with objects to develop their understanding of mathematical concepts.

In addition, the Marko-D test, based on the empirically validated model of learners' progressive understanding of numerical concepts, supports concrete, representational and abstract learning by assessing the learner's number concept development. It provides diagnostic information that can inform re-teaching, interventions, and support. Overall, these sources highlight the importance of combining different learning to cater to the diverse needs of learners.

PCK, in this study, involves the integration of both the content of numbers, operations, and relationships as well as the pedagogy of mathematics teaching in Grade R. According to studies, the Grade R teacher's involvement in mathematics learning is critical, with the intersecting domains of PK and CK being especially important (Ball, Thames & Phelps, 2008; Hill, Ball, & Schilling, 2008). With this in mind, the following section focuses on how numbers, operations, and relationships are taught in ELEs across the globe, as well as in a South African context. From an international perspective, the notion of PCK is elucidated in Japanese, Singaporean as well as New Zealand ELEs. The 2019 average mathematics achievement and scale score distributions reported by TIMSS indicate that Singapore and Japan are among the five best-achieving countries, with Singapore being first (Mullis *et al.*, 2020). Therefore, I chose to include these two countries in this study and to understand how they teach mathematics. I also included New Zealand due to the praise their playful curriculum has received.

2.3.4.1 Play-based mathematics teaching

The fundamental goal of the FP and Grade R mathematics teacher is to make sure learners are numerate, that is, to understand how the world works and how mathematics may be used for constructive purposes (Naudé, 2014). Learners gain an understanding of daily life through the use of mathematics that enhances their ability to comprehend concepts like addition and subtraction (Burton, 2010; DBE, 2011b; Özdoğan, 2011). Björklund (2008) and Reikerås, Løge and Knivsberg (2012) found that learners under the age of three already learn important mathematical concepts and skills through playing. Moreover, other studies claim that many mathematical ideas are included from birth in a learner's exploration and interaction with his or her surroundings, providing the learner with meaningful mathematical experience from which he or she learns (Reikerås *et al.*, 2012; Reikerås, 2020). When a learner then reaches Grade R, the learner is competent in a broad field of mathematics (Reikerås *et al.*, 2012; Reikerås, 2020). As the teacher supports the learners to solve problems, he or she also encourages communication, thinking and reasoning. Furthermore, when teachers create opportunities for learners to enhance their curiosity, the learners are engaged playfully (Oldridge, 2019).

In a study conducted by Stipek (2017), the author visited two LEs. In the first learning environment, the author explains that she was confused when visiting the Grade R learning environment and seeing that all the learners were only wearing one shoe. In the other learning environment, three learners were standing in equally-spaced positions on the playground with a rope pulled around them. She explains that she soon realised these activities were carefully thought out by the teacher, who wanted to teach the learners in the first environment about data handling (through the shoes) and the qualities of shapes to the learners (in the second environment). In the minds of these learners, they were playing, but the teacher was teaching purposefully through the play-based method. The author states that she has also witnessed learners enthusiastically count everyday objects, such as toy animals and erasers and record their findings; hunt shapes in the learning environment; and look for objects by following the teacher's positional language. She infers that these learners were probably not aware that they were participating in mathematics lessons but that they were learning mathematics through "playful instruction" (Stipek, 2017:9).

All of these activities observed by Stipek (2017) were planned by the teacher, who had specific mathematics learning objectives in mind. Some had the added benefit of allowing the learners to walk about, which made the exercise more interesting for the learners who struggle to sit still. In all of these activities, the teacher had the chance to test the learners' knowledge by observing them and encouraging specific learners to participate in the discussion. Stipek (2017) furthermore explains that many teachers have expressed their concerns about how academic demands might prevent young learners to learn through play and, therefore, stifle their natural curiosity and motivation. Nevertheless, these mathematical activities presented above show that "there is no need to choose between play and teaching academic knowledge and skills" (Stipek, 2017:9). Although this study focuses on how teachers should integrate different subjects or content areas, it is also necessary to examine the opportunities of learning provided by the teacher and how learners are engaged in play.

2.3.4.2 A South African perspective: Policy and curriculum for Grade R mathematics

The development of ECE in South Africa since 1997 needs to be analysed in order to comprehend the regulations and curricula that support mathematics teaching in Grade R. In order to prepare for the introduction of Curriculum 2005 (C2005) in 1998, chances for in-service training for Grade R teachers were provided in 1997 (Department of Education [DE], 2003). However, C2005 was amended as early as 2002, when the Revised National Curriculum Statement (RNCS) was introduced (DE, 2003). The RNCS provided Grade R teachers with information on how to construct their numeracy programmes, work schedules, lesson plans as well as their learning and teaching support materials (LTSMs). Although there were possibilities for in-service training, some teachers were still unable to create a Grade R learning programme. There was a need for more practical, hands-on training and opportunities to acquire mathematical teaching techniques (Barnard & Braund, 2016). As a result, some teachers started employing a formal approach, based on commercially-generated resources, to compensate for their lack of methodological understanding (ibid.). These teachers' practices were incompatible with the policy, which recommended an informal approach that incorporates hands-on experiences, manipulative tools, questioning, explanation of reasoning, and problem-solving approaches (ibid.). This policy also recommends that rote practice and memorisation, as well as the use of worksheets, should be minimised. When the CAPS was introduced in 2011, the RNCS was updated (DBE, 2011a).

Grade R teachers had another opportunity to undergo training on the implementation of CAPS. The CAPS document advocates informal learning by stating that learning should occur during free play, routines, and teacher-guided activities as seen in the daily programme (ibid.). Nevertheless, it appears that some Grade R teachers still only prefer free play to let learners learn through play without setting up the LE or structuring their play activities for learning to occur (Barnard & Braund, 2016). It is, however, recommended that Grade R teachers should plan play activities for learners to actively explore, experiment, discover, investigate, reason, and report mathematical concepts (ibid.). More guidance is offered in CAPS regarding the integration of mathematical activities into the daily programme, as well as establishing the time available for teacher-directed and learner-focused mathematical activities (ibid.). CAPS also offers lesson plans that can be used in the Grade R LE to develop the necessary mathematical concepts (ibid.). However, this contrasts with several of CAPS' principles, which suggest, as did previous curricular policy papers, that learning in Grade R should be informal and focused on play (ibid.). Furthermore, CAPS emphasises the need for incorporating three phases of using mathematical concepts (see 2.3.4.6 A South African perspective: Teaching Grade R mathematics).

The DBE (2011b) and Naudé (2021) emphasise that mathematics teaching in Grade R should be implemented through integration and play-based methods. To teach mathematics playfully, the DBE (2011b) states that the teacher should be a proactive mediator during child-centred and teacher-guided activities. The main focus should be the holistic development of each learner and playful teaching can occur through storytelling, singing songs, reciting rhymes, playing games, as well as other play opportunities, such as constructing, exploring, and imagining (ibid.). Stach and Veldsman (2021) add that learners are encouraged to take chances, try out new ideas, experiment, explore, fail, and try again when they are given the opportunity to play. Furthermore, as mentioned previously, the teaching of mathematics should move through three stages of learning, as explained by DBE (2011b). These stages are the kinaesthetic stage, the concrete stage, and the semi-concrete stage. The semi-concrete stage can also be referred to as the representational stage (ibid.) and forms part of the concrete-representational-abstract (CRA) approach used in this study. Figure 2.10 visually represents these stages and I have used photographs taken in this study to show the different stages of learning.

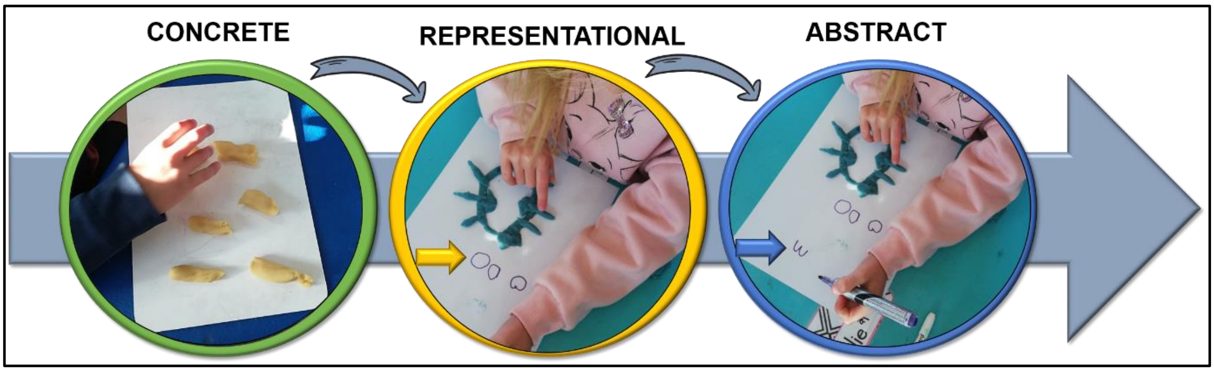


Figure 2.10: The CRA approach

In the next section I will unpack what concrete; representational and abstract learning entails in the context of this study as seen in Figure 2.10 above.

The initial picture demonstrates the concrete stage of learning or the ‘doing’ stage (Wolf, 2017). The inclusion of concrete experiences and manipulatives has gained recognition as valuable tools in ECE (Baroody, 2017). Empirical evidence suggests that concrete experiences have the potential to expand young learner's informal knowledge by allowing them to discover and apply mathematical patterns or devise and practice informal strategies (Boggan, Harper & Whitmire, 2010; Clements & Sarama, 2012). According to Sarama and Clements (2016), the significance of manipulatives in learning lies in their relationship to learners' activities and cognitive processes. Both physical and virtual manipulatives can offer value, but their effectiveness is enhanced when integrated into well-designed and comprehensive instructional environments. The physical nature of manipulatives holds less importance compared to their capacity for manipulation and the meaningfulness they bring to educational experiences.

This study adopts Clements and Sarama (2012:127) and Sarama and Clements (2016:75) explanation that concrete objects are "physical objects that students [learners] can grasp with their hands" to “reflect on and talk about their actions”. These manipulatives possess a sensory characteristic that makes them ‘real’ and relatable to learners on an intuitively meaningful level, thereby facilitating understanding when learners are able to understand how and why these manipulatives are used (Clements & Sarama, 2012; Sarama & Clements 2016). In this study, the implied definition of concrete objects aligns with this notion, referring to the stage of learning in which learners engage with physical manipulatives, such as counting the quantity of physical objects as seen in Figure 2.10, to enhance understanding.

The second image portrays the representational stage or the ‘seeing’ stage of learning (Wolf, 2017). According to Wolf (2017), the representational stage involves the transformation of the concrete model into a semi-concrete level, which can be achieved through activities such as drawing pictures; using circles, dots, and tallies; or using stamps to create imprints for counting purposes. In the context of this study, as depicted in Figure 2.10, the learner draws a specific number of circles to symbolically represent the number '6'.

The final image exemplifies the abstract or ‘symbolic stage’ of learning, as defined by Wolf (2017). During this stage, the mathematical concept is demonstrated at a symbolic level, employing numbers, notation, and mathematical symbols to represent the number algorithm. Operation symbols, such as addition (+), multiplication (×), division (÷), or subtraction (–), are also used to denote the corresponding mathematical operations. As seen in Figure 2.10, the learner demonstrates the mathematical concept on a symbolic level by writing the numeral representing the number of feet that the ant has.

These three stages are referred to as the CRA approach and it is rooted in Bruner and Kennedy’s (1965) stages of representation. The CRA approach provides a platform to create meaningful connections among concrete, representational, and abstract levels of understanding (Wolf, 2017). Wolf (2017:2) furthermore describes this approach as an “intervention for mathematics instruction” aimed at enhancing learners’ conceptual mathematical understanding.

The DBE (2011b) mentions the importance of kinaesthetic learning, or enactive learning, as explained by Bruner and Kennedy (1965), preceding concrete, representational and semi-concrete learning. Therefore, this study employed kinaesthetic learning as the first stage of learning in Grade R. In the context of numbers, operations, and relationships, Figure 2.11 illustrates the inclusion of kinaesthetic learning as explained by the DBE (2011b) to precede CRA learning.

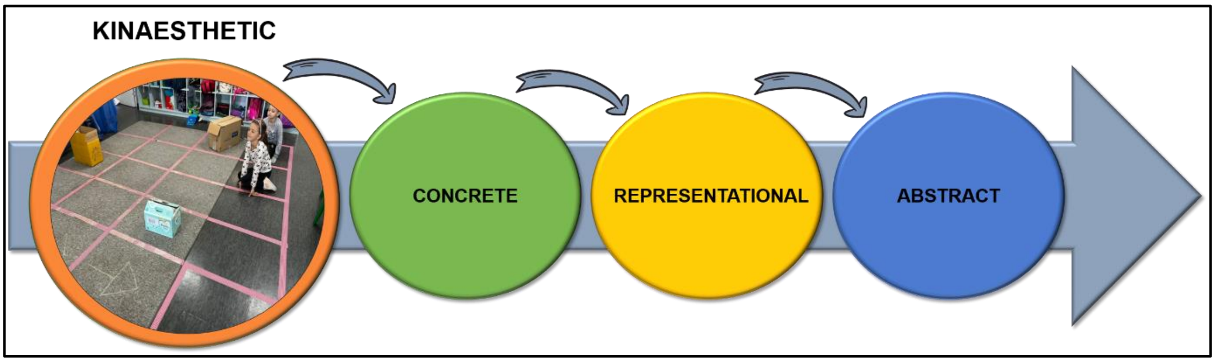


Figure 2.11: Representation of KCRA learning

The learner is involved in kinaesthetic learning since the learner has to throw a die in order to move the correct number of blocks on a grid. Tranquillo (2008) advocates the use of kinaesthetic experiences and states that it provides learners with the opportunity to build their own unique interpretations of concepts and to establish links to other ideas and concepts. Moreover, the use of the CRA approach is advocated by Witzel (2005) who explains that concrete materials increase the retention of procedural alternatives by the learner, when addressing mathematical problems. Furthermore, concrete materials allow learners to encode and retrieve information in a variety of sensory ways (ibid.). Witzel (2005) also found that learners that were involved in CRA activities to solve mathematical problems performed better than their peers who received traditional teaching. The use of CRA activities is also supported by Butler, Miller, Crehan, Babbit and Pierce (2003) who found that learners rely on representational drawings to solve mathematical problems during post-testing in their study. Moreover, the steps of CRA are imperative to teach learners conceptual mathematical understanding (Wolf, 2017). Since various research supports both the use and implementation of kinaesthetic learning and the CRA approach as discussed in this section, subsequently, this study employed both.

The steps of the stages of learning of the CRA approach, as well as kinaesthetic learning, have been visually illustrated in both Figures 2.10 and 2.11. These steps and kinaesthetic learning will be renamed as the kinaesthetic-concrete-representational-abstract (KCRA) approach in the ten steps that follow (adapted from Wolf, 2017):

1. The prerequisite for teaching a specific mathematical concept is introduced by the teacher.
2. The mathematical concept is practised kinaesthetically.
3. The concept is connected to a concrete representation of the kinaesthetic activity.
4. The mathematical concept is practised on a concrete level.
5. The concept is connected to a representation of the concrete activity.
6. The mathematical concept is practised on a representational level.
7. The concept is connected to an abstract presentation of the representational activity.

8. The mathematical concept is practised on an abstract level.
9. The teacher supports the learners to make connections between the four stages to support learners' understanding of the concept.
10. The learner has the opportunity to practise the concept within the stage of their own choice.

These steps are visually illustrated in Figure 2.12 below.

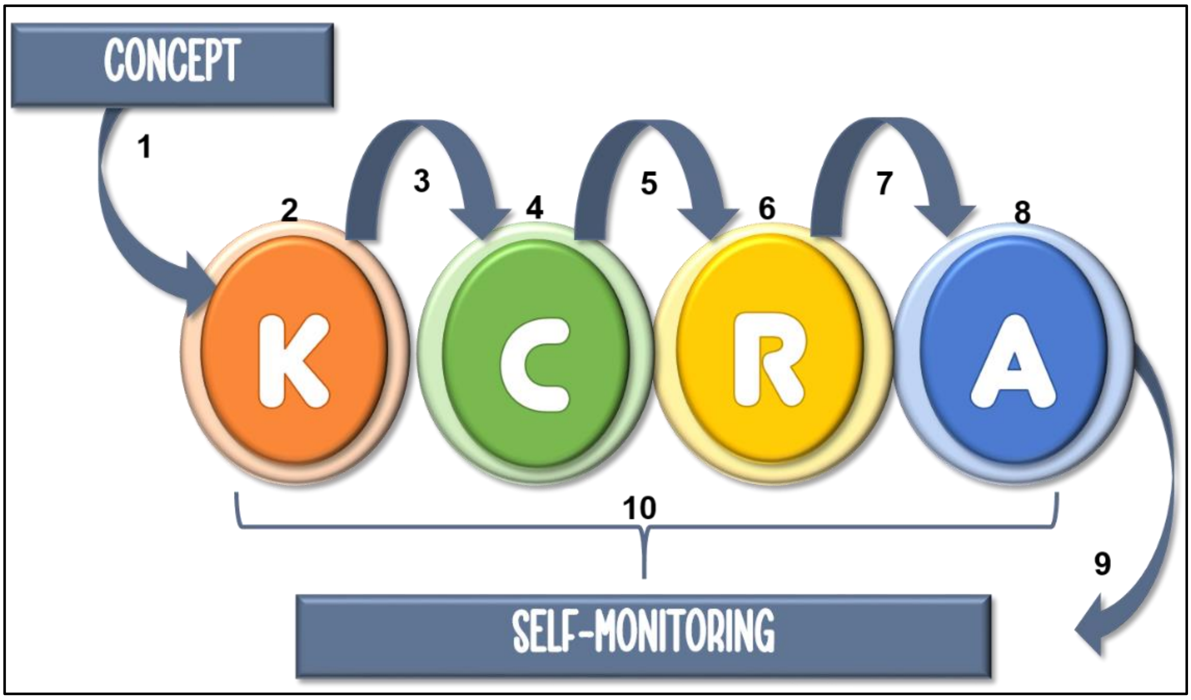


Figure 2.12: The stages of learning of the KCRA approach

The KCRA approach was employed in this study to develop activities that integrates coding and robotics with the content area of numbers, operations, and relationships.

2.3.4.3 A perspective from Japan: Grade R mathematical learning experiences

Japanese learners have been characterised as outperforming their peers from other countries in mathematics, therefore, this study wanted to investigate how mathematical learning experiences is used in Japan so as to possibly draw important conclusions from the literature and implement it in this study (Sakakibara, 2014). Foreign educational philosophies and approaches, like Montessori's nursing theory from the Soviet Union from the 1930s to the 1950s, and the Reggio Emilia approach from Italy since the 1990s, have all had an influence on Japanese preschool education (Abumiya, 2015). In each individual learning environment, these approaches and philosophies have been assimilated and adapted to fit the Japanese milieu and setting, and they are still evolving (ibid.).

In Japan, a preschool is called *Yochien*, and the importance of play-based learning and teaching is emphasised in the curriculum guidelines (Mori, Nezu, Samizo, Naito & Ishizuka, 2009). Furthermore, Mori *et al.* (2009:127) acknowledge that Japanese parents value the importance of play as they know it provides their children with opportunities for decision-making and interaction. The Japanese curriculum for EC specifically refers to the term "arithmetic"[10] that is taught to young learners (The Ministry of Education, Culture, Sports, Science and Technology [MEXT], 2018:7). The aim is to support learners to acquire fundamental knowledge and skills of "numbers, quantities and geometrical figures" and to develop learners' competencies of logic and their abilities to think and express matters of "everyday life with good perspectives" (MEXT, 2018:7). Furthermore, mathematics learning experiences in Japanese ELEs are provided through a variety of kinaesthetic, concrete, representational and abstract activities (Sakakibara, 2014).

Muto (2006 cited in Abumiya, 2015:7) mentions the following about the characteristics of Japanese early education and care:

Firstly, there is a focus on both intellectual as well as emotional and social growth, and both types of development are thought to be intertwined. Special teaching for the learning of literacy or numeracy is uncommon, but such skills are gained through play or activities with peers based on the group's developmental level. Secondly, teachers provide education, not only for specific exercises, but also for leisure and other elements of learners' lives. However, rather than formal and standardised learning, recommendations and advice are given to encourage learners' initiative, and resources are placed in the room so that learners will naturally desire to play. From the preceding information, we can conclude that all learning occurs through play-based teaching and learning opportunities.

[10] Arithmetic refers to numbers, operations, and relationships.

2.3.4.4 A perspective from New Zealand: Grade R mathematical learning experiences

I chose to explore how mathematical learning experiences is facilitated in New Zealand, due to the praise that New Zealand's ECE curriculum, Te Whāriki, has received. EC development is explained as having a crucial role in New Zealand (White, Ellis, O'Malley, Rockel, Stover & Toso, 2009) since Te Whāriki is explained as "*providing mokopuna*[11] *with culturally responsive environments that support their learning and by ensuring that they are provided with equitable opportunities to learn*" (Ministry of Education, 2017a:3).

Since the 1980s, play is seen as an appropriate manner in which culture and language can be transmitted in New Zealand (Royal-Tangaere, 1997). Te Whāriki states that mathematics, as well as statistics, is one of the learning areas in EC that have to be mastered by young learners through a play-based approach (Ministry of Education, 2017a). In this learning area, learners should explore mathematical relationships in quantities, space and data in real-life situations (ibid.). The learning outcome of mathematics in Grade R is called "he kōrero pāngarau", which means that learners should be able to recognise mathematical symbols and concepts and be able to use them with enjoyment, meaning and purpose (Ministry of Education, 2017a:25, 42, 56). Te Whāriki does not provide specific learning processes that a teacher should follow when teaching Grade R mathematics, rather, the outcomes of all subjects are grounded in principles, such as empowerment and holistic development (ibid.). However, New Zealand strongly supports the use of concrete materials as a successful method to develop deeper mathematical understandings (Ingram, Holmes, Linsell, Livy, McCormick & Sullivan, 2020).

2.3.4.5 A perspective from Singapore: Grade R mathematical learning experiences

[11] In Māori (indigenous population and language of New Zealand), a child is called a "mokopuna" (Ministry of Education, 2017:13).

The last international perspective of teaching Grade R mathematics that I want to explore is from Singapore. The Nurturing Early Learners: A Curriculum Framework for Preschool Education in Singapore (NEL Framework) promotes preschool curriculum development in Singapore. The NEL Framework supports teachers to provide high-quality ECE to learners based on nurturing learners' curiosity to explore and discover the world; to encourage active learning through experimenting and experiencing; and to foster learners' competencies to promote thinking and reasoning skills (Ministry of Education, 2012). The Singaporean Ministry of Education (2012) furthermore recognises that learners should learn, and their learning should be faciliated, through play that is enjoyable and carefully planned.

The NEL Framework posits that numeracy experiences should develop learners' knowledge and skills of recognising number patterns and relationships, recognising basic shapes, and developing spatial concepts, based on Vygotsky's ZPD (ibid.). Within this learning area, learners should be provided with the opportunity to explore and experiment through engaging in purposeful play learning opportunities (ibid.). Furthermore, the Singaporean Ministry of Education (2012) postulates that learners should be provided with different manipulatives to group, sort, count, share, and represent numerical relationships. All the activities that are presented by the teacher should focus on mastery, which is attained through deliberate topic sequencing, which should commence as concrete, hands-on experiences that progress to representational experiences, and be concluded with abstract experiences (ibid.).

The previous sections focused on how Grade R mathematics is taught in Japan, New Zealand, Singapore, and South Africa. Each of these countries advocate the use of play-based teaching, which is why this study highlighted its importance. Moreover, Singapore, as well as South Africa, provide important information on how the facilitation of mathematical learning experiences should progress, which has been named the KCRA approach in this study. Table 2.4 provides a summarised overview of how mathematics is taught in each of these countries.

Table 2.4: Grade R mathematical learning experiences in Japan, New Zealand, Singapore, and South Africa

COUNTRY	GRADE R MATHEMATICAL LEARNING EXPERIENCES
Japan	Play-based teaching A variety of kinaesthetic, concrete, representational, and abstract learning experiences in no specific order
New Zealand	Play-based teaching Concrete learning experiences
Singapore	Play-based teaching Concrete, hands-on experiences that progress to representational experiences, which are concluded by abstract experiences
South Africa	Play-based teaching Kinaesthetic learning experiences are followed by concrete and semi-concrete representations
Application in this study	Play-based teaching KCRA learning experiences in a chronological order

As seen in Table 2.4 above, all four countries advocate that learning in Grade R should take place through play-based teaching. Singapore and South Africa mention that learning experiences should sequentially take place through specific constructs of KCRA. Japan implements all the constructs of the KCRA in no specific order. New Zealand places a focus on concrete learning experiences. The application of these countries' PCK in this study is firstly the importance of play-based teaching and, secondly, that learning experiences should chronologically be offered through kinaesthetic, concrete, representational, and abstract activities.

2.3.4.6 Guided play

The teachers in a study conducted by Stach (2017) are not convinced that play-based learning opportunities are the best way for learners to learn and rather advocate for direct instruction, which includes workbook exercises, drill-and-practice, as well as an overemphasis on standardised testing. Nevertheless, the preferred approach for Grade R learners in South Africa is to learn through a play-based learning pedagogy (DBE, 2011b). The CAPS (ibid.) mentions that there are three opportunities in the daily programme of the Grade R curriculum where learners can be involved to learn important mathematical concepts. These opportunities are teacher-guided activities, routines, and child-initiated activities, also known as free play (ibid.). Fisher, Hirsh-

Pasek, Newcombe and Golinkoff (2013), and Weisberg and Zosh (2018) agree that children's mathematical learning has been found to benefit through guided play[12].

Fisher *et al*. (2013) studied alternative ways for teaching Grade R learners the properties of various geometrical shapes, such as triangles, by allowing them to interact with concrete objects. The learners who actively participated in the activity through exploration and scaffolding by a qualified teacher indicated a greater understanding of the shapes' characteristics. Moreover, Bonawitz, Shafto, Gweon, Goodman, Spelke and Schulz (2011) compared the effects of direct instruction versus allowing the learners to discover the qualities of a toy on their own. The teacher gave detailed instructions on how to utilise the toy to one set of youngsters in the research, whereas the second group was allowed to discover the toy on their own. The second group of learners were able to figure out the toy's intended function as well as extra uses without the teacher's support or intervention. The research presented here indicates that guided play, rather than direct instruction, is the best way for young learners to acquire the necessary skills. To maximise learners' learning during play-based mathematics early learning sessions, the Grade R teacher needs to ensure that he or she guides the learners' play.

Mardell *et al.* (2016) collaborated with a Danish international school to investigate the characteristics that must be present in an ELE for a play-based pedagogy to be successful. Mardell *et al*. (2016) argue that guided play, which is also known as playful learning, is not always present in all ELEs since there is tension between play and direct instruction as approaches for teaching young learners. A play-based pedagogy necessitates the transformation of the entire ELE where playfulness is encouraged by teachers. Play-based learning also encourages learners to take chances, experiment with new ideas, make errors, and have fun (ibid.). Playfulness should not only be encouraged in the Grade R ELE but teachers should also use innovative methods to convey the notion of fun, which may be implemented through integrating coding and robotics as complementary teaching tools.

---

[12] Guided play is defined as when teachers promote learners' exploration and learning by providing helpful assistance while remaining non-intrusive (Stach & Veldsman, 2021).

Figure 2.13 depicts where guided play is situated on the conceptual play continuum. This adaptation from Miller and Almon (2009), Stach (2017) and Stach and Veldsman (2021) illustrates guided play as the balance between learning through play that occurs without an adult, and learning through play that is controlled by an adult. Guided play combines the autonomy of the learner with the teacher's supervision (Stach, 2017; Stach & Veldsman, 2021). Teachers provide the environment where learning should occur, and learners have the freedom to explore it. In this learning environment, the teacher scaffolds the learner's learning by observing and encouraging the learner (Stach, 2017; Stach & Veldsman, 2021). The teacher's responsibility is to assist learners in problem-solving and to propose new challenges for them to solve, while also paying attention to their natural interests and appreciating their desire to learn more about the world (Stach, 2017; Stach & Veldsman, 2021).

Figure 2.13: Guided play
(Adapted from Miller & Almon, 2009; Stach, 2017; Stach & Veldsman, 2021)

When guided play is paired with sustained shared thinking, which relies on the teacher's awareness of and responsiveness to the learners' comprehension and capacities while participating in an activity, the activity is strengthened. The learner must be aware of what he or she is learning, and the learner and teacher must work together to develop a concept or skill. Sustained shared thinking encourages the principle of 'scaffolding' into the play area. The teacher then progressively decreases the level of assistance until the learner is able to complete the task on his or her own (ibid.). Table 2.5 provides observable actions that a teacher needs to adhere to when implementing guided play, and also, how it implicates the context of this study.

Table 2.5: Implementing guided play

Key characteristic		Explanation	Implication for the context of this study
Uninterrupted play	• Excell and Linington (2015) • Stach and Veldsman (2021)	The teacher encourages learners to play uninterrupted.	Ample time should be scheduled for observations and activities so that the teacher (and the learners) did not feel rushed to complete an activity.
Safe and inclusive environmen	• Excell and Linington (2015) • Stach and Veldsman (2021)	The teacher creates an environment that is both physically and emotionally safe and welcoming.	The teacher should ensure that the learning environment is safe and welcoming.
Guided play	• Excell and Linington (2015) • Stach and Veldsman (2021)	The teacher encourages learners to engage in play by being involved, expressing interest in what they are doing, and participating in learners' play when asked or at an opportune time to further their learning.	The Grade R teacher should set the learning activities for the learners to engage in. The teacher should be involved in the learners' play but should not seek a specific outcome even though the learning objective will focus on mathematics.
Effective communication	• Jordan (2009) • Jalongo and Isenberg (2012) • Stach and Veldsman (2021)	The teacher interacts constructively with the learners and speaks to them frequently in order to establish a relationship and enhance content understanding and communication skills.	The teacher should talk to learners in a positive manner while they are exploring the activities that have been presented.
Interesting and open-ended	• Excell and Linington (2015) • Stach and Veldsman (2021)	The teacher gives sufficient resources that pique learners' interest and are open-ended in nature to encourage innovation.	The use of coding and robotics could pique the learners' interest and is open-ended.

As seen in Table 2.5, when a teacher implements these key characteristics, guided play will take place. The learners' play should not be interrupted, and there should be enough of time for them to explore, for guided play to be successful. Additionally, the surroundings should be welcoming and safe on a physical and emotional level. The teacher should also engage in play with the learners and interact with them. The teacher should also provide the learners with a selection of engaging and flexible resources.

2.3.5 Technological pedagogical knowledge

In this section, the focus is on how coding and robotics is used in ELEs. It also provides an overview of how coding and robotics are used in Grade R LEs in South Africa, Japan, New Zealand, and Singapore.

2.3.5.1 Play-based digital learning

“Play-based digital learning” (PBDL) is a term introduced by Campbell and Walsh (2017:10). The authors describe PBDL as an approach to integrate coding and robotics into ECE. In play-based LEs, PBDL provides an acceptable, scaffolded, and deliberate approach to familiarise young learners with coding and robotics, and more specifically, the Bee-Bot. The mission of PBDL is to support EC teachers to increase young learners’ engagement in STEAM education in order to improve their DL abilities. PBDL is built on the foundations of best practices in ECE. Some of these practices include aspects from the United Nations Convention on the Rights of the Child (United Nations Children's Fund, 1989), the Melbourne Declaration on Educational Goals for Young Australians (Barr, Gillard, Firth, Scrymgour, Welford, Lomax-Smith, Bartlett, Pike & Constable, 2008), the Early Years Learning Framework of Australia (Australian Government Department of Education and Training for the Council of Australian Government, 2009), and the Australian Curriculum Technologies learning area (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2011).

Moreover, PBDL provides young learners with “concise statements that outline tasks in simple terms” where the focus commences with the learner and what is familiar, to ensure the learners experience the learning opportunity as relevant to their daily lives (Campbell & Walsh, 2017:10). It then gradually proceeds, through scaffolding and support, to ask learners to transfer what they know about themselves, familiar things, and familiar surroundings to less familiar individuals, materials, and/or contexts. PBDL also purposefully employs the use of important coding terms (see 2.3.3.5 Coding) since observations conducted by the authors indicate that even young learners comprehend and utilise these concepts as part of their play. Figure 2.14 visually represents how learning should take place through PBDL.

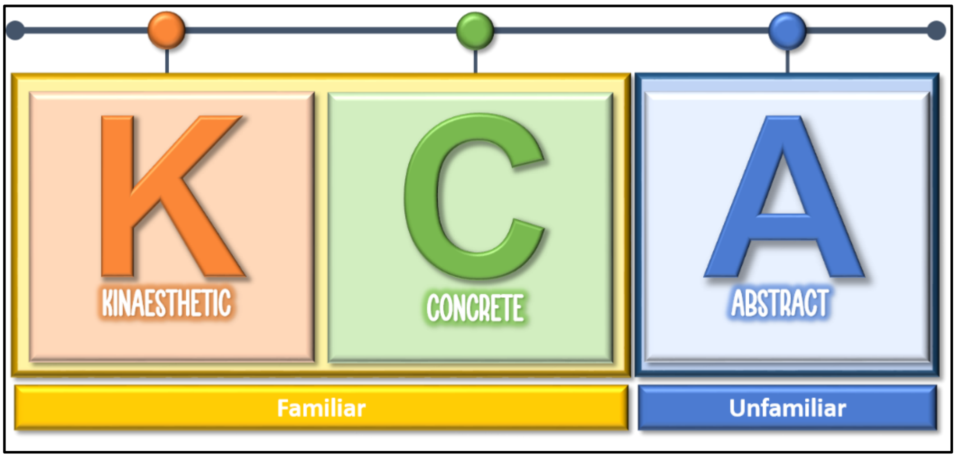


Figure 2.14: Integrating coding and robotics through PBDL

As seen in Figure 2.14, PBDL indicates that teaching should commence through kinaesthetic and concrete learning before concluding with abstract learning. An example of an activity provided by Campbell and Walsh (2017) is to provide the learners with concrete directional arrows in which they should move their bodies as this is familiar to them. This promotes concrete as well as kinaesthetic learning. The learners are then required to transfer what they have learned about coding themselves to coding a peer. Learning then progresses to the unfamiliar where, finally, the learners code the Bee-Bot.

2.3.5.2 Planning for digital learning

EC teachers have a significant role to play in the learning and development of their learners. The South African Council for Educators Professional Teaching Standards emphasise learning to plan as a basic teaching activity that all teachers should master (South African Council for Educators [SACE], 2019). Danielson (2007:27) reiterates the importance of planning by stating:

> "*It is difficult to overstate the importance of planning. In fact, one could go further and argue that a teacher's role is not so much to teach as it is to arrange for*

> *learning. That is, a teacher's essential responsibility is to ensure that students* [learners] *learn, to design (or select of adapt) learning activities such that students* [learners] *learn important content. Thus, planning is a matter of design*."

Good planning becomes a strategy for making the learning and development of young learners apparent, as well as a tool to enhance the teacher's thinking. The planning cycle developed by the Australian Government Department of Education, Employment and Workplace Relations (DEEWR, 2010) proposes that a teacher follows the subsequent four steps during planning for learners' learning in general as well as their engagement with technology:

1. Firstly, the teacher needs to familiarise him- or herself with the learner's social and cultural context. This will ensure that the activities presented are meaningful (see 2.3.1 Pedagogical knowledge: Play-based learning) and responds to each learner's context. The context in this study is the Grade R teaching and learning environment influenced by various cultural and socioeconomic notions.
2. Secondly, the learning experiences offered to the learners must scaffold (see 2.3.2.1 Grand theorist of play: Lev Vygotsky) their learning and development in order to develop 21st-century skills.
3. Thirdly, the teacher should put a plan into action to support their digital engagement through play-based learning (see 1.5 Clarification of Key Concepts).
4. Lastly, the teacher should then reflect on the learners' learning and development and consider if they should adapt or change the learning experiences.

2.3.5.3 Using coding in the Grade R learning environment

There are two sorts of coding practices to consider when using coding in the Grade R learning environment, namely, unplugged and plugged experiences (Lee & Junho, 2019). When teaching young learners how to code, it is important to start with concrete representations that involve unplugged, hands-on activities that allow them to physically move things around without having to use abstract coding and to engage in PBDL (Campbell & Walsh, 2017; Lee & Junho, 2019). When learners have mastered their understanding of unplugged coding experiences, they can be introduced to plugged experiences, which involve programming coding toys (Lee & Junho, 2019). Despite the fact that coding is a relatively new phrase in ECE, learners experience and apply coding in their daily lives and routines through unplugged practices, for example, learning to button a shirt by following a series of steps (ibid.). Although both teachers and learners may be unaware that they are coding, these daily activities illustrate essential coding principles, such as following or defining a step-by-step approach to finish a task (ibid.).

When teachers want to introduce a new concept to young learners, the teacher should consider the learners' interests and make the learning experience relevant to their personal circumstances (Campbell & Walsh, 2017; Lee & Junho, 2019). In order for teachers to introduce coding, they should use daily activities that reflect 'algorithm design', such as tying shoelaces, taking a bath, or other sequential activities (Lee & Junho, 2019). These activities can easily be connected to learners' daily lives and involve step-by-step procedures which can be considered as 'a code'. Lee and Junho (2019) briefly elaborate on how coding can be introduced by using these daily activities, for example, the learners can each be asked to show the steps they implement to wash their hands. When each learner has had the opportunity to discuss these steps, 'debugging' takes place when unnecessary steps are removed or steps are changed. These steps can be visually represented by coding cards, to illustrate which steps need to be taken when the learners wash their hands. This process will ensure learning takes place on a concrete level first before moving to semi-concrete representations.

2.3.5.4 Using a floor robot in the Grade R learning environment

When learners are provided with an opportunity to learn through the use of robots, it offers them intrinsic motivation and fosters their imagination and curiosity (Lopez-Caudana, Ramirez-Montoya, Martínez-Pérez & Rodríquez-Abita, 2020). This is because learners are supported to investigate, ask questions, work collaboratively, and to be responsible for their own learning process (Nugent, Barker, Grandgenett & Welch, 2016; Di Lieto, Inguaggiato, Castro, Cecchi, Cioni, Dell'Omo, Laschi, Pecini, Santerini, Sgandurra & Dario, 2017). Using robotics in LEs also stimulates learners' interest and motivates them to participate (Lopez-Caudana *et al.*, 2020).

Existing literature indicates that robotics can facilitate teaching practices because it provides learners with visual and hands-on activities (Gura, 2012), immerses learners in problem-solving activities (Clements, Battista & Sarama, 2001; Bers & Portsmore, 2005; Highfield, 2010; Chalmers, Chandra & Hudson, 2012; Gura, 2012), and provides learners with the opportunity to connect activities to their real-life experiences and prior knowledge (Khanlari, 2014).

The Bee-Bot has been used in diverse ELEs across the globe. The next section elaborates on a few of these implementations.

A case study conducted by Vázquez, Lledó, Carreres, Lledó and Cerdá (2019) employed the Bee-Bot to conduct an intervention for the understanding, recognition, and expression of emotions for learners with Autism Spectrum Disorder (ASD). Ten learners, from as young as five years old, were invited to participate in the study and the findings indicated that these learners made significant progress in their understanding of basic emotions, as well as spatial orientation and coding (ibid.). The authors argue that robotics is a powerful tool for the socio-emotional intervention of learners with ASD, as it creates settings in which to acquire and practice various abilities.

Angeli and Valanides (2020) investigated the effects of learning with the Bee-Bot on young learners' computational thinking by using scaffolding techniques. The study found statistically significant learning gains between the initial and final assessments of the learners' computational thinking skills. The findings of this study are significant because they reveal that even at a young age, learners can cope with the complexity of a learning activity by breaking it down into smaller subtasks that are easier for them to complete. The scaffolding technique used by Angeli and Valanides (2020) commenced by providing each learner with some directional cards and asking them to develop a path for the Bee-Bot. When this activity was completed, the learners had to develop a path by drawing the directions that the Bee-Bot had to move on a piece of paper. This study holds particular value for the implementation of this research study as it investigates both how scaffolding is implemented and the effects thereof when using the Bee-Bot. Scaffolding is one of the constructs of the theory presented by Lev

Vygotsky, which is a foundational theory used in this study (Wood *et al.*, 1976; Rogoff, 2003).

Another study that also investigated the Bee-Bot's effect on learners' computational thinking skills is a study conducted by Diago, González-Calero and Yáñez (2022). The authors invited 24 learners to participate in a study where an experimental and a control group were formed – the experimental group had the opportunity to use the Bee-Bot for map-based route-finding activities whereas the control group used the traditional paper-and-pen approach. The study found that the learners who had the opportunity to use the Bee-Bot had statistically significant greater improvements in computational thinking skills compared to their peers who had used the traditional method (Diago *et al.*, 2022).

Janka (2008) implemented a variety of learner-centred activities by using the Bee-Bot. The learners were grouped into groups of no more than five individuals, with some groups designing, drawing, painting, or constructing elements for Bee-Bot scenarios, and the other learners interacted with the Bee-Bot's buttons. The teacher's role when teaching by using the Bee-Bot is indispensable as the teacher should manage turn-taking, encourage learners, provide age-appropriate challenges, as well as monitor and evaluate the learners' progress, according to Janka (2008). The aim of the author's study was to assist individuals to create high-quality games based on the use of a commercialised coding toy (ibid.).

In a study by Urlings, Coppens and Borghans (2019), they observed how the Bee-Bot affected young learners' executive functioning[13] skills. The authors found that allowing young learners to play with the Bee-Bot can reveal important information about their memory, nonverbal competence, verbal fluency, and planning ability (ibid.).

[13] Executive function refers to the cognitive and behavioural abilities that enable an individual to complete a task (Etokabeka, 2021).

2.3.5.5 A perspective from Japan: Using coding and robotics in the Grade R learning environment

Learners learning to program is a priority in Japan's national education policy, in fact, beginning in 2020, learning programming was required in ELEs (Ohnishi, Honda, Nishioka, Mori & Kawada, 2017). After scrutinising the curriculum and policy documents available for ECE in Japan, I concluded that coding and robotics are not currently included. Subjects, such as language, arithmetic, music, art, and moral education are the main focus of ECE in Japan (Kanemune, Shirai & Tani, 2017). Nevertheless, within each of these subjects, mention is made of using information-processing and interactive technology (MEXT, 2018), which could possibly include commercialised coding toys, such as robots (Ministry of Education, 2017a). In arithmetic, one learner explains that he uses these information-processing and interactive technologies to compare his answers with his peers by using a tablet (MEXT, 2018).

2.3.5.6 A perspective from New Zealand: Using coding and robotics in the Grade R learning environment

The New Zealand curriculum was revised to incorporate the teaching of digital technologies to ensure that all learners have the opportunity to develop digital skills (Ministry of Education, 2018). It highlights the importance of putting more emphasis on the learners to develop their abilities so that they may be inventive creators of digital solutions rather than just users and consumers of digital technologies (ibid.). These revisions had to be fully integrated into the curriculum by 2020. Nevertheless, the revision does not include specific activities or guidelines to use coding and robotics in the learning environment, rather, the focus is on technological practice, technological knowledge, and the nature of technology in general (ibid.).

2.3.5.7 A perspective from Singapore: Using coding and robotics in the Grade R learning environment

Singapore has placed a greater focus on technology and engineering in ECE in recent years. The Playmaker Programme, their newest endeavour, focuses on teaching robotics and coding in ELEs (Sullivan & Bers, 2016). Singaporean schools have a complete guideline on the use of information and communication technology in ELEs. The guidelines document titled '*Teaching and Learning Guidelines on the Use of Information and Communication Technology in Pre-School Centres'* is based on how learners learn through play and quality interactions (Ministry of Education, 2017b). The guiding principles are that the use of technology should enhance learners' learning and be based on developmentally-appropriate practices; it should be teacher-guided and teacher-facilitated; and it should guarantee learners' well-being (ibid.). Although there is not any specific mention made of coding or robotics, the curriculum refers to information-processing and interactive technology used by teachers and learners in ELEs, which include commercialised coding toys (ibid.). Teachers have to follow three guiding principles when using these types of technology in the learning environment. Firstly, all technologies used in the learning environment should be concrete and support hands-on learning in a developmentally-appropriate manner. Secondly, teachers should facilitate the learning process of learners by encouraging play, assisted discovery, and collaborative learning. Lastly, the use of technology should not be inappropriate or used in excessive amounts as it could be detrimental to learners' development.

2.3.5.8 A South African perspective: Using coding and robotics in the Grade R learning environment

The draft Coding and Robotics subject is essential for learners' growth because it teaches them how to use digital ICT skills to address problems in everyday life (DBE, 2023). It is focused on the many interconnected fields of engineering and information technology (ibid.). The subject examines tasks involving the solution of problems through logical and computational thinking (ibid.). Figure 2.14 visually represents the five subject areas of coding and robotics as well as the foundation it is built on as adapted from the DBE (2023). In this study, the focus is only on the first three circles as indicated in blue, yellow and green.

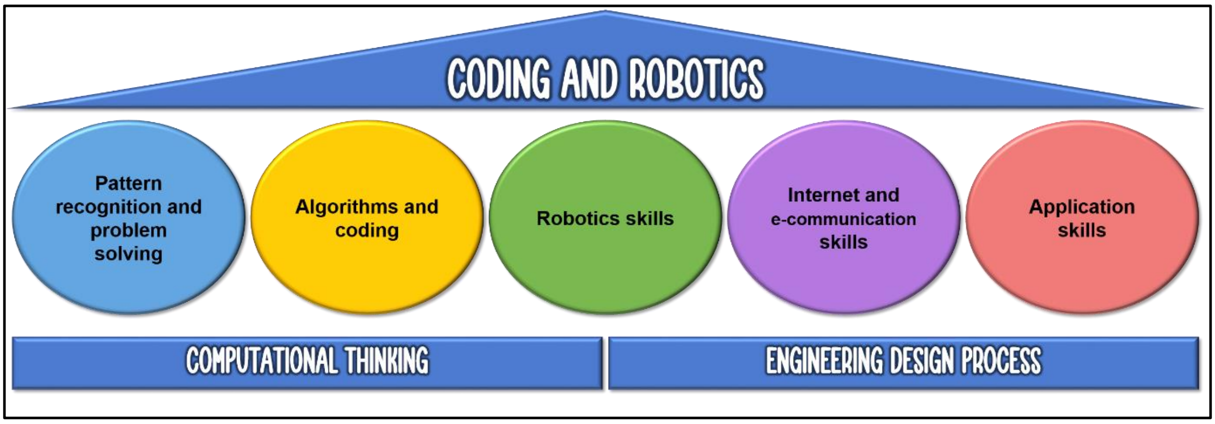


Figure 2.15: The five subject areas of coding and robotics (Adapted from DBE, 2023)

Five study areas have been designated for the FP subject of coding and robotics in the CAPS (ibid.), namely, pattern recognition; algorithms and coding; robotics skills; Internet and e-communicating; as well as application skills. The subjects life skills, specifically beginning knowledge as well as personal and social relationships, furthermore language, mathematics, and coding and robotics are all interconnected and strengthened by the study of coding and robotics as argued by the DBE (2023). The engineering design process and computational thinking are the foundations of the subject methodology.

Through coding and robotics, which foster learners' aesthetic, creative, and cognitive development, the learners are exposed to a variety of knowledge, skills, and values; through activities involving dance, music, drama, and visual art; through knowledge of digital and ICT skills supported by the technological process; and rudimentary knowledge of society and the environment (ibid.). In the CAPS (ibid.), a reference is made to coding by explaining that learners should be able to create logical steps that a robot can follow. These steps should allow an introduction of the input and output to control a robot to move it forwards, backwards, left, and right (ibid.). The learners are also allowed to use code cards that include 'debugging' in terms three and four[14] of the Grade R year. Learners may learn by participating in coding activities and improving their computational thinking abilities (Govind *et al.*, 2020). CAPS does not make mention of using any specific type of robot in the Grade R learning environment.

[14] The Grade R year comprises four terms in an academic year.

The previous sections explored how coding and robotics in the Grade R learning environment are used both in international environments, as well as in the South African context. Table 2.6 provides a summary of how coding and robotics activities transpire in the different countries.

Table 2.6: Grade R coding and robotics in Japan, New Zealand, Singapore, and South Africa

Country	Using coding and robotics in the Grade R learning environment
Japan • Ohnishi *et al.* (2017)	Learning to program a robot with code is prioritised
New Zealand • Ministry of Education (2018)	The emphasis is on digital technologies that include technological practice, technological knowledge, and the nature of technology
Singapore • Ministry of Education (2017b)	• Concrete • Hands-on learning • Developmentally appropriate • Playful • Assisted discovery • Collaborative learning
South Africa • DBE (2023)	• Implementation of routine, structured, and free play activities involving coding and robotics that are both enjoyable and manageable for learners • Recognition and examination of patterns in various forms, such as physical objects, drawings, and symbolic representations, to facilitate problem-solving and prediction-making • Articulation of patterns and relationships using symbolic expressions and grids • Identification of code patterns by observing sequences of lines, shapes, and objects within the coding environment. • Identification and analysis of solutions for specific foundational problems • Development of logical steps and algorithms that robots can follow, including the process of debugging and refining the instructions

Although the international curricula did not provide specific guidelines or learning processes that should be followed, the Singaporean ECE curriculum provided important instructions on how it should be used. In the CAPS (DBE, 2023), information on the sequence of what should be taught in coding and robotics in the Grade R learning environment is included.

2.3.5.9 Teachers' understandings and perceptions of integrating coding and robotics in early childhood education

Vidal-Hall, Flewitt and Wyse (2020) and Papadakis *et al*. (2021) suggest a strong correlation between EC teachers' opinion of technology and their activities in their individual LEs. Teachers are the key role players in the ELE when it comes to building a dynamic environment where coding and robotics and mathematics activities may be integrated (Papadakis *et al.*, 2021). To accomplish this, the teacher must provide the resources and necessary support to increase learner engagement and maximise their potential through various activities in an open and non-judgemental environment to enable a collaborative learning environment that fosters creativity and knowledge creation (ibid.). The teacher's role in creating this type of environment is to ensure that all learning opportunities are learner-centred and to move away from traditional teaching where the teacher is seen as an authoritative figure transmitting knowledge (Papadakis *et al.*, 2021; Yıldırım, 2021).

A number of studies have investigated teachers' beliefs and attitudes in integrating coding and robotics with mathematics due to the crucial role they play; for example, research has found that, while teachers are enthusiastic about coding and robotics, and they recognise its benefits, teachers are wary of utilising robots in the learning environment regardless of their age or gender (Negrini, 2020; Papadakis *et al.*, 2021). According to one study, up to 25% of teachers were opposed to adopting new kinds of technology in an ELE, creating substantial concerns about how they would introduce coding and robotics to young learners if it became necessary (Papadakis *et al.*, 2021).

The foregoing findings were explained by taking into account various systemic barriers that prevent a teacher from incorporating educational technology, and more specifically coding and robotics, into the learning environment. These systemic barriers include overcrowded LEs, inappropriate language of learning and teaching (LoLT), insufficient training opportunities for teachers, and a lack of funds (ibid.).

Many teachers are unsure, anxious, or even afraid of using educational technology in their everyday teaching practice due to a lack of expertise, resources, and institutional support (MacDonald, Huser, Sikder & Danaia, 2020; Papadakis *et al.*, 2021; Yıldırım, 2021). Outside of technology-oriented subjects, teachers seldom obtain enough training (Papadakis *et al.*, 2021), which may lead to misunderstandings about the utility, simplicity of use, and applicability of coding and robotics, as well as a perceived inability to organise such activities, especially when gender preconceptions about STEM ideas are evident. These barriers[15] result in limited learning materials in the learning environment and a reduction of the time available to engage – both actively and mindfully – in coding and robotics activities (McClure, Guernsey, Clements, Bales, Nichols, Kendall-Taylor & Levine, 2017; Negrini, 2020; Tang, Wing Sun Tung & Cheng, 2020; Papadakis *et al.*, 2021; Yıldırım, 2021). Teachers' lack of confidence in using educational technology in the learning environment also leads them to avoid using coding and robotics (Papadakis *et al.*, 2021).

Professional development opportunities are essential for EC teachers to effectively evaluate, create, and monitor technology experiences in their LEs. Often, teachers attempt to determine the developmental appropriateness of technology without a comprehensive understanding of its use. Parette, Hourcade, Blum, Watts, Stoner, Wojcik and Chrismore (2013) conducted research that identified this specific gap and concluded that when teachers were informed about a particular technology, they felt more confident and comfortable using it, resulting in additional efforts to ensure developmentally-appropriate experiences. Teachers must be proficient in using technology to support their teaching, be able to design and implement instructional activities and products using technology, and have a basic understanding of technology and its potential contributions to education in order to successfully integrate it into the LE (ibid.).

This section investigated teachers' perspectives and understanding of factors that may impact the effective implementation of utilising coding and robotics to develop mathematical skills. These are summarised in Table 2.7.

Table 2.7: Possible challenges to successfully integrate coding and robotics with mathematical concepts

Challenge	Literature
Shortage of resources	Khanlari (2014)**;** MacDonald *et al*. (2020)
Development opportunities needed	Bers *et al*. (2013); Parette, Hourcade, Blum, Watts, Stoner, Wojcik and Chrismore (2013);

[15] Including a lack of understanding about the educational benefits of education technology, underfunding, the relatively high cost of educational technology systems, and the absence of particular institutional injunctions.

Challenge	Literature
	Savard and Highfield (2015); Papadakis *et al.* (2021)
Inappropriate LoLT	Papadakis *et al.* (2021)
Lack of confidence and expertise	Khanlari (2014); MacDonald *et al.* (2020)
Lack of funds	Papadakis *et al.* (2021)
Lack of support	Khanlari (2014); MacDonald *et al.* (2020)
Overcrowded learning environments	Papadakis *et al.* (2021)

As seen in Table 2.7, literature substantiates that a shortage of resources; teachers' need for development opportunities; inappropriate LoLT; teachers' lack of confidence and expertise; a lack of funds; a lack of support; and overcrowded LEs are all aspects that could influence the successful integration of coding and/or robotics with mathematical concepts.

2.3.6 Technological content knowledge

TCK refers to a teacher's understanding of how to successfully integrate technology into their teaching and learning activities. It necessitates familiarity with both the content being taught and the technology tools used to convey that content (Schmidt *et al.*, 2009; Howell, 2012). TCK includes the ability to select appropriate technology tools and resources as well as adapt and modify those tools to meet the requirements of individual learners and instructional goals (Schmidt *et al.*, 2009; Howell, 2012). A competent TCK teacher understands how to use technology to promote learning and increase learner engagement and achievement (Schmidt *et al.*, 2009; Howell, 2012).

In this study, TCK focuses on how robotics and coding are integrated with mathematics. I wished to draw a comparison on how coding and robotics is implemented in Japan, New Zealand, Singapore, and South Africa, however, very little was found on how it is implemented in ELEs in an international context. In South Africa, CAPS (DBE, 2023) only describes how the content of coding and robotics should be sequenced and which skills associated with other subjects it might help develop. For this reason, this section provides research of different authors and how they integrated coding and robotics with mathematical concepts.

2.3.6.1 Integrating coding and robotics with mathematical concepts

Coding and robotics has become important tools for education in the modern era of technology (Francis & Davis, 2018). Their integration with mathematical concepts in ECE, particularly in Grade R, holds tremendous potential for promoting computational thinking, critical thinking, and problem-solving skills. Regarding the integration of coding and robotics with mathematics, Bers and Ettinger (2012:182) stated the following:

> "*We believe that robotics could be beneficially integrated into any receptive Kindergarten [Grade R] curriculum, if accomplished in a manner that is sensitive to the needs and abilities of young children*."

Table 2.8 illustrates the integration of coding and robotics with numbers, operations and relationships (see Table 2.3) in Grade R by providing examples of the integration substantiated by the reviewed literature.

Table 2.8: Integrating coding and robotics with mathematical concepts

MATHEMATICAL CONCEPTS	LITERATURE (Examples of integration)	
NUMBERS, OPERATIONS, AND RELATIONSHIPS		
Counting objects	Highfield (2010)	• The learners engaged in both perceptual and figurative counting to determine the number of steps needed to successfully navigate a given pathway with a robot.
	Bers (2021)	• Two learners were involved to code a robot. Their engagement in this activity integrated counting.
	Shumway, Welch, Kozlowski, Clake-Midura and Lee (2021)	• Learners used number words to count either movements or objects. • Learners stated the accurate number of movements or codes when prompted about quantity. • Learners used gestures on a board, grid, or with fingers to indicate a specific number of squares or movements while simultaneously using **number names**.
	Emen-Parlatan, Ördek-İnceoğlu, Gürgah-Oğu and Aslan (2023)	• The activity possessed a predetermined objective, which required the learners to count to direct the robot towards the target location.
Counting forwards and backwards	Shumway *et al*. (2021)	• Learners counted forward from a designated space on the grid, such as the starting point of a robot. This demonstrates the understanding that the count represents the movements of the robot, rather than the individual squares on the grid. • Learners used a sliding or jumping motion on the grid, starting from the designated point, to visually demonstrate counting forward from a specific location in space. This can be likened to the concept of counting on a number line. • Learners verbally articulated that the counting begins after the initial square, clarifying that it is the starting point for the count.
Describe, compare, and order numbers	Highfield (2010:26)	• When comparing movement pathways of a robot, learners often used numerical comparisons. For instance, they would say things like, “I went eight forward and you only went six forward and so mine went further”.
Problem-solving techniques	Highfield (2010)	• Learners engaged in the process of predicting and estimating the precise number of steps necessary for a robot to successfully complete a given pathway. • Learners demonstrated the ability to recall and apply previously acquired knowledge and skills. • Learners used predictive thinking and problem-solving skills to generate multiple solutions for tasks, such as determining the direction of travel of the robot, whether clockwise or counterclockwise.

MATHEMATICAL CONCEPTS	LITERATURE (Examples of integration)	
NUMBERS, OPERATIONS, AND RELATIONSHIPS		
		• Learners evaluated the efficiency of a code in order to determine its effectiveness, thereby fostering critical thinking and analysis skills.
	Emen-Parlatan *et al*. (2023)	• The learners were presented with a variety of distinct problems and were tasked with resolving them either collaboratively or individually. Through these activities, the learners acquired knowledge by formulating commands to navigate and achieve predefined targets using robotics. By actively participating in these problem-solving endeavours, the learners engaged in a hands-on learning experience.
Addition and subtraction	Shumway *et al*. (2021:10)	• Learners physically modify a quantity of codes by adding or subtracting, typically by ±1 block or arrow. • Learners modify a quantity of movements by adding or subtracting, usually by ±1, such as saying "we need one more forward".

As seen in Table 2.8, the literature examined various aspects of learners' engagement with coding and robotics activities involving counting, problem-solving, and mathematical operations. Highfield (2010) found that learners utilised both perceptual and figurative counting to navigate pathways with robots, while also making numerical comparisons when comparing movement pathways. Bers (2021) observed learners coding robots and integrating counting into their engagement. Shumway *et al*. (2021) identified learners using number words to count movements or objects accurately, as well as employing gestures to indicate specific quantities. The authors also noted learners counting forward from designated spaces on grids and clarifying the starting point of the count. Additionally, Highfield (2010) posits that learners were found to engage in problem-solving techniques, such as predicting and estimating the number of steps required for completing pathways, recalling prior knowledge, generating multiple solutions, and evaluating code efficiency.

Emen-Parlatan *et al*. (2023) highlighted learners' hands-on problem-solving experiences, where they formulated commands to navigate robots and achieve predefined targets. Finally, Shumway *et al*. (2021) observed learners physically modifying quantities of codes and movements through addition or subtraction operations. Overall, these studies emphasise the integration of coding and robotics with mathematical concepts, highlighting the multifaceted nature of learners' engagement.

Other literature that explores how coding and robotics can be integrated with mathematics is that of Lydon (2007). The author wrote a textbook named ‘Let’s Go with Bee-Bot’ that can be utilised by teachers to use the Bee-Bot in their ELEs for learners as young as three years old. In this textbook, various activities are presented that include learners’ mathematical skills – such as counting, properties of shapes, estimation, number recognition, mental mathematics as well as ordinal words (ibid.).

2.3.7 Technological, pedagogical, and content knowledge

In light of the literature presented in the previous sections, TPACK refers to the knowledge that teachers possess and use when integrating technology with mathematics. Understanding how technology can be integrated with mathematics, selecting developmentally suitable digital tools and resources, and scaffolding learners’ learning through playful and engaging experiences are all part of TPACK in EC mathematics. This necessitates a thorough grasp of mathematical concepts as well as pedagogical strategies through playful learning, in addition to the effective use of technology to support and enhance these experiences. TPACK is the use of digital tools and resources to create engaging and interactive learning experiences that are aligned with pedagogical goals and subject knowledge in playful teaching. This necessitates that teachers have a solid grasp of how to use technology to support playful learning experiences, create activities that align with learning objectives and curriculum standards, and assess learners’ learning through these experiences. For this reason, this study focused specifically on how teachers can be supported to integrate coding and robotics with Grade R mathematical concepts in a playful manner.

2.4 SUMMARY OF CHAPTER 2

Figure 2.16 is a visual representation that provides a summarised overview of Chapter 2 of the research study. It is also referred to as a start list, which was used in the deductive thematic data analysis explained in Chapter 3 (see 3.6.1 Data analysis of this study). By using the TPACK framework as a start list, I was able to explore how technology can be integrated with pedagogy and content knowledge in a meaningful way in the context of the study.

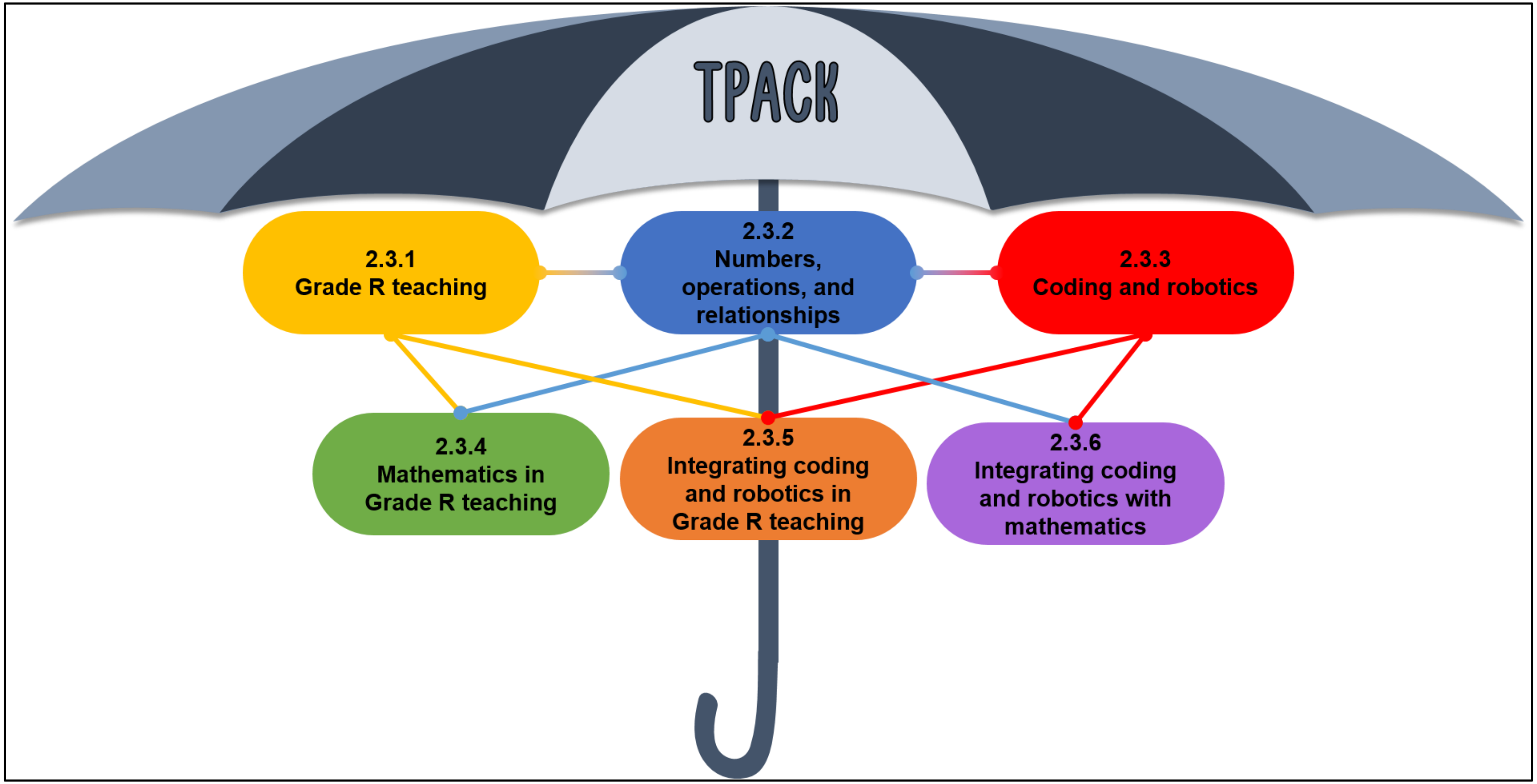


Figure 2.16: Summarised overview of Chapter 2

This chapter researched, analysed, and synthesised the literature pertaining to integrating coding and robotics with Grade R mathematical concepts. The literature was situated within the TPACK theoretical framework and investigated topics related to, and integrated with PK, CK, and TK (see Figure 2.2). The following chapter focuses on this study's research design and methodology, which includes its paradigmatic assumptions, research design and sampling, ethical considerations, as well as how data generation was implemented. The chapter lastly focuses on qualitative data analysis and interpretation through PAR and thematic data analysis.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

In the previous chapter, the literature was reviewed within the context of coding and robotics as well as Grade R mathematical concepts. I also discussed the theoretical framework that is relevant to this study that formed a guideline according to which the literature could be categorised and organised. This chapter discusses the research design and methodology that were employed to answer the research questions of this study. The research methods and procedures used in this study are summarised in Table 3.1.

Table 3.1: Overview of the research methods and processes

METHODOLOGICAL FRAMEWORK	METHODOLOGICAL CHOICES	PRACTICAL IMPLICATIONS
Meta-theoretical paradigm	Theoretical framework	• Interpretivism • TPACK • Research questions
	Research design	
Research paradigm	Interpretivism	• Ontology • Epistemology • Axiology • Methodological preferences
Research approach	Qualitative	Underlying principles
Research strategy	PAR	Cycles
Research methods	Sampling and research site	**Non-probability sampling** • Grade R learning environments in the Tshwane South district of Gauteng that do not necessarily need to be connected to primary schools • Five LEs, ten teacher participants, one EP
	Data generation and documentation	• Semi-structured individual interview schedules • Reflection journal • Collaborative discussion groups • Guided observations • Photovoice • Systematising expert interview
	Researcher's role	• Honest and ethical behaviour • Keeping participants and their data secure and safe • Participants' attitudes and opinions • Contribute to the body of scholarship by sharing my knowledge

METHODOLOGICAL FRAMEWORK	METHODOLOGICAL CHOICES	PRACTICAL IMPLICATIONS
Data analysis	Thematic data analysis	Deductive and inductive reasoning
Quality assurance	Data authentication method	• Credibility • Transferability • Dependability • Confirmability • Reliability
Ethical considerations	Institutional	• Ethical clearance from Faculty of Education • Permission from the Gauteng Department of Education

Sources: Maree (2016); Nieuwenhuis (2016a, 2016b, 2016c); and Etokabeka (2021)

The research paradigm, approach, and type are all included in the research design. The sampling procedure, participants, data generating procedures, data analysis techniques, and ethical issues that influenced this qualitative study are all included in the research methodology. Additionally, the implications for this study were discussed when appropriate.

3.1.1 Meta-theoretical paradigm

Collins and Stockton (2018) assert that theory is used in qualitative research because it clarifies the relationship between the researcher and the phenomena; as a result, it helps a researcher reflect on the reasoning behind methodological decisions. Denzin and Lincoln (2018) posit that theory-free research does not exist, but rather, that theory enables a chance for research to be transferred to a variety of settings, contexts, populations and times (Saldaña & Omasta, 2017; Etokabeka, 2021). Collins and Stockton (2018) maintain that a researcher may not have completed the difficult and required task of unearthing their core operational principles and prejudices regarding their research if they are unable to develop a theoretical framework.

A study's methodological theory, or paradigm, is not the same as the meta-theoretical paradigm (Collins & Stockton, 2018). Researchers can use a paradigm to help them make educated decisions about which methodologies will best help them answer their research questions. Table 3.2 presents the application and methodological considerations of TPACK as the meta-theoretical paradigm in this study.

Table 3.2: The impact of the theoretical framework on the methodological framework

TPACK	APPLICATION AND METHODOLOGICAL CONSIDERATION
	TPACK offers…
Santos and Castro (2021)	• Benefits of technological advancements to both teachers and learners in the learning environment. • A set of skills that teachers must have in order to properly teach learners and use technology. • An attempt to figure out what kind of knowledge teachers need to integrate technology into their LEs, while also recognising the multidimensional, multifaceted, and situational character of teacher knowledge.
• Ruggiero and Mong (2015) • Santos and Castro (2021)	In terms of data generation and analysis, the teachers and external participant should have:
	• Knowledge that technology is available to them as a way to improve education and make it more authentic for learners. • Knowledge that technology must be used to increase learners' learning and, as a result, their performance. • An intuitive understanding of the subtle interplay between the three fundamental components of knowledge (CK, PK, TK). • Understanding of teaching material through the use of relevant pedagogical methods and technology.

3.1.2 Research questions revisited

A research question offers the researcher direction to relevant literary resources as well as a focus for data generation (Ratan, Anand & Ratan, 2019). Although the research questions were comprehensively discussed in Chapter 1 (see 1.5 Research questions), it is deemed essential to reiterate them in this present chapter. The primary research question of this study, "*How can Grade R teachers be supported to integrate coding and robotics with mathematical concepts?*" underpinned this study. The participants in this study, both Grade R teachers and the EP, were immersed in PAR to answer the research question. The following research questions served to understand and describe the teachers' experiences in integrating coding and robotics with mathematical concepts, as well as provide a framework for the successful implementation of this:

3.1.2.1 How does pedagogical knowledge support Grade R teaching?

3.1.2.2 How does coding and robotics support Grade R teaching?

3.1.2.3 How can Grade R mathematical concepts be used in play-based teaching?

3.2 RESEARCH DESIGN

A research design is a plan that is informed by the underlying philosophical assumptions of a study (Nieuwenhuis, 2016c). It aims to specify how participants will be selected, how data generation will be conducted, and how data analysis will be employed (ibid.). Furthermore, the research design can be described as a "logical plan" to connect the research questions with the findings of a research study (Yin, 2009:36). A description of interpretivism as a research paradigm served as the first step in the design of the research for this study. Following that, the qualitative research approach, as well as PAR, were discussed. Finally, the techniques for data generation and processing, as well as trustworthiness and other ethical aspects, were explained.

3.2.1 Research paradigm

As humans, we are always interpreting. In fact, trying to comprehend is our way of being in the world. All research, whether expressly declared or not, is governed by theoretical orientations or ways of interpreting the world that we refer to as paradigms (Cooper & White, 2012). A paradigm, according to Cooper and White (2012), is a set of logically related beliefs, conceptions, or laws that tend to impact our thinking and key assumptions about how the world works. This qualitative study employed interpretivism as a research paradigm since the goal of the study was to understand how teachers can be supported to integrate coding and robotics with specific Grade R mathematical concepts. Furthermore, since teachers were engaged through PAR, their own views formed the ontological and epistemological assumptions of this study – a key characteristic of interpretivist research paradigms (Bonache & Festing, 2020). My epistemological stance in this study stemmed from the belief that Grade R teachers may possess knowledge of how to integrate coding and robotics with specific mathematical concepts, and for this reason, I conducted data generation with these participants.

In education research, a paradigm refers to a researcher's "worldview", which informs the meaning or interpretation of research findings by providing a set of common views (Kivunja & Kuyini, 2017:26). The aforementioned illustrates how a paradigm works as a lens through which one interprets reality. In this way, the goal of my research was to support teachers to integrate coding and robotics with mathematical concepts. In an interpretivist paradigm, the goal of research is to obtain in-depth empathetic insight into participants' realities (Nieuwenhuis, 2016b). Given the aforementioned, I employed an interpretative paradigm to make sense of reality, relying on teachers' subjective perspectives and experiences rather than objective, numerical, and scientific evidence.

In my study, I approached the research from an interpretive perspective, which means that I believe reality is created through the way in which individuals interpret their experiences (Aliyu, Singhry, Adamu & Abubakar, 2015; Kivunja & Kuyini, 2017). This led me to carefully select participants who could create meaning and make sense of their experiences (Aliyu *et al.*, 2015; Kivunja & Kuyini, 2017). By understanding the individual realities of my participants, as well as the social and cultural contexts in which they live, I could better address my research questions.

This ontological perspective also influenced my epistemology, which recognises that knowledge is subjective and shaped by individuals' beliefs, values, and reasons (Aliyu *et al.*, 2015; Kivunja & Kuyini, 2017). In my study, I sought to understand the subjective experiences of my participants by considering their individual realities and how they interpret the world around them.

The combination of my ontological and epistemological assumptions informed the axiology, which suggests that there are no absolute values or truths that exist independently of individuals' interpretations (Aliyu *et al.*, 2015; Kivunja & Kuyini, 2017). Instead, values are socially constructed and shaped by cultural and historical contexts (Aliyu *et al.*, 2015; Kivunja & Kuyini, 2017). Overall, by using an interpretive perspective, I sought to gain a more nuanced understanding of the subjective experiences of individuals, while recognising the role of culture and history in shaping values. This approach allows for a deeper understanding of educational phenomena that consider the diversity of perspectives and experiences of individuals.

3.2.2 Research approach

Cooper and White (2012) argue that the majority of research is organised around two major approaches, namely, qualitative and quantitative research. However, Creswell and Creswell (2018) also mention the importance of the mixed method approach. Even though I appreciate the significance of each of these methods, a qualitative approach allowed me to observe the events and the chosen participants as they were creating knowledge in their natural setting (Lodico, Spaulding & Voegtle, 2010).

As a researcher, I believe that an interpretive paradigm is the best approach to understanding complex social phenomena, as it enables me to understand the meanings that individuals attach to their experiences. Qualitative research methods align well with this paradigm because they allow for the exploration of subjective experiences and perspectives. By collecting and analysing data through methods, such as interviews and observations, I can gain a deeper understanding of the lived experiences of individuals within a particular social context. However, I am aware that this approach is time-consuming and can be challenging to analyse, but I believe that the insights gained from this type of research are valuable in informing policy and practice. It is important that I remain aware of the practical implications of this approach, such as the need for thorough analysis and the importance of respecting the privacy and confidentiality of participants.

Liamputtong (2010) and Nieuwenhuis (2016b) reiterate that qualitative research is socially oriented and naturalistic, which emphasises the importance of understanding individuals' subjective experiences. This formal definition can be supplemented by a more practical guideline: in general, qualitative research incorporates data in the form of words rather than numbers (Punch, 2013).

Qualitative research assisted me in understanding how coding and robotics can be integrated with specific mathematical concepts in this context, since it was based on Grade R teachers' dispositions, opinions, and personal experiences. I used photovoice, a researcher reflection journal, semi-structured individual interviews, collaborative discussion groups, and guided observations to capture data from the participants' lived experiences (Lodico *et al.*, 2010). I also invited an EP to review the guidelines developed from the findings (see 3.3.2.4 Systematising expert interview). In a qualitative study, the research process entails answering research questions and describing activities to obtain required data; deductively and inductively assessing data through the interpretation of knowledge; and constructing new meanings from the data set (Creswell & Creswell, 2018). Table 3.3 uses key characteristics of a qualitative study to explain how it related to my research.

Table 3.3: Key characteristics of this qualitative study

KEY CHARACTERISTICS	DESCRIPTION	INFERENCES FOR THE STUDY
Natural environment • McMillan and Schumacher (2014) • Muzari, Shava and Shonhiwa (2022)	This approach is based on real-life experiences since it focuses on the natural environment where human interactions take place.	I visited five ELEs in the Gauteng area where I conducted data generation with Grade R teachers in their working environments. I also invited an EP to partake in this study, however, the systematising expert interview took place on an electronic platform.
Context sensitivity • McMillan and Schumacher (2014) • Muzari *et al.* (2022)	This is predicated on the concept that the context in which human behaviours occur has a significant impact on them.	
Direct data generation • McMillan and Schumacher (2014) • Muzari *et al.* (2022)	Qualitative researchers prefer knowledge that comes straight from the source. They accomplish this by spending a significant amount of time in close proximity to the places, persons, and materials they are researching.	I gathered a wealth of information by probing and observing the participants in their natural environments. I had a better chance of understanding how teachers integrate coding and robotics with specific mathematical concepts since I spent time with the participants.
Rich narrative discussions • McMillan and Schumacher (2014) • Da Silva, Júnior, Silva and Nunes (2022) • Muzari *et al*. (2022)	Nothing is minor or irrelevant to qualitative researchers when they approach a problem. Every piece of information gathered is supposed to aid in the comprehension of behaviour.	Ten Grade R teachers were recruited to take part in this study. Various data generation methods were used to elicit rich narrative discussions from the participants.
Process orientation • McMillan and Schumacher (2014) • Muzari *et al*. (2022)	Qualitative researchers look for the process by which behaviour occurs, as well as reasons, and not only the outcomes or products.	
Deductive data analysis • McMillan and Schumacher (2014) • Da Silva et al. (2022) • Muzari *et al*. (2022)	Qualitative researchers construct together a picture from the data they collect. The data may appear to be unconnected and too large to make much sense at first, but as the researcher works with the data, more specific insights emerge.	Through deductive and inductive thematic data analysis, I was able to develop a framework to integrate coding and robotics with specific mathematical concepts. Moreover, inductive data analysis supported me to develop the categories, themes, and main theme applicable to this study.
Inductive data analysis • McMillan and Schumacher (2014)		

KEY CHARACTERISTICS	DESCRIPTION	INFERENCES FOR THE STUDY
• Muzari *et al*. (2022)		
Participant perspectives • McMillan and Schumacher (2014) • Da Silva *et al*. (2022) • Muzari *et al.* (2022)	Qualitative researchers attempt to rebuild reality from participant viewpoints, as seen by the individuals they are researching.	Through the data generation, I gathered a variety of viewpoints and a wealth of information from Grade R teachers.
Emergent design McMillan and Schumacher (2014) Muzari *et al*. (2022)	A qualitative researcher will have some notion of what data will be captured and what techniques will be used at the start of the study, but a thorough account of the methodology will be completed after all of the data has been collected. The design is emergent in the sense that it changes over time.	I was able to base the development of the teaching framework on the intricacies of the teachers' lived experiences by visiting several research sites and conducting the data generation procedure with different Grade R teachers. The preliminary framework was furthermore reviewed by an EP to ensure the trustworthiness and triangulation of the findings.
Complexity of understanding and explanation • McMillan and Schumacher (2014) • Da Silva *et al.* (2022) • Muzari *et al.* (2022)	The concept that the world is complex and that there are few straightforward explanations for human behaviour is central to qualitative research.	

As seen in Table 3.3, qualitative research is based on real-life experiences, focusing on natural environments where human interactions take place. Qualitative researchers prefer knowledge straight from the source and gather every piece of information to comprehend behaviour. They analyse the process, reasons, and outcomes, constructing a picture from the collected data. These researchers rebuild reality from participants' viewpoints, and methodology is emergent, changing over time. In this study, ten Grade R teachers were recruited, and various data generation methods were used to develop a framework for integrating coding and robotics with specific mathematical concepts. The framework was developed based on teachers' lived experiences, with input from an EP to ensure the trustworthiness and triangulation of findings.

3.2.3 Research strategy: Participatory Action Research

Teaching is frequently structured using a top-down approach in which instructional information is developed outside of the learning environment and conveyed to teachers, who must then execute the chosen curriculum or material (Ghisho, 2012). Such common patterns are disrupted by PAR, which enables democratic participation in research cycles where new knowledge and understanding are generated by teachers that are safeguarded against practice and policy homogenisation from practitioners and policymakers[16] (Goto, 2010; Schneider, 2012; Lawson, 2015). This is relevant to this study since teachers were immersed in the research cycles to provide their own dispositions, notions, and ideas from their own natural environments, moreover, the findings of this study can only be applied to this specific context. The use of this type of democratic participation in education leads to a relational empowerment practice (Lawson, 2015).

PAR involves ordinary individuals that are concerned or affected by a problem who take the lead in developing and disseminating information about it (Schneider, 2012). More specifically, in this study, the teachers were involved integrating coding and robotics with specific mathematical concepts and to reflect on these activities. This supported the teachers to present what they already know works and assess these examples from other points of view, in order to rethink practice in light of their new knowledge (Conner & Duncan, 2013). Furthermore, PAR is driven by the research participants who are viewed as co-constructors of knowledge, where PAR is intended to result in some form of action, change, or intervention on the topic under investigation (Schneider, 2012). Since PAR aims to improve the practices of the individuals involved, this study specifically aimed to develop a framework for the teachers in this study that they can use (Cohen *et al.*, 2007).

There is evidence that research partnerships within early years learning communities improve outcomes for learners, while also fostering teachers' growth as practitioners of their own practice (Conner & Duncan, 2013). This not only adds to the new knowledge about and for the profession, but it may also improve teachers' capabilities and capacity to add to their own learning as well as the learning of the early years' education community as a whole (ibid.). Therefore, it appears that EC teachers are beginning to accept the idea that involvement in such research projects, when accompanied by support, can give opportunities to consider practice from an informed perspective as opposed to using a more instinctive approach or one that simply reinforces past practices (ibid.). The participants'

[16] Policy and practice homogenisation occurs when mainstream researchers claim their investigations can be applied to local contexts, however, when local contexts are neglected and ignored there are manifest risks and dangers at stake (Lawson, 2015).

opinions, views, and reflections were used during different cycles of PAR to develop a teaching framework consisting of guidelines that they can use. The framework that was developed incorporated the teachers' voices from interviews and their considerations and reflections from the collaborative discussion groups to develop the preliminary framework. A technology and early mathematics external reviewer was also recruited to provide professional feedback on the framework.

3.2.3.1 The application of PAR in this study

As discussed previously, PAR involved four cycles in the study namely, (1) cycle 1, (2) cycle 2, (3) cycle 3, and (4) cycle 4. Each of these four cycles consisted of four phases: (1) action planning, (2) taking action, (3) observation, as well as (4) reflection. PAR enabled me to develop a teacher framework with the collaboration of teachers and an EP that aided in the development of guidelines to integrate coding and robotics with specific mathematical concepts. Figure 3.1 is a visual representation of PAR applied in this study.

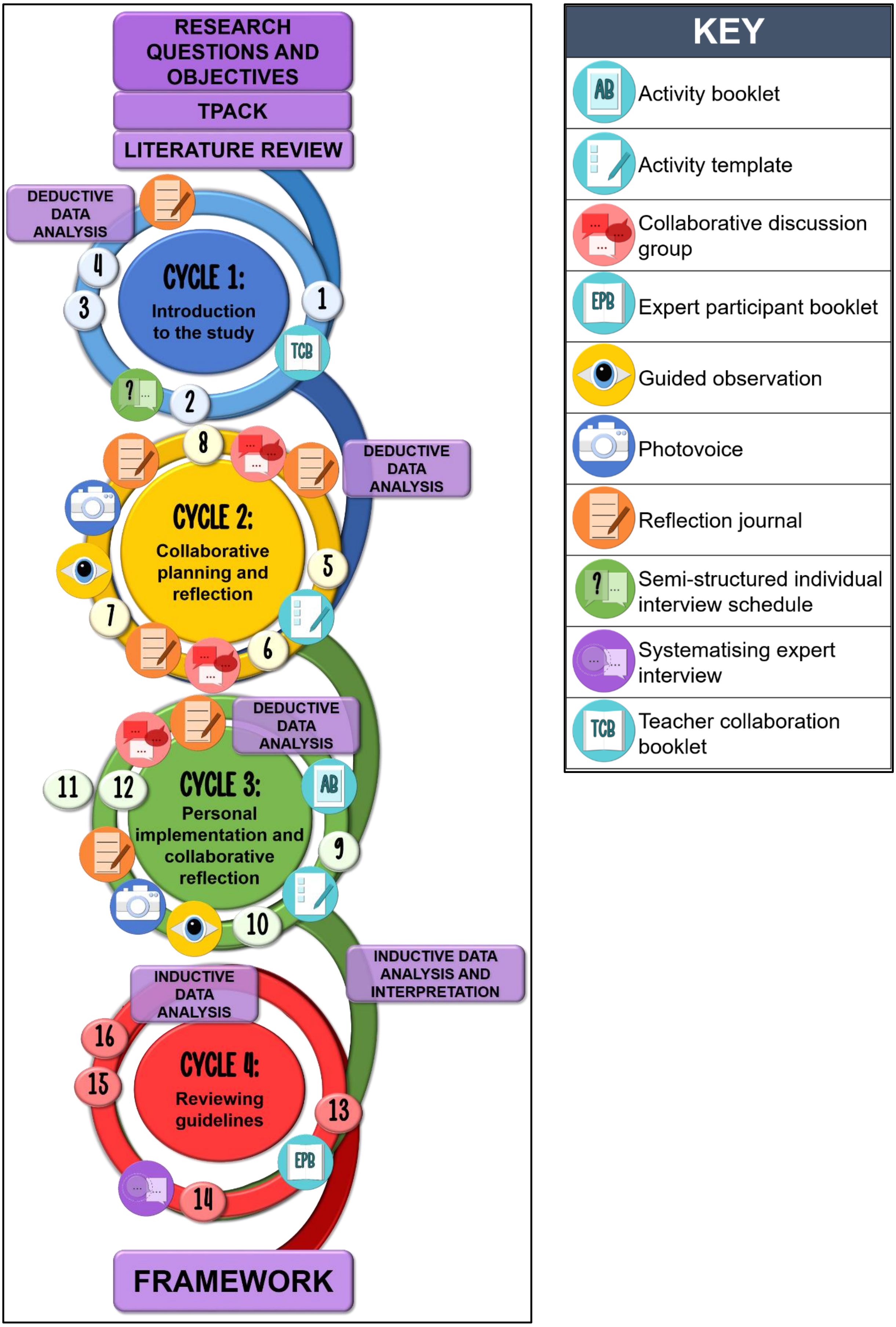


Figure 3.1: A visual representation of this study's research design

In this section, a brief discussion is presented on the various phases encompassed within PAR. Additionally, emphasis is placed on these phases through the use of **grey highlighting**.

PAR commenced after I developed the research questions by investigating the literature. The research questions then allowed me to investigate the literature applicable to this study by using TPACK. When the PRQ had been identified, I decided to conduct data generation at schools that had not had prior exposure to coding and robotics before the commencement of this study. Owing to the nature of these schools, I planned how I can support teachers to know more about the topic without influencing them either negatively or positively. The ***planning*** of this is indicated in phase one of Cycle 1 (blue). I decided that the most neutral way to introduce the teachers to the topic was to develop the TCB. The TCB consisted of factual information pertaining to the topic of the study by providing the teachers with information regarding the pedagogical theories and international best practices; numbers, operations, and relationships; the KCRA approach; what coding and robotics entail; as well as the Bee-Bot. The TCB was developed by using literature from Chapter 2. Furthermore, I met with the teachers in their respective LEs to introduce myself and the study. During this session, I also gave each teacher a printed and bound TCB and I invited them to partake in a semi-structured individual interview schedule that was captured through *Qualtrics*[17]. The semi-structured individual interview schedule is visually represented as the ***action*** phase (number two) in Cycle 1. During the ***observation*** and ***reflection*** phase (numbers three and four) of Cycle 1, I immersed myself in the findings of the interviews through deductive reasoning. It also consisted of my own personal reflection on the implementation of the TCB as well as the outcome of the semi-structured interview schedule. I had to analyse the responses received in the semi-structured individual interviews to realise that the teachers still did not know a lot about the implementation of coding and robotics to teach mathematical concepts.

For the ***planning*** (number five) of Cycle 2, I decided that I had to support the teachers in some way to develop an activity to integrate coding and robotics with specific mathematical concepts. I consequently developed an activity template (AT) that the teachers could use to

[17] Qualtrics is a data collection and analysis tool that allows users to develop and distribute surveys, analyse results, and generate reports (Stevens, 2019).

plan their activities. Number 6 indicates the ***action*** phase where the teachers were allowed to design an activity with their peers in order to ease their understanding and share ideas using the template during this session to develop their activity. They had to discuss the introduction, development, and consolidation of the activity; the theories and/or practices that could be used; which construct of the KCRA approach it used; as well as which skill or knowledge was integrated in the chosen mathematical content area. Phase seven of Cycle 2 (***observe***) was the presentation of the first activity and the reflections thereof. I conducted a guided observation in each teacher's ELE and I took photographs of the activities. After each observation, a reflection journal entry was compiled as well as a concluding entry. Phase eight (***reflection*** and evaluation) consisted of a collaborative discussion group where teachers had the opportunity to reflect on the activities they presented. The teachers were also informed that during the following observation, they would have to develop their own activities by using the AT. I also compiled a journal entry after the discussion group was held.

Cycle 3, indicated in green, also consisted of four phases. Phase nine (***planning***) required the teachers to use the AT and design their own activity. They were allowed to contact me if they had any enquiries regarding the planning phase. Phase 10 (***action***) consisted of the presentation of the activities in each teacher's ELE. Phases 11 and 12 (***observation and reflection***) consisted of a collaborative discussion group, a final journal entry as well as analysing the data. During the last collaborative discussion group, the teachers had the opportunity to not only reflect on the activity they presented but also on the main topic of interest: integrating coding and robotics with specific Grade R mathematical concepts.

Between Cycle 3 and Cycle 4, I compiled all the activities that the teachers developed into an activity booklet (AB) (see Appendix K) that they could use in future. The AB consisted of an explanation of numbers, operations, and relationships; an explanation of what play-based learning is and how teachers implement play-based teaching, which included a summary of the theoretical stances and pedagogical practices applicable to this study; an explanation of the KCRA approach; as well as the 11 activities developed by the teachers. This was shared with all the teachers in an electronic format.

The last cycle, Cycle 4 (indicated in red), required me to employ inductive data analysis and interpretation of the first three cycles. The data analysis supported the ***planning*** phase

(phase 13), which enabled me to develop the first set of guidelines that I wanted the EP to review. I compiled these guidelines in the EPB to provide the external reviewer with an overview before the interview took place. The guidelines were then discussed with the EP during the ***action*** phase (number 14) by employing the systematising expert interview and 90 minutes were used in total. The EP's feedback and comments were ***observed*** during phase 15 where I noted differences and similarities between the teachers' guidelines and the EP's reviewed guidelines. To ***reflect*** and evaluate during phase 16, I incorporated all the necessary changes. PAR was then concluded with the final framework consisting of four guidelines applicable to the context of this study.

3.2.3.2 Strengths and limitations of PAR

All research is informed by strengths and limitations, and PAR is no different. Table 3.4 summarises the possible strengths (green) and limitations (red) of PAR as well as describes the implication thereof in this study.

Table 3.4: The strengths and limitations of PAR

STRENGTHS	**Empowering and actively engaging participants** • Conner and Duncan (2013) • Johnson (2013) • Mubuuke and Leibowitz (2013) • Lawson (2015) • Ebersöhn *et al*. (2016)	The participants, more specifically the teachers, had the opportunity to engage in different cycles of PAR by providing their own dispositions, opinions, views, and partaking in discussions, which brought a sense of empowerment.
	Combination of scholarly work • Mubuuke and Leibowitz (2013:30) • Lawson (2015) • Ebersöhn *et al*. (2016)	The teachers, EP, and I contributed to the various cycles of PAR to create a framework and answer the research questions. It is likely that this collaborative approach contributed "to the ownership of the intervention introduced" and provided teachers with the opportunity to contribute to improvements and innovations that affect their own teaching practices. It also, hopefully, equipped the teachers with the tools they need to take charge of their own teaching and learning requirements in their own LEs.
	Learning and immediate action Mubuuke and Leibowitz (2013:30)	All the teacher participants mentioned that they had not participated in a study that implemented PAR before. As a result, the participants might be encouraged to use the information and skills they have gained to use a similar strategy to begin the change in a collaborative and engaging manner, such as developing a community of practice within their immediate teaching environments.
	Promoting collaboration Mubuuke and Leibowitz (2013)	The participants, specifically the teachers, were engaged in collaborative discussion groups that promoted teamwork and collaboration.
	Obtaining rich contextual data Ebersöhn *et al*. (2016)	The findings of the study report on participants' own perspectives and points of view regarding the topic of the study. This also supports the teachers to plan solutions and acting these out in the learning environment.
	Practical solution • Conner and Duncan (2013) • Ebersöhn *et al*. (2016)	PAR enabled the participants to lead real-life solutions and see tangible outcomes.
LIMITATIONS	**Limited and unpredictable participation** Bennett (2019)	PAR required the participants to be involved in the study for quite some time. Even though it was possible that some participants might not want to invest their time and energy into a project that will take up a lot of time, all the participants that provided informed consent, completed the PAR cycles. I used purposive sampling until I obtained consent from the number of teachers I wanted to include in the study, however, a larger sample might have generated even more information that could have been beneficial to this study.
	A multitude of differences • Conner and Duncan (2013) • Bennett (2019)	There are a variety of interconnected axes of differences within groups and/or communities, including socioeconomic status, gender, age, religion, health, ethnicity, and power. I considered these differences among the participants and

		took into consideration each contribution that a participant provided.
LIMITATIONS	**Earning trust** Ebersöhn *et al*. (2016)	To earn the trust of the participants, I provided them with an introductory session as well as the opportunity to ask questions during the course of the whole study. I also talked to the participants during informal encounters and communicated on the level that the participants require. Lastly, I ensured that I was always on time and dressed professionally.
	Generalisability Ebersöhn *et al*. (2016)	The findings of this study are only applicable to the selected population. However, the opportunity for future research to be conducted or built on this research exists.

The strengths of PAR as listed in Table 3.4, confirmed that it was an ideal choice for my study as it allowed the participants, particularly the teachers, to engage in multiple cycles of PAR and contribute their own perspectives and views. This approach empowered them and gave them a sense of ownership of the intervention introduced. The collaborative approach promoted teamwork and equipped the teachers with the tools they need to take charge of their own learning requirements. The study's findings were based on the participants' own viewpoints and allowed them to plan solutions and see tangible outcomes. This experience of PAR could encourage participants to use similar strategies for change and development in their teaching environments. However, I recognised that PAR required a significant time investment from the participants, and I took steps to mitigate this by ensuring that all participants who provided informed consent completed the PAR cycles without feeling coerced. Additionally, I used purposive sampling to select the number of teachers I wanted to include in the study, while considering the potential benefits of a larger sample size. I also took into consideration the interconnected axes of differences within the participant group, such as socioeconomic status, gender, age, religion, health, ethnicity, and power, and valued each contribution made by a participant. To establish trust with the participants, I provided an introductory session and opportunities for questions throughout the study, communicated effectively, and remained punctual and professional. While the findings of this study are specific to the selected population, it presents an opportunity for future research to build on its findings.

Brinkmann and Kvale (2008) assert that the researcher must maintain moral integrity when conducting research. In their opinion, it may be difficult for a qualitative researcher to maintain neutrality while doing research, therefore, moral integrity may be called into question. Smith and Noble (2014) believe that the researcher should maintain objectivity and neutrality by acknowledging and eliminating any potential preconceptions, expectations, or past experiences that may influence the study, using reflective approaches, such as member checking and triangulation (see 3.7.1 Credibility). To be a successful qualitative researcher, one must build a picture by combining practice, theory, and experience (ibid.). In this study, my role was to facilitate and plan each cycle in PAR, and to include the participants by eliciting their experiences and notions to guide the study. This ensured that I maintained objectivity since data generation was conducted with the participants by allowing them to form part of the process.

PAR researchers also have other roles that they need to acknowledge and uphold when conducting research. Firstly, Conner and Duncan (2013) assert that the PAR researcher should ensure that there is ongoing communication between the researcher and the participants. The communication should be informed by the participants' dispositions that foster reflection and discussions about practices. This was upheld in this study since the development of the framework and answering the research questions were based on the reflections and dispositions of the participants. The participants were also engaged in various ways throughout PAR to ensure that they had a platform to voice their beliefs. Furthermore, Conner and Duncan (2013) add that the PAR researcher should provide the participants with a multitude of activities for these discussions, which, in this study, was upheld through the use of interviews, observations, and discussion groups.

Second, PAR researchers should rely on how they and the participants might collaborate to develop new information in a synergistic manner (Conner & Duncan, 2013; Johnson, 2013; Mubuuke & Leibowitz, 2013; Lawson, 2015; Ebersöhn *et al.*, 2016). This was also upheld in this study since I created various opportunities for the participants to generate new knowledge regarding the topic of the study. I ensured that all participants knew that their views were valued, even if these views were different than my own or to those of the other participants.

Watters, Comeau and Restall (2010) propose that PAR researchers have distinct roles that require different skills and ways of implementation. Firstly, the researcher should take on the role of the principal investigator. This role implies that the researcher should supervise research activities, provide input for data generation and data analysis methods, and facilitate decision-making among participants. Secondly, the researcher should take on the role of coordinator to guide, support, and facilitate the participants during the research process. The PAR researcher is also seen as a manager and organiser since it is the researcher's responsibility to ensure that data generation is conducted and recorded appropriately. Furthermore, this role also requires scheduling different opportunities for data generation according to the participants' availability. These roles required me to have organisational, interpersonal, and computer skills as well as to delegate tasks, facilitate discussions, and possess knowledge of PAR, research methods, and data generation methods.

3.3 RESEARCH METHODS

The methodology comprises a number of steps, including selecting the research site, recruiting participants, as well as describing the procedures used to generate and analyse the data sets (Creswell & Creswell, 2018). These are discussed in this section.

3.3.1 Participant selection and research sites

In qualitative research, sampling focuses on identifying a few key participants who can provide the most information and have the greatest impact on the development of relevant knowledge in a study (Patton, 2015). In this study, the participants' contributions were determined through non-probability sampling, in other words, the participants were not selected at random (Persuad, 2010; Etikan, Musa & Alkassim, 2016). Purposive sampling, often used in qualitative research, involves selecting participants based on their knowledge or their possession of a given attribute; the sample is selected for a specific reason (Maree & Pietersen, 2016). Andrade (2021) posits that purposeful sampling cannot be used to represent the views of the larger population, due to the responses being subjective and biased. Nevertheless, Andrade (2021) adds that even though the views cannot be generalised to a larger population, the criteria to select participants need to be elucidated in order for the reader to have a thorough understanding of the population. Moreover, Tongco (2007) is of the opinion that to minimise bias, the researcher cannot apply the findings of the study beyond the sampled population. For this reason, I chose to indicate a detailed explanation of the population that I chose to partake in this study. Moreover, as mentioned previously, the findings of this study only apply to these selected participants and cannot be generalised to indicate the views of a large population.

Purposive sampling enabled me to access individuals that have a wealth of knowledge regarding coding and robotics may be integrated with specific mathematical concepts. Creswell (2014) identifies important areas that researchers should consider when conducting participant and research site selection, which are: 1) knowing the research site and why it was chosen for the study, 2) knowing how data generation and data analysis will be conducted, as well as 3) knowing the participants and how the study could potentially benefit their practices. I used purposive sampling because it corresponds with the character of qualitative studies and it allowed me to recruit specific participants.

3.3.1.1 Research site

The research site that was selected for this study were five ELEs. Three of these LEs were preschool LEs and the other two were LEs connected to a primary school. All of these LEs were in the Tshwane South district of Gauteng and neither the teachers nor the learners were exposed to using coding and robotics prior to the study. As mentioned previously, Grade R is meant to provide the foundation on which all other mathematical comprehension and skills are built, therefore, I decided to conduct research within this context. This is also the context of the TPACK framework, which influences all the other segments.

3.3.1.2 Sampling and selection criteria

Three types of participants were selected for this study, namely, ten practising Grade R teachers, one EP, and the learners in the teachers' ELEs. However, the Grade R learners were considered as secondary participants, who are defined as:

> "*A secondary participant is someone who was not initially designated as a primary participant in a study, but about whom information is gathered from persons who are primary participants*" (Given, 2008:804).

The Grade R teachers developed and presented activities that integrated coding and robotics with specific mathematical concepts, therefore, although the learners were not directly involved in the study, it was necessary for the teachers to observe how the learners' understandings and skills were affected. As previously stated, purposeful sampling encompasses inclusion and exclusion criteria (Daniel, 2012). These criteria were applied to the selection of Grade R teachers and an EP, as shown in Figure 3.2.

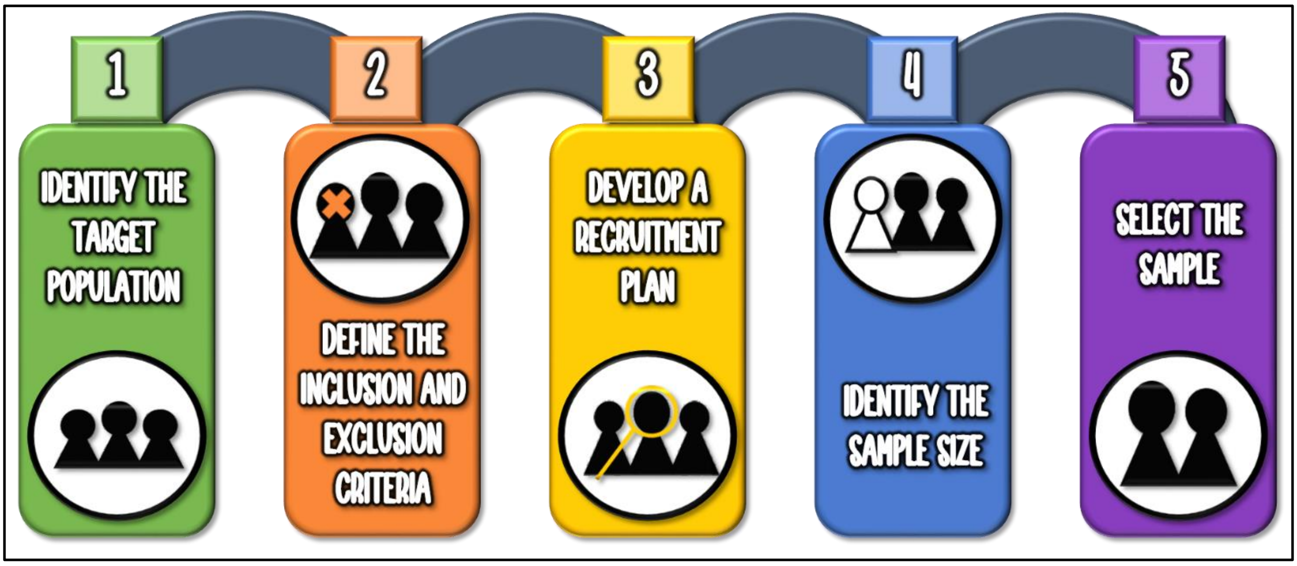


Figure 3.2: Selecting purposive samples
(Adapted from Daniel, 2013)

The target population had already been identified as teachers and the EP (see Figure 3.2: number 1, green). The criteria that were adhered to when selecting participants were: that the teachers had to be Grade R teachers and they had to be proficient in either English or Afrikaans since these are the languages I am competent in. The teachers also had to be willing and able to partake in the study. To be eligible as an EP, candidates must have completed a doctorate in education and published one or more peer-review articles that relate to coding and robotics or the use of technology in ELEs (see Figure 3.2: number 2, orange). Furthermore, it was a prerequisite for the participants to have an affiliation with a university or tertiary institution other than the University of Pretoria. Numbers 3, 4 and 5 are discussed in the next section.

3.3.1.3 Selection process

I contacted each ELCs principal via email as well as cell phone calls to determine their availability and their interest (see Figure 3.2: number 3, yellow). After I saw each principal, and he or she agreed that data generation could be conducted at their ELC, I met with the teachers face-to-face, to obtain their contact information. I then contacted each teacher through a phone call (see Figure 3.2: number 3, yellow). The teachers' availability was determined for a first meeting to discuss the study with them. Initially, I only sought to include eight teachers in the study but in the end, ten teachers agreed to participate in the study (see Figure 3.2: numbers 4 and, blue and purple).

During this introductory session, I asked the teachers to provide informed consent. I ensured that I explained the nature of the study to all role players by providing them with the TCB. The learners in each teacher's learning environment also formed part of this process and informed assent was obtained from them after receiving informed consent from their parents or caregivers. I left the parental consent forms with the teachers and received them on the day of the first guided observation. In some instances, the parents did not provide consent and these learners did not form part of the guided observations, they were moved to another teacher's LE or they were allowed to play freely.

After the first three cycles of PAR, I identified and approached the EP via email. I explained to the external reviewer what the aims, significance and purpose of my research were and obtained informed consent electronically. The external reviewer's participation only commenced when the cycles of PAR had been concluded with the ten teachers.

Table 3.5 provides an overview of the inclusion and exclusion criteria employed to identify the participants and research site of the study.

Table 3.5: The inclusion and exclusion criteria employed in this study

	Description	Amount	Inclusion criteria	Exclusion criteria
Research site	Early learning centres	5	• Tshwane South district of Gauteng in South Africa • Grade R learning environments	• Grade 1 classrooms • Grade RR learning environments
Participants	Teachers	10	• Teaching Grade R learners • Competency in English or Afrikaans	• Foundation Phase or primary school teachers
	Learners *(secondary)*		• Must be learners in one of the selected teacher's ELEs	
	External participant	1	• Doctorate in education • Published and peer-reviewed article relating to the topic of the study • Affiliation with a university of tertiary institution other than the University of Pretoria	

The section provides an overview of the inclusion and exclusion criteria used to identify the participants and research site of the study. The research site consisted of five ELCs in the Tshwane South district of Gauteng, South Africa. The inclusion criteria for learners were that they must be in Grade R LEs, while exclusion criteria included Grade 1 classrooms and Grade RR LEs. The ten selected teachers were required to teach Grade R learners and be competent in English or Afrikaans, with exclusion criteria including Foundation Phase or primary school teachers. The one external reviewer included in the study needed to have a doctorate in education and have published and peer-reviewed articles relating to the topic of the study. The next section focuses on data generation.

3.3.2 Data generation

The second factor to consider under methodological considerations is data generation. "Data collection" is a popular and established term used to describe the process of how researchers obtain data (Bryman, 2016:10), however, Goldkuhl (2019) believes that this term implies that the data is already established and only needs to be collected, whereas the term 'data generation' suggests that one needs to purposefully arrange a situation in which comprehensible questions must be presented to generate and capture the data. For this reason, I use the term ‘data generation’, as the situations which yielded meaningful data were organised by myself. These situations refer to the occurrences in which data generation took place (Bryman, 2016) and in this study, it refers to photovoice, a reflection journal, semi-structured individual interviews, collaborative discussion groups and guided observations (see Figure 3.1). Table 3.6 summarises the various data generation approaches, their types, and the benefits and limitations of each one and how I addressed these limitations in this study.

Table 3.6: Summary of qualitative data collection (Adapted from Creswell, 2009)

Instrument	Type	Advantages	Limitations
Documents	Reflection journal (researcher)	It is a non-obtrusive source of knowledge that may be accessed whenever it is convenient for the researcher.	The limitations of using documents as a data generation technique include transferring the entries electronically as well as that information might be missing from the entries. After each entry I transferred it electronically by scanning and typing it, this ensured that all the entries were available for data analysis when I required it. The entries were also only used to substantiate or contradict other findings.
Interviews	Semi-structured individual interview schedules Collaborative discussion groups Systematising expert interview	This method is useful when participants cannot be observed directly. It also allows participants to provide historical information and it allows the researcher to steer the course of the enquiry.	Interviews have the constraint of delivering filtered information based on the perspectives of participants and providing information in a specified location rather than in a natural field environment. Furthermore, the presence of a researcher may influence responses, and not everyone is as eloquent or as insightful as the next. Firstly, I overcame these limitations by observing the participants in their natural contexts and also met them for the first time in their respective environments. Secondly, because ten participants were invited to engage in the study, they could share insights and express their reservations. I offered a safe environment for the participants to engage in because I always treated them with respect and provided opportunities for reflection.
Audio-visual materials	Photovoice	It draws the viewer's attention visually.	Although the limitations of photovoice suggest that it could be difficult to decipher and that it could be seen as an intrusive method of data generation, I overcame this by firstly obtaining informed consent and assent from the relevant parties. Where applicable I also hid the participants' faces from the photographs by either cropping the picture or blurring their faces. Secondly, I used both deductive and inductive data analysis to decipher the photographs taken.
Observations	Observer as participant (guided observations)	The researcher receives first-hand knowledge of the participants and can keep track of information as it occurs through observations. Observation can also disclose unexpected aspects and be beneficial in delving into topics that participants may find difficult to address.	Limitations of observations are that participants may consider the researcher as invasive; confidential information may be observed that the researcher is unable to divulge; and the researcher may lack adequate listening and observation abilities. I overcame these by constantly asking the participants when it would be most convenient for them to meet. This allowed them to plan and prepare ahead of time. In order to ensure the accuracy of my observations and listening, I provided the participants with the transcribed data for verification. This step was taken to ensure that their statements had been accurately transcribed. Finally, no private information was released that could have an impact on this study because the participants were not required to provide sensitive information other than information related to constructing a participant profile.

Each of these data generation instruments are now briefly explored but the detail of each of these is only explained in Chapter 4. Permission was sought prior to the commencement of PAR from all parties involved (see Appendices A to E).

3.3.2.1 Photovoice

Various authors (Hannaway, 2016; Agbagbla, 2018; Jordaan & Pieterse, 2020) refer to photovoice or reflexive photography as the method by which people are enabled to take pictures of people or activities that are related to the purpose of a study. I photographed static representations of moments of time that integrate coding and robots with numbers, operations, and relationships. Despite the fact that teachers were encouraged to participate in photovoice, their facilitation of the learning activities resulted in only me employing photovoice. Following each observation, I showed them these photographs of their respective activities. These photographs included how the Grade R teacher integrated coding and robotics with specific mathematical concepts. The purpose of these photographs was to provide visual representations regarding the topic of the study, and also, to elicit discussions among the participants during the collaborative discussion groups. I did not show any individual faces in the photographs for the collaborative discussion groups to maintain confidentiality.

All the necessary precautions were taken to guarantee that the participants provided informed consent before participating. The learners also provided informed assent[18] after their parents provided informed consent first. The precautions included that the participants had to note that the photographs would be used in the study but that their identities would remain unknown (see Appendices A to D). Consent forms were given to the teachers, while assent forms were created expressly to demonstrate that the minor was willing to engage in the study and understood what he or she would be expected to accomplish as part of it.

[18] A consent form is provided to participants who are over the age of 18, whereas an assent form is a written document provided to participants who are under the age of 18 (Harding, 2013).

3.3.2.2 Reflection journal

Cohen *et al*. (2007) emphasise the importance of using a reflection journal to document progress and reflections regarding the practices that are being researched, as well as the process thereof. The reflection journal allowed me to capture my “thoughts, ideas, feelings, and reflections” (Göker, 2016:63). Given the acknowledgement in qualitative research of the existence of multiple realities, I took the initiative to address potential methodological bias by practicing reflexivity and reflecting upon my own experiences and viewpoints. In doing so, I outlined my personal perspectives, thus maintaining a critical awareness of how they may have influenced the research process. According to the US Department of Education Office of Educational Technology (2016:8), individuals should ask themselves the following questions when reflecting:

- **Content**: Did the activity support learners to learn, engage, express, imagine or explore?
- **Context**: What kinds of social interactions occur before, during, and after the usage of DT (for example, conversations with the teacher or peers)? Does it add to, rather than take away from learners’ learning opportunities and natural play patterns?
- **Individual learner**: Is this DT a good fit for this learner's needs, abilities, interests, and stage of development?

The aforementioned questions were incorporated into my reflection journal, which served as a consistent tool throughout the various PAR cycles. I used the reflection journal to record my personal observations and findings, which were subsequently shared with the participants to mitigate bias. This approach aided in identifying any underlying biases or assumptions that may have been overlooked, fostering an open process where assumptions could be questioned and a consensus could be reached.

3.3.2.3 Semi-structured individual interviews

Semi-structured individual interviews are defined as purposeful conversations between interviewers and interviewees to generate information on a particular issue (Persuad, 2010). Interviews, according to Creswell (2009), give participants the chance to talk about the interpretations and understandings they have of phenomena. Additionally, it offers individuals an opportunity to articulate their understanding in their own words. During semi-structured interviews, researchers can record detailed information, allowing meanings and interpretations to emerge (Lodico *et al*., 2010; Leedy & Ormrod, 2014). Semi-structured interviews are recommended for circumstances that require structure and guidance so that probing questions can be asked (Harding, 2013).

The interview questions for this study were open-ended, which allowed the participants to express their thoughts and opinions (see Appendix G). In retrospect, it is important to note that some of these questions should have been phrased differently, considering that the focus was on the integration of coding and robotics with mathematics, as well as how teachers can be supported in this process, rather than solely on how teachers teach or implement specific theories or international practices. These questions focused on supporting Grade R teachers in integrating coding and robotics with mathematical concepts. The questions inquired about the learners' exposure to technology; the training opportunities provided to teachers; the influence of technology on learners' learning and teachers' teaching; the advantages and disadvantages of using technology-enhanced tools; the relevance of coding and robotics in Grade R; the utilisation of KCRA; and the implementation of theories and practices. By examining the influence of technology on mathematical content and play-based teaching methods for numbers, operations, and relationships, the study aimed to provide valuable insights into supporting Grade R teachers in effectively integrating coding and robotics with mathematics in the ELE.

For the semi-structured individual interview schedule, I captured the participants' responses through *Qualtrics*. *Qualtrics* is an online software application that allows users to create and distribute surveys, as well as collect and analyse data from survey responses (Stevens, 2019). Although *Qualtrics* can analyse results, I exclusively utilised it to capture the responses obtained during the interviews. Each interview took approximately 30 – 45 minutes to complete and included 20 questions. The information from the interviews was then analysed. Some of the concepts and terms in the interviews were unknown to the teachers; for this reason, these concepts and terms were elucidated in the TCB when I met them the first time. The terms that were unknown to the teachers were PAR, KCRA, coding and robotics, as well as the Bee-Bot.

3.3.2.4 Systematising expert interview

The systematising expert interview was informed by the data generation and analysis of data from photovoice, interviews, and collaborative discussion groups. Van Audenhove (2007) describes the three types of expert interviews, as well as the strategies and procedures used in conducting them. Table 3.7 categorises the three types of expert interviews according to when they are used and how they should be conducted.

Table 3.7: The three types of expert interviews

Types of expert interview	When it is used	The strategies and procedures used
Explorative expert interview	• First orientation in a new field • Preparing interview topics	• Open and unstructured • Topics vary according to the expertise of the interviewee
Systematising expert interview	• Focuses on the exclusivity of expert knowledge • Focuses on comparability	• Systematic and full disclosure of information • Allows the interviewee to answer extensively
Theory generating interview	• Focuses on the subjective aspects of the expert's knowledge • The interviewee is more than an information source	• Relates more to the function of the expert and less to knowledge • Questions focus on motives, beliefs, and routines

I chose to conduct a systematising expert interview, which focuses on the uniqueness of the expert and process knowledge, in this case, a person with a specialised understanding of technology education and early mathematics. The EP, who had specialised knowledge of integrating technology and mathematics, reviewed the preliminary framework to see if there were any major shortcomings or omissions. The expert interview lasted 90 minutes and was conducted via Microsoft Teams. The interview featured seven questions, however, each question allowed for the expert's own perceptions and ideas to ensure that the expert offered extensive information (see Appendix H).

Several researchers have advocated for the use of the Delphi technique, which includes the involvement of experts, in research studies (Brooks, 1979; Yousuf, 2007; Ruppert & Duncan, 2017; Cataldi & Sena, 2021). The Delphi technique is a group-based process that involves a researcher and a panel of identified experts who provide input on a specific topic. Its purpose is to reach a consensus and gather insights on future trends and projections by systematically collecting information (Yousuf, 2007; Ruppert & Duncan, 2017). The technique proves particularly valuable when seeking the opinions and judgments of experts and practitioners (Yousuf, 2007; Cataldi & Sena, 2021).

However, it is important to note that the present study did not follow the traditional Delphi technique involving multiple experts. Instead, an external reviewer, referred to as the expert participant in the study, was included as part of the development of the teaching framework for integrating coding and robotics in Grade R mathematics (see 3.4.2 Developing a framework to integrate coding and robotics with Grade R mathematical concepts). The inclusion of the external reviewer as an EP aimed to ensure the validity, applicability, and clarity of the teaching framework, rather than seeking consensus from a panel of experts. It is crucial to highlight that the EP's involvement was solely based on their expertise and contribution to the refinement of the teaching framework through a structured expert interview process.

While recognising the importance of involving multiple experts in the Delphi technique, the specific context and objectives of the study led to the inclusion of an EP in the form of an external reviewer. This approach aligned with the strategies and procedures employed to systematise the expert interview and enhance the credibility of the teaching framework for integrating coding and robotics with Grade R mathematics.

3.3.2.5 Collaborative discussion groups

Researchers gather data in collaborative discussion groups by conversing with participants about their experiences (Nyumba, Wilson, Derrick & Mukherjee, 2017). Moreover, in collaborative discussion groups, the participants can also assist with the design of research initiatives and the contributions of participations are used to make decisions (Alvarez, Alarcon & Nussbaum, 2011). For this reason, this study employed collaborative discussion groups as a data generation method. In total, four collaborative discussion groups were conducted during the different cycles of PAR (one of these was held with only two participants as the other participants had prior commitments). To elicit a community of practice, all participants from the various research sites were invited to participate in discussion groups. These discussions took place on Google Meet because the participants were from separate research sites, and they had the opportunity to discuss photographs, reflection journal entries, and observations. There was no set time limit for these discussion groups, however, each session was initially scheduled for two hours.

3.3.2.6 Guided observations

Observations cover events in real-time; these happenings are documented as they occur (Yin, 2009). By using observations, I was able to capture instances when teachers integrated coding and robotics with specific mathematical concepts. Yin (2009) posits that observations hold a weakness in that it is open to observer prejudice and subjectivity due to non-reflexivity. For this reason, I recorded the events exactly as they took place by analysing the photographs, and asked the participating teacher to read through the notes, look at the respective photograph, and provide feedback. The Grade R teachers were observed in this study as they integrated coding and robotics with specific mathematical concepts. Nieuwenhuis (2016c:91) asserts that action research projects, such as PAR are typically informed by the participant as an observer, because the researcher becomes part of the research process and works together with the participants to design intervention strategies. I, therefore, immersed myself in the observation process to gain an emic perspective[19] as a participant observer.

Before the observations commenced, I explained to the teachers the content of coding and robotics in Grade R as discussed by the DBE (2023) and how to use the Bee-Bot. I also provided them with an opportunity to develop any activity that integrates coding and robotics with either numbers, operations, or relationships. I did not place any restrictions on what the teacher can and cannot do. Being a participant as an observer, I was able to provide the teacher with support during the presentation of the activity if needed. In total, two observations were conducted in each participant's learning environment, except for T9 and T10 who opted to conduct their activities together – each session being between 15 to 35 minutes, or the time that was needed by the teacher for the activity. The teachers were observed and special attention was given to how they integrate coding and robotics with specific mathematical concepts. The learners were indirectly involved so I could note how their knowledge, understanding, and skill development were affected.

[19] An emic viewpoint, which allows a person to frame a thought, idea, or condition before expanding on it, is required to understand how people interpret the world around them (Given, 2008).

3.3.2.7 Data generation summary

In the previous sections, I discussed the different data generation methods that were used in the study. A condensed timeline of data generation is presented in Appendix O. Table 3.8 provides a summary of when each of these methods was implemented during the different cycles of PAR.

Table 3.8: Data generation during the different cycles of PAR

Instrument	Duration, platform, and recording of data	Amount	Goal
CYCLE 1: INTRODUCTION TO THE STUDY			
Introductory session	• 30-45 minutes • Face-to-face	5	Provide participants with information before data generation commences
Semi-structured individual interview	• 30-45 minutes • *Qualtrics*	1 participant per interview (10 in total)	Preliminary understanding of integrating coding and robotics in Grade R with numbers, operations, and relationships
CYCLE 2: COLLABORATIVE PLANNING AND REFLECTION			
Collaborative discussion group	• 2 hours • Google Meet • Recorded via Google Meet	All participants at once	Developing an activity that integrates coding and/or robotics with mathematics
Guided observation	• 15-45 minutes • Face-to-face • Photovoice • AT	1 participant per observation, except T9 and T10 (9 in total)	Observe how teachers integrate coding and/or robotics with mathematics
Collaborative discussion group	• 1 hour-2 hours • Google Meet • Recorded via Google Meet	All participants at once	Reflection of first activity
CYCLE 3: PERSONAL IMPLEMENTATION AND COLLABORATIVE REFLECTION			
Guided observation	• 15-45 minutes • Face-to-face • Photovoice • AT	1 participant per observation, except T9 and T10 (9 in total)	Observe how teachers integrate coding and/or robotics with mathematics
Collaborative discussion group	• 2 hours • Google Meet • Recorded via Google Meet	All participants at once	Reflection of second activity and PAR as a whole
CYCLE 4: REVIEWING GUIDELINES			
Systematising expert interview	• 90 minutes • Microsoft Teams • Recorded via Microsoft Teams	1	Ensure trustworthiness by reviewing the guidelines of the preliminary framework

This study was conducted in four PAR cycles, as seen in Table 3.8. After completing the first three cycles, an expert review was conducted to ensure the trustworthiness of the guidelines that were produced in collaboration with the Grade R teachers. The EP reviewed the preliminary framework's guidelines, ensuring that it was based on sound and reliable principles. The development of the guidelines was also based on my own ontological stance as a researcher. In the following section, I introduce the data analysis process.

3.4 DEDUCTIVE AND INDUCTIVE THEMATIC DATA ANALYSIS AND INTERPRETATION

In essence, data analysis is the process of interpreting the meaning of data by reflecting on the findings and how they relate to the existing literature as well as the purposes of the study and the research questions (Creswell, 2015). The purpose of data analysis is to find trends, comparisons, and contrasts within a set of data (ibid.). Thematic analysis supported me to identify, analyse, organise, describe and narrate themes within the large set of data obtained (Braun & Clarke, 2012). A theme represents some kind of patterned reaction or meaning that arises from grouping categories together and then analysing the data during data generation (Fereday & Muir-Cochrane, 2006; Braun & Clarke, 2012). Azungah (2018) created a model that was applied in this study to demonstrate how deductive and inductive reasoning was used to analyse the qualitative data. The deductive approach employs an organising framework, often known as a start list, that contains topics for the coding process employed in the analysis, with the anticipation that the data will contain certain essential ideas (Bradley, Curry & Devers, 2007; Pearse, 2019; Tracy, 2020). Deductive qualitative research differs from other qualitative methodologies in that it uses the theoretical arguments produced from a review of the literature as its starting point and then applies these arguments to the gathering and analysis of data (Fereday & Muir-Cochrane, 2006; Pearse, 2019).

On the other hand, the inductive method solely draws on participant experiences as the analysis' driving force. The term inductive analysis refers to approaches that predominantly use precise readings of raw data to extract concepts and themes (Thomas, 2006). It requires carefully looking over the data line-by-line and giving codes to paragraphs or sections of texts as notions develop that are pertinent to the research questions (Thomas, 2006; Braun & Clarke, 2012). It is used to capture "the most empirically grounded and theoretically interesting factors" (Schüßler, Rüling & Wittneben, 2014:147) and is a recursive process that requires switching back and forth between data analysis and the literature to make sense of developing notions (Neeley & Dumas, 2016). In inductive analysis, "*although the findings are influenced by the evaluation objectives or questions outlined by the researcher, the findings arise directly from the analysis of the raw data, not from a priori expectations or models*" (Thomas, 2006:239). Figure 3.3 visually presents the preparation, organisation and data analysis process applied in this study, as adapted from Azungah (2018:392).

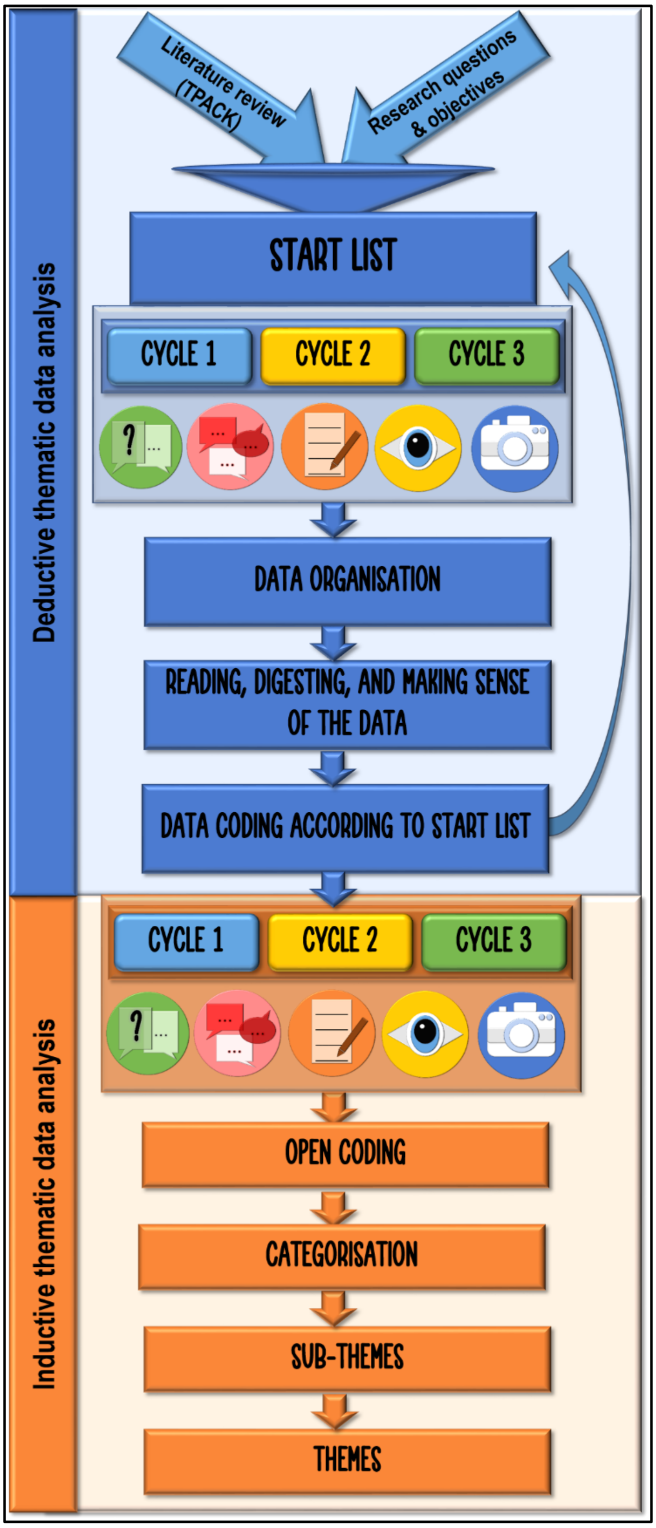


Figure 3.3: The preparation, organisation and data analysis process (Adapted from Azungah, 2018)

Deductive data analysis began by using the literature from Chapter 2, research questions, and objectives to develop a start list, which guided the creation of data generation instruments for Cycles 1, 2, and 3. Within each cycle, the data generation instruments were reviewed, organised, and coded according to the start list. Before Cycle 4, inductive data analysis was conducted by revisiting each instrument and starting anew. During inductive thematic data analysis, open coding, categorisation, and the creation of sub-themes and main themes were used. This process was carried out without the influence of the start list to identify any new findings emerging from the data. The following section provides a detailed account of this process.

3.4.1 Data analysis of this study

During data analysis, I initially adopted a deductive approach. With the deductive approach, initial codes were drawn from the existing literature on the topic of enquiry. Based on familiarity with the body of existing literature, the methodology made certain key assumptions about the data (Thomas, 2006; Bradley *et al.*, 2007; Azungah, 2018). A start list was used to code the data into categories, which were derived from the main constructs of TPACK, as discussed in the literature review of Chapter 2. Table 3.4 presents the start list that I used, as previously presented in Chapter 2 (see 2.4 Summary of Chapter 2). Each data generation instrument also addressed each of these categories.

Table 3.9: Using the TPACK framework to create a start list for deductive reasoning

Construct of TPACK	Literature review (see Chapter 2)	Start list
PK	Play-based teaching theories and best practices	Grade R teaching
PCK	• Policy and curriculum for Grade R mathematics • Play-based mathematics teaching	Mathematics in Grade R teaching
CK	Grade R mathematical concepts	Numbers, operations, and relationships
TCK	Integrating coding and robotics with mathematics	Integrating coding and robotics with mathematics
TK	• 21st-century skills • Digital literacy • 21st-century teaching skills • STEAM education • Play-based digital teaching • Coding and robotics	Coding and robotics
TPK	Play-based digital learning	Integrating coding and robotics in Grade R teaching

Table 3.9 presents the start list that I used to organise the data, namely, Grade R teaaching (PK); Mathematics in Grade R teaching (PCK); numbers, operations, and relationships (CK); integrating coding and robotics with mathematics (TCK); coding and robotics (TK); and, integrating coding and robotics in Grade R teaching (TPK).

This list was created before data generation and inductive analysis commenced and stayed the same throughout the first three cycles of PAR. For each instrument used in each cycle of PAR, I transferred the categories onto a blank A2 page by using the visual representation of TPACK in Figure 1.2, as TPACK was used to organise the literature review. Each instrument's data was then organised by transcribing it and, if necessary, translating it. In order to make sense of the entire collection of data and comprehend "what is going on" (Morse, 1999:404; Braun & Clarke, 2012; Azungah, 2018) through reflexivity, open-mindedness, and adhering to the logic of participants' narratives, I first immersed myself in the data, absorbing and digesting it. These passages were then cut out and pasted onto the A2 page by categorising the data according to the start list. I also made sure to indicate which passage belonged to which participant (if necessary). The last step of deductive reasoning was to code the data according to the start list by circling important terms.

Following the development of data clusters from the deductive analysis, an inductive analysis was also carried out in accordance with Thomas (2006) by carefully reviewing the data (Gale, Heath, Cameron, Rashid & Redwood, 2013; Azungah, 2018) to ensure that all significant aspects of the data were recorded (Gale *et al.*, 2013; Charmaz, 2014; Azungah, 2018). By adopting the inductive method, themes were extracted from the raw data by using an Excel spreadsheet without the risk of imposing a predetermined conclusion (Bradley *et al.*, 2007; Braun and Clarke, 2012; Azungah, 2018). By using clustering, overlapping categories were found, refined, and reduced (Braun & Clarke, 2012; Pearse, 2019). For each data instrument I employed, a separate analysis was done before categories were established. In order to create these categories, I triangulated data from all the data generation instruments to group data that had a similar meaning (Neeley & Dumas, 2016; Vuori & Huy, 2016; Azungah, 2018). After establishing the codes, the analysis' following step entailed figuring out how the categories related to one another in order to combine them into theoretically separate sub-themes (Lawrence & Dover, 2015; Azungah, 2018).

This stage of the analysis was also iterative, switching between the categories and the evolving data patterns until conceptual patterns for sub-themes were established. As a result, sub-themes used "researcher-centric concepts, themes, and dimensions", whereas the categories used "informant-centric terms" (Gioia, Corley & Hamilton, 2013:18; Azungah, 2018). The "facts" of the research, in the words of Van Maanen (1979:540), are informant-centric terms. These are the "routinized practical activities actually engaged in by members of the studied organisation" that have been interpreted (Van Maanen, 1979:542).

As a result, categories that are informant-centric indicate how informants understand their actual experiences with subsidiary human resource activities. On the other side, researcher-centric terms are the researcher's interpretations of participants' interpretations of their personal experiences with the topic under study. They "represent what could be called interpretations of interpretations", according to Van Maanen (1979:541). In order to condense the sub-themes into aggregate theoretical dimensions, I evaluated how the sub-themes interacted with and linked to one another within a larger context (Lawrence & Dover, 2015; Petriglieri, 2015; Neeley & Dumas, 2016; Azungah, 2018).

3.4.2 Developing a framework to integrate coding and robotics with Grade R mathematical concepts

In a general sense, Vojislav, Vlajić, Milic and Ognjanovic (2011:1) define a framework as a "skeleton" or an outline for a particular domain that includes guidelines that need to be implemented. Furthermore, Jimoyiannis (2012) mentions that a framework should consist of more than just a series of activities and the result thereof, but should also focus on the reflections and collaboration of role players.

To create guidelines, Fulton and Britton (2011) suggest considering multiple perspectives and diverse contexts, and involving stakeholders in their development. This ensures that guidelines align with the community needs and values, as well as the experiences and backgrounds of learners, teachers, and parents. Gentry, Sallie and Sanders (2013) recommend adopting a dimensional approach to teaching that accounts for learners' developmental needs and learning styles. Teachers should personalise lesson plans, and use differentiated instruction, and other methods to accommodate learners' unique needs (ibid.). Hubert (2021) also emphasises the importance of interdisciplinary approaches in teaching, which involve integrating multiple subject areas to increase engagement and help learners make connections between different topics.

Furthermore, Haleem, Javaid, Qadri and Suman (2022) stress the importance of incorporating digital literacy skills and investigating the role of technology in improving education and learning experiences. A dimensional approach is necessary to create comprehensive and adaptable teaching guidelines in a framework for integrating coding and robotics with mathematics in a Grade R context. Teachers should consider cultural context, socioeconomic variables, developmental requirements, learning styles and interdisciplinary connections (Darling-Hammond, Flook, Cook-Harvey, Barron & Osher, 2020; Hubert, 2021). Additionally, teachers should explore the potential of technology in improving teaching and learning. By considering these various dimensions, teachers can create more effective and engaging learning experiences that meet the diverse needs of their learners (Stephen & Plowman, 2013).

As mentioned previously, to create the comprehensive and adaptable teaching guidelines, I needed to take a dimensional approach. I followed Fulton and Britton's (2011) recommendation to consider multiple perspectives and diverse contexts, and involve stakeholders in the framework's development to ensure they align with community needs and values, as well as the experiences and backgrounds of learners and teachers. I also explored the potential of technology in improving teaching and learning, as emphasised by Haleem et al. (2022). Additionally, I took Hubert's (2021) advice and considered interdisciplinary approaches in teaching to increase engagement and help learners make connections between different topics through integration. To create more effective and engaging learning experiences that meet the diverse needs of the learners, I considered cultural context, socioeconomic variables, developmental requirements, and interdisciplinary connections, as recommended by Darling-Hammond *et al*. (2020) and Hubert (2021).

Implication for this study

When developing guidelines for the integration of coding and robotics with mathematical concepts, I drew on a range of educational theories and international best practices. To ensure that the guidelines were comprehensive and effective, the teachers were encouraged to consider the needs of learners with different learning styles, by including concrete, kinaesthetic, representational, and abstract learning experiences.

By drawing on a dimensional approach that considered cultural context, socioeconomic variables, developmental requirements, and interdisciplinary connections, the framework aimed to create guidelines that align with community needs and values. Additionally, I explored the potential of integrating technology, specifically coding and robotics. By doing so, I aimed to ensure that the guidelines are adaptable and effective for a range of learners.

As mentioned previously, Danielson (2007:1, 6, 10) advocates using a framework since it provides teachers with a “road map” to enrich, evaluate, and improve their practices.

A guideline is defined as “advice about how to do something” by The University of Cambridge (2004:302). This definition is adopted in this study because the framework contains guidelines on how coding and robotics can be integrated with numbers, operations, and relationships. Shekelle, Woolf, Eccles and Grimshaw (1999) state that the approaches individuals use to produce guidelines should ensure that the implementation thereof will result in the anticipated outcomes. Additionally, the development of a framework can take into account outcomes, topic implementation, and professional development for teachers (Jackl, Baenen & Regan, 2017). The steps needed for the development of guidelines identified by Shekelle *et al*. (1999) should be addressed by firstly determining and refining the subject area; secondly, forming and leading working groups for the formulation of guidelines; the group then evaluates the evidence about the subject using a systematic review; subsequently, the evidence is then grouped into a preliminary framework; and lastly, the framework is reviewed externally. In this study, the development of the framework addressed all these steps and also included an external participant (EP) to ensure that the content is valid, applicable and clear (ibid.). Figure 3.4 visually represents the aforementioned steps.

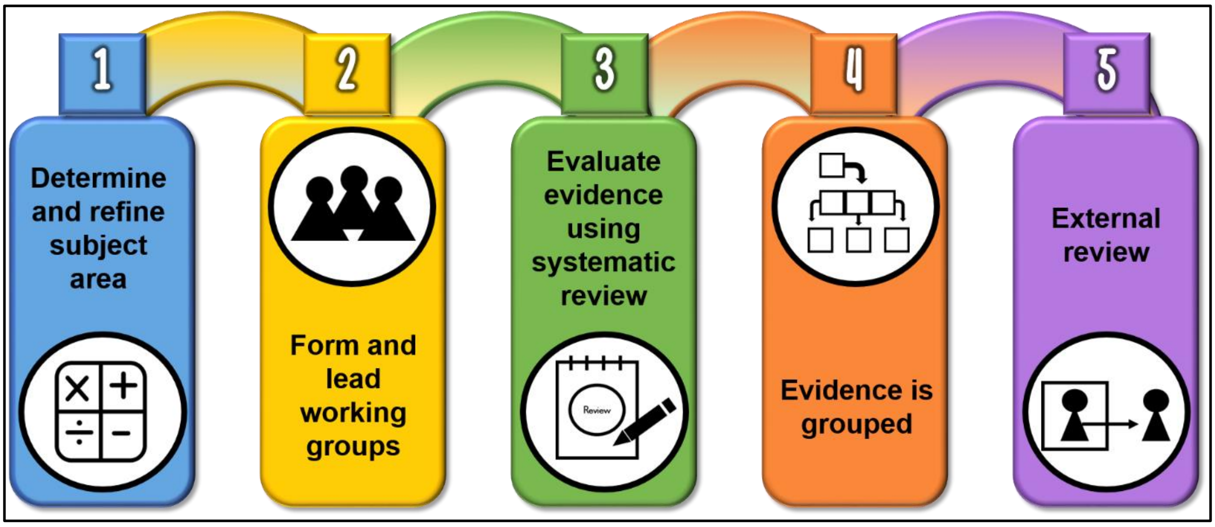


Figure 3.4: Steps taken to develop a framework with guidelines

The first step in developing a framework has already been addressed; the subject area of numbers, operations, and relationships. Secondly, the participants were immersed in PAR, which included collaborative discussion groups to formulate the guidelines. The information gathered from the participants was then evaluated using a systematic review through inductive thematic data analysis and interpretation. The findings were then grouped and organised to form a preliminary framework. Finally, the preliminary framework was externally reviewed by using a systematising expert interview with an

EP specialising in ECE with a specific focus on the integration technology and early mathematics.

3.5 ENSURING THE QUALITY AND RIGOUR OF THE STUDY

As an overarching quality criterion, trustworthiness can be defined as the process by which a study assures that its research findings are conscientious and transparent (Nieuwenhuis, 2016a). Various authors (Yin, 2009; Creswell, 2014; Nieuwenhuis, 2016a, Korstjens & Moser, 2018) posit that each qualitative study needs to be tested through concepts, such as reliability, credibility, transferability, dependability and confirmability to ensure that trustworthiness is upheld. The following section focuses on the definition and a short discussion of these concepts to explain how each was ensured in the study.

3.5.1 Credibility

Maree (2016), and Korstjens and Moser (2018) define credibility as the level of trust that can be placed in the accuracy of the research findings. This is determined by the extent to which the study represents believable information derived from the participants' original data and whether there is a correct interpretation of the participants' original opinions. Credibility also relates to the research process, in other words, determining how data and analysis procedures are carried out and what steps are taken to ensure that no significant data is left out (Bengtsson, 2016). Four strategies to ensure credibility is discussed by Korstjens and Moser (2018) which are; prolonged engagement, persistent observation, triangulation, and member checking.

Firstly, to ensure prolonged engagement, I invested ample time to become acquainted with the various LEs and to create a sense of trust with the participants (ibid.). The data generation of this study was a lengthy process, therefore, I was able to engage with the participants over a long period of time. Moreover, all participants attended an introductory session prior to the commencement of data generation. The purpose of these sessions was to explain the nature of the study and provided the participants with an opportunity to ask or clarify concepts that they did not understand (Anney, 2014; Korstjens & Moser, 2018).

Secondly, persistent observation is defined as identifying the qualities and features that are most important to the problem or subject under investigation, and on which you will concentrate your efforts (Korstjens & Moser, 2018). The development of the codes, categories, and sub-themes supported the analysis of the findings. I immersed myself in an extensive cycle of data analysis through deductive and inductive reasoning, which required me to read and reread the data, analyse it, revise it, and update the concepts as was needed.

Triangulation is explained as the use of multiple data generation procedures to ensure authenticity (Elo, Kääriäinen, Kanste, Pölkki, Utriainen & Kyngäs, 2014; Yin, 2016). Korstjens and Moser (2018) identify three types of triangulation, namely, data triangulation, investigator triangulation, and method triangulation. All three these types of triangulation were upheld in the study. Firstly, data triangulation is defined as using multiple sources of data over a period of time, from different settings, and different individuals (ibid.). This study conducted data generation by using PAR, which took place over the course of ten inconsecutive weeks spread over approximately one year. Data generation was conducted with ten Grade R teachers as well as an EP. Secondly, investigator triangulation refers to when one codes, analyses, and interprets the data (ibid.). This was upheld since both the teachers and the EP were invited to comment on the findings that produced a preliminary framework. Lastly, method triangulation refers to using various methods of data generation, which were also adhered to in the study since I used photovoice, a reflection journal, semi-structured individual interviews, collaborative discussion groups, guided observations, and a systematising expert interview.

The last strategy to ensure credibility is member checking. Member checking can be defined as a procedure that allows participants to confirm that the information derived from data generation is accurate and not falsified (Birt, Scott, Cavers, Campbell & Walter, 2016). This also allows for the rectification of any misinterpretations as well as the clarification of any facts that may have been overlooked (ibid.). Since PAR was employed in this study, which sought active participation and collaboration from the participants, member checking was employed continuously. Every session created during the PAR cycles was centred on allowing the participants to offer feedback on the results that were produced. Additionally, I provided thorough descriptions to convey the reality and experiences of the participants in order to ensure the study's transferability, allowing readers to make use of the information that is pertinent to them.

3.5.2 Transferability

Transferability is defined as the degree to which a qualitative study's conclusions may be applied to a variety of contexts and subjects, and it is supported by the use of thorough descriptions and purposeful sampling (Bengtsson, 2016; Korstjens & Moser, 2018). I provided a detailed description of descriptive data, including the study's context, setting, sample, sample size, sample strategy, demographics, socioeconomic characteristics, inclusion and exclusion criteria, data generation methods and findings, excerpts from the collaborative group discussions and semi-structured individual interview schedules, and photographs. The nature and characteristics of the participants, as well as the research site, were also outlined so that the same findings from one group may also be applied to other people (Bengtsson, 2016). Purposeful sampling was used to define the criteria for participants in my study (see 3.5.1 Participant selection and research sites). As a result, it is once again emphasised that the results of this study and the way that coding and robotics are integrated with mathematical concepts only apply to the context of this research.

3.5.3 Dependability and reliability

Dependability and reliability, which minimise errors and biases, ensure that it will be possible to replicate the findings of a study if a researcher employed the same study in the future (Yin, 2009; Gushta & Rupp, 2012; Creswell, 2014; Morgan & Ravitch, 2018). Yin (2016) adds that dependability also includes the review of the data by other individuals that make suggestions. Anney (2014) posits that when dependability and reliability are implemented in a study, the researcher should include triangulation, member checking, and an audit trail. An audit trail can be explained as an in-depth explanation of the data generation and analysis procedures (ibid.).

I implemented several strategies in my study to ensure the dependability and reliability of the research findings. One of the strategies I used was triangulation, which involved using multiple data generation methods to gather and analyse data. This approach helped to validate the findings by providing different perspectives on the same topic, and it reduced the risk of bias, which increased the accuracy of my results. Another strategy I employed was member checking, which involved sharing the results with the participants (the transcribed data of the interviews, observations, and discussion groups were shared with the participants) to get their feedback and ensure that their perspectives were accurately represented in the study. By doing this, I was able to enhance the credibility of the findings and ensure that the research was grounded in the experiences of the participants.

Additionally, I included an audit trail in my study, which provides a detailed description of the data generation and analysis procedures. This approach helped to ensure the transparency of the research process and may facilitate replication by other researchers in the future. It also helped to identify potential errors or biases in the research process, which ensured that the findings were based on a rigorous and systematic approach. Overall, by using triangulation, member checking, and an audit trail, I was able to ensure the dependability and reliability of my study. These strategies helped to promote consistency in the findings, minimise errors and biases, and increase the likelihood of replicating the study in the future.

3.5.4 Confirmability and objectivity

Confirmability and objectivity are maintained when the participants shape the findings of a study to eliminate any potential bias or competing interests (Nieuwenhuis, 2016a). Two methods for enhancing confirmability are triangulation and minimising the impact of researcher bias (Anney, 2014; Nieuwenhuis, 2016a). To end bias among researchers, such researchers must be aware of their own prejudices (Nieuwenhuis, 2016a). The deeper their engagement with the research participants and the study, the greater the danger of bias entering into the results. The issue of bias can be solved by implementing member checking (ibid.). By asking the participants for input on the data gathered when appropriate and inviting an EP to examine the guidelines that resulted from the initial data analysis and interpretation, I maintained confirmability and objectivity.

3.5.5 Quality assurance

Tracy and Hinrichs (2017:3-4) developed a model to demonstrate credibility, rigour, and other elements of quality assurance in qualitative research. These "big-tent criteria" are delineated by eight dimensions, as summarised in Table 3.10 in the context of this study.

Table 3.10: The elements of quality assurance

QUALITY CRITERIA	MEASURE EMPLOYED	QUALITY CRITERIA	MEASURE EMPLOYED
Deserving topic	• Meaningful • Interesting • Contemporary • Admissible	**High level of rigour**	• Concept clarification • Rich descriptions and explanations
Sincerity	• Cognisance of researcher bias • Transparency about methods and limitations • Honesty	**Credibility**	• Rich descriptions • Specific details • Triangulation • Continuous self-reflection • Member checking
Resonance and relationship	• Awareness of wider audience • Real-life generalisations • Transferable conclusions	**Substantial input**	• Sound methodology • Practical application
Uphold ethical standards	• Ethical processes • Informed consent • Confidentiality	**Meaningful coherence**	• Consistency • Address research questions • Employ appropriate data generation methods

Adapted from Etokabeka (2021)

In my study, I ensured that I addressed all of the important dimensions of qualitative research quality, as delineated by Tracy and Hinrichs (2017). My topic was deserving of investigation, and I approached it with sincerity, and with a deep commitment to understanding the nuances of the issue at hand. I made sure that my research resonated with my participants and established a strong professional relationship with them, which helped me to gather rich data that truly represented their experiences. Upholding ethical standards was of the utmost importance to me, and I took great care to ensure that I obtained informed consent from my participants, protected their privacy and confidentiality, and conducted the research in a responsible and ethical manner (see Appendices A-E; J).

To ensure a high level of rigour and credibility, I employed various techniques, including member checking and triangulation. I also paid close attention to ensuring meaningful coherence in my data analysis, by using a systematic approach that involved coding, categorising, and interpreting the data in an organised and logical way. Throughout the research process, I made substantial input into the study, ensuring that I engaged in self-reflection and critically examined my own biases and assumptions. By doing this, I was able to ensure that my findings were authentic and genuine and that I remained accountable for the quality of my research.

Overall, I approached my study with a deep sense of responsibility and commitment to excellence. By addressing all of the important dimensions of qualitative research quality, I was able to ensure that my research was rigorous, credible, and meaningful.

3.6 ETHICAL CONSIDERATIONS

Each study needs to be informed by ethical considerations (Maree, 2016). Researchers in the field of ethical education play a key role in the development, execution, and dissemination of research; as a result, they must uphold and treat these duties with the highest dignity (Ravitch, 2018). Ravitch (2018) posits that the ethical dimensions of a researcher's reflexive nature should be determined through certain considerations. Firstly, an ethical researcher should be informed by avoiding the 'expert-learner' dynamics and relationships. Researchers should avoid the assumption that they are more knowledgeable and possess more expertise than the participants of a study (ibid.). This 'expert-learner' dynamic and relationship can be pre-empted by employing a relational approach[20] to research. In addition, Ravitch (2018) suggests that education researchers consciously construct research boundaries by carefully assessing and reflecting on the methodological consequences of how they position themselves in the educational spaces and interactions at the

[20] A relational approach to research focuses on the relationship between researchers and participants, which encapsulates the roles, power structures, and language used (Ravitch, 2018).

centre of their work. I took all the precedent aspects into consideration during the data generation process.

3.6.1 Informed consent

In order to protect the rights, values, needs, and preferences of participants, a researcher must obtain their consent (Silverman, 2017). In order to ensure that the participants' welfare is prioritised and that they are comfortable with the study's procedure, informed consent is characterised by constant contact between the researcher and the participants (Owens, 2010; Hays & Singh, 2012). Mukherji and Albon (2018) suggest that when participants provide informed consent, they should have the following understandings: the research aim; the purpose of their involvement; their responsibilities and roles; the importance of their role in member checking; their anonymous participation; data generation methods and storage; as well as how the data will be used. Usually, a researcher will provide participants with a letter to obtain informed consent containing this information (ibid.); as was the case in this study. Similarly, Harding (2013) defines informed consent as written agreements that participants offer, without coercion, to participate in a study. Prior to data generation, researchers must obtain the participants' permission; as a result, participants can only partake after they have provided their consent. Table 3.11 outlines the criteria proposed by Harding (2013) and Arifin (2018:30) to ensure informed consent.

Table 3.11: The criteria of informed consent

CRITERIA OF INFORMED CONSENT	IMPLICATION FOR THE STUDY
Competency in providing consent	Since I gave the participants the information they needed about the study, I included responsible and capable volunteers in my study who were capable of making the best decisions.
Voluntary participation	The permission slip that I included in the consent forms asked the participants to indicate their informed consent to take part in the study by signing it. Additionally, this stipulated that participants could disregard a question or refuse to respond at any moment without repercussions and that they would be audio recorded as well as that photovoice would be used (Ravitch, 2018).
Disclosing all information and understanding the study's intention	The consent forms contained all the necessary information, including how I would conduct the study, its purpose, any potential advantages to their (the participants') involvement, and how the results would be used.
Permission	Principals, teachers, caregivers, the EP, and Grade R learners were provided with a consent or assent letter.

I recruited responsible and capable volunteers for my study after providing them with all the necessary information about the study. I included a permission slip in the consent forms, which asked the participants to indicate their informed consent to take part in the study by signing it. I made sure to let the participants know that they could disregard a question or refuse to respond at any moment without repercussions. I also informed them that I would be using photovoice and audio recording. The consent forms contained all the important details about the study, including its purpose, methodology, and potential benefits of participation, as well as how the results would be used.

I provided consent letters to the principals (see Appendix A), teachers (see Appendix B), caregivers (see Appendix C), the external participant (see Appendix E), and assent letters to the Grade R learners (see Appendix D). Throughout the study, I made sure to follow all ethical guidelines and take appropriate measures to protect the privacy and confidentiality of the participants.

3.6.2 Confidentiality and pseudonyms

Confidentiality refers to how the data will be used, who will have access to it, and how the data will be retrieved (Creswell, 2014). Ravitch (2018) is of the opinion that privacy or confidentiality is upheld by not disclosing participants' names or unique attributes, but rather by using pseudonyms and not providing any other identifying information (Mukherji & Albon, 2018; Ravitch, 2018). To uphold this critical ethical standard, Arifin (2018) suggests that researchers utilise pseudonym identities and verbatim quotations. Each participant received a pseudonym that indicated their participation order. The pseudonym for the external participant is 'EP'. Furthermore, the raw data for this study has been stored safely and securely, only my supervisor and I have access to it (Harding, 2013).

3.6.3 No harm or risk to participants

Multiple examples of unethical research studies undertaken in the past have thrown a shadow over research involving humans (Barrow, Brannan & Khandhar, 2021). For this reason, clear guidelines for human-subject research procedures were established and all research needs to abide by these guidelines. This study adhered to these guidelines by summarising the issue of concern and how it was addressed in this study, in Table 3.12.

Table 3.12: Issues of concern when using research that involves human subjects

ISSUE OF CONCERN	IMPLICATION FOR THE STUDY
Human dignity • Sims (2010) • Franklin, Rowland, Fox and Nicolson (2012) • Miracle (2016) • Harding (2013) • Arifin (2018:30) • Chiong, Leonard and Chang (2018)	• I ensured that the participants understood that they have a right to decide whether or not they wanted to participate in the study. • I ensured that the participants knew that their withdrawal or refusal to participate did not hold any consequences. • I provided multiple opportunities for the participants to ask questions and I also ensured that they understood what was expected of them.
Voluntary participation • Sims (2010) • Franklin *et al*. (2012) • Miracle (2016) • Harding (2013) • Arifin (2018) • Chiong *et al*. (2018)	• I ensured that the participants knew that their withdrawal or refusal to participate did not hold any consequences. • I did not provide the participants with any incentives to participate in the study.
Disclosing all information • Harding (2013) • Arifin (2018)	• The consent letters provided all pertinent information to the participants. This contained information, such as how I would conduct the study, the study's aim, the potential advantages of their involvement, and how the data were to be used.
Beneficence Johansen, Aagaard-Hansen and Riis (2008)	• I ensured that the participants were free from harm and discomfort. • I ensured that the participants were protected from exploitation.

Participants in this study were solely invited to disclose their thoughts regarding the topic at issue; I did not become involved in any way that would have harmed them. Second, all data generation techniques were either carried out in the teacher's ELE or on an electronic platform where they would feel comfortable and at ease. However, the first possible risk I addressed was that participants may have felt uneasy when presenting an activity while I was watching them. In order to prevent this, I went through the objectives of the study with the participants during the introductory session. By giving each participant a consent letter, I was able to gain their trust. Additionally, I took part in the observations as a participant observer, so that the teacher would not feel as though I was passing judgement on what was going on because I was there to offer support if necessary. Additionally, because it was their first time, the participants may have been under pressure to present an activity involving coding and robots. To overcome this, I gave teachers the freedom to arrange the observations and interviews at a time that worked for them. I also assured them that they could contact me for any support if deemed necessary. The collaborative discussion groups were likewise scheduled based on everyone's availability.

To summarise, ethics is concerned with what constitutes moral conduct when undertaking research (Barrow *et al.*, 2021) The Faculty of Education Research Committee at the University of Pretoria provided its ethical approval in order to guarantee that all guidelines and procedures were followed. Secondly, I requested approval from the DBE (see Appendix J), and from principals, teachers, and legal guardians/parents of learners, using consent forms. Table 3.13 depicts the entire process of applying ethical considerations as well as when each step was conducted during the study.

Table 3.13: Ethical considerations in the study

POINT IN RESEARCH PROCESS	ETHICAL CONSIDERATIONS
Prior to the study	• The research problem that I identified speaks to the reality of the participants, especially since coding and robotics will be implemented in the curriculum in the near future. • I obtained ethical clearance from the university's ethics committee in the form of a certificate. • I obtained approval from the DBE. • I identified possible ELCs to participate in the study.
When the study commenced • Harding (2013) • Arifin (2018)	• I approached the identified ELCs. • I explained the objective and nature of the study to the participants. • I determined the disposition of teachers and Grade R learners regarding their voluntary participation. • I provided letters of consent to the school, participants, and caregivers. The learners were given assent forms that they completed while I was present. • I respected their decision regarding their voluntary participation. • I scheduled a date for the introductory sessions and the interviews.
Data generation phase • Anney (2014) • Nieuwenhuis (2016a)	• I respected the research site and I did not disturb the environment. • I treated all participants with respect and integrity. • I minimised researcher bias. • I scheduled dates for the observations and collaborative discussion groups according to the participants' availability. • I provided a letter of consent to the EP to determine voluntary participation. • I respected the decision regarding the EP's voluntary participation.
Data analysis phase Creswell and Plano Clark (2018)	• I remained objective during the analysis by revisiting my own assumptions. • I maintained the privacy and anonymity of the participants in the highest confidentiality.
Reporting, sharing, and archiving the results Creswell and Plano Clark (2018)	• I did not plagiarise. • I did not reveal exclusively good or only negative results. • I spoke and wrote in a straightforward, unambiguous manner. • According to the University of Pretoria's request, original data sets have been stored in a secure location to which only my supervisor and I have access.

Adapted from Etokabeka (2021)

3.7 SUMMARY OF CHAPTER 3

Chapter 3 provided an outline of the research methodology that was explored in this study. The study paradigm that was utilised to examine TPACK, the research approach, and the research type were described in the chapter's opening section. Purposeful sampling was used to identify relevant participants from five LEs in the Tshwane South district of Gauteng, using photovoice, semi-structured individual interview schedules, guided observations, collaborative discussion groups, a reflection journal, and a systematising expert interview for the data generation process. The chapter explained how deductive and inductive thematic data analysis were employed. The chapter concluded with a full account of how trustworthiness was assured, as well as an examination of all ethical aspects. Figure 3.5 visually presents the unpacking of Chapter 3, adapted from Haarhoff (2020).

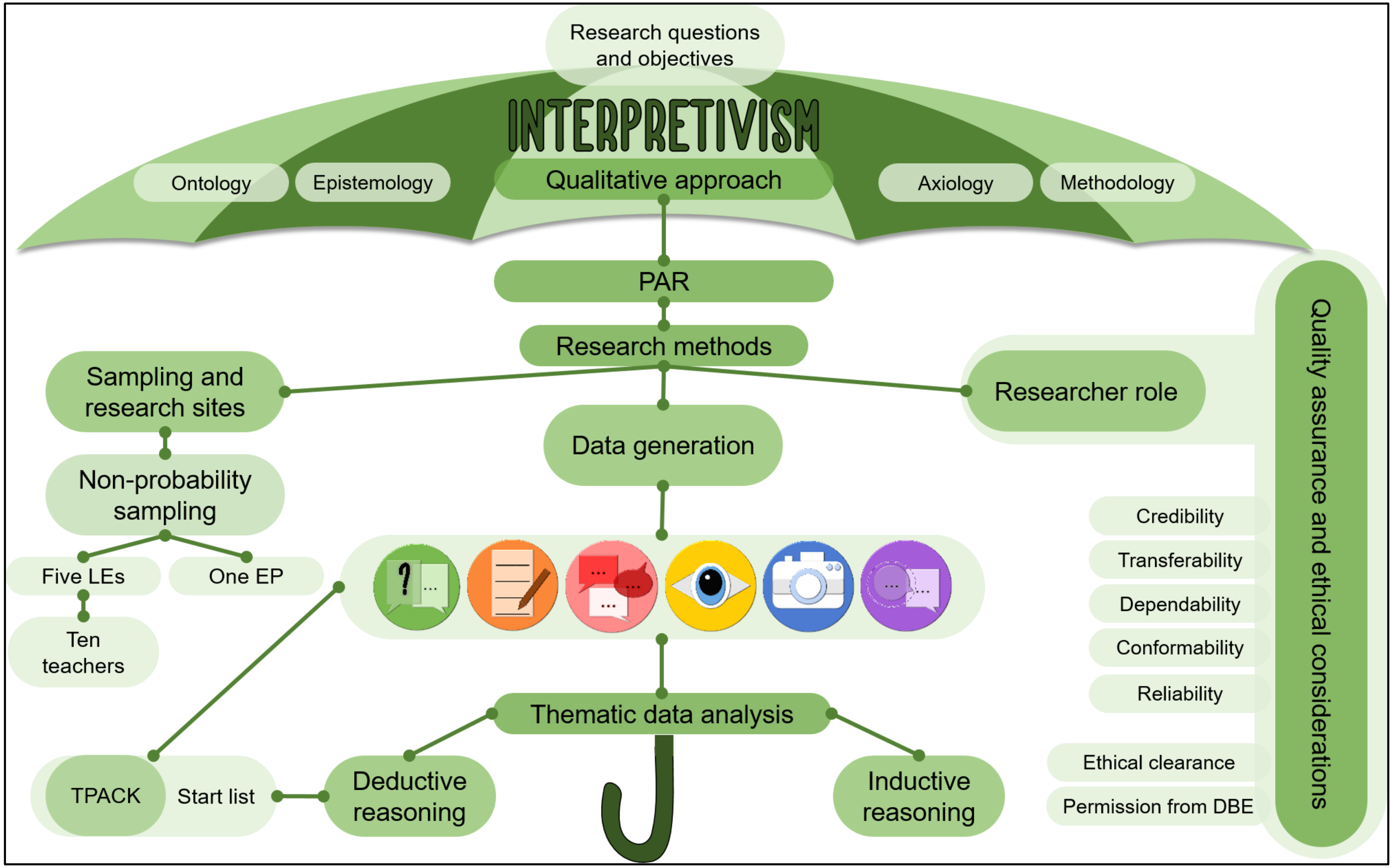


Figure 3.5: Visual representation of Chapter 3
(Adapted from Haarhoff, 2020)

As seen in Figure 3.5, the overarching paradigm that influenced my whole study was interpretivism. I chose interpretivism after determining the research questions and objectives from the literature I reviewed. Interpretivism enabled me to gain a more detailed grasp of the participants' subjective experiences. These individuals were asked to participate in the study by using non-probability sampling. One EP and ten teachers from five ELEs participated. The teachers were asked to participate in a semi-structured individual interview, observations, photovoice, and collaborative discussion groups, while the EP only participated in a systematising expert interview. I used a reflection journal throughout the data generation process to record my thoughts and observations. The data generation process was carried out by ensuring quality assurance and upholding all ethical considerations. Thematic data analysis was then carried out by using both deductive and inductive reasoning. In Chapter 4, I present the data generation procedures and deductive thematic data analysis.

CHAPTER 4: DATA GENERATION PROCEDURES AND DEDUCTIVE DATA ANALYSIS DESCRIPTION

4.1 INTRODUCTION

Chapter 3 detailed the research design and data generation instruments utilised to create information for the study. It presented the selected methodology to discover how coding and robotics can be integrated with specific mathematical concepts in Grade R. In my study, I employed PAR and implemented four cycles to ensure that the research was collaborative and inclusive.

The first cycle was dedicated to introducing the teacher participants to the study and ensuring that they had a clear understanding of the research objectives and methodology. In the second cycle, the teacher participants were required to collaboratively plan and individually present an activity. This allowed for a collaborative and reflective process that engaged the participants and provided them with a sense of ownership over the research. The third cycle focused on individual planning and presentation of another activity, providing the participants with an opportunity to develop their skills and knowledge further. In this cycle the participants also had to reflect on the first activity they had planned and implemented to inform their practice. In the final cycle, which is elucidated in this chapter, an EP was invited to partake in the research. This allowed for a unique perspective and added depth to the guidelines.

Throughout each cycle, the planning, acting, observation, and reflection phases were thoroughly discussed, as outlined in the previous chapter. This ensured that each phase was carefully considered and that the research was conducted in a rigorous and systematic manner. Overall, the implementation of PAR and the four cycles allowed for a collaborative and inclusive research process that engaged all participants and provided a comprehensive understanding of the research topic.

In this chapter, I provide a comprehensive overview of the study's participants, including their demographic information and relevant background details. This information is crucial in understanding the context in which the research was conducted and provides a foundation for the subsequent analysis. Following this, I describe in detail the data generation procedures employed in the study, including the methods used to collect and record the data. This includes a thorough discussion of the data collection instruments and the steps taken to ensure the reliability and validity of the data.

I then proceed to describe the deductive thematic data analysis process, which involved identifying key themes and patterns within the data that related to the research objectives. This approach allowed for a systematic and rigorous analysis of the data that yielded meaningful insights and provided a solid foundation for the subsequent discussion of the research findings. While the results of the study are not discussed in this chapter, the information presented here provides essential background information and lays the groundwork for the subsequent results, analysis and interpretation of the data. By providing a detailed overview of the participants, data generation procedures, and data analysis process, this chapter sets the stage for a thorough and insightful discussion of the research findings.

4.2 PARTICIPANTS AND RESEARCH SITES

The teachers and schools engaged in the study were described in detail in Chapter 3 (see 3.5.1 Participant selection and research sites). Figure 4.1 depicts the qualifications and years of experience of these participants.

Teacher 1
This female teacher has been teaching Grade R learners for seven years. There is only one Grade R class at this teacher's preschool that consists of 15 learners. This teacher has a degree in ECD and FP teaching. Her home language is Afrikaans and she also teaches in Afrikaans in her ELE, however, English is taught as an additional language.

Teacher 2
This female teacher has been teaching Grade R learners for one year but has been a teacher for more than six years. There are 17 Grade R learners in her ELE. She has a degree in ECD and FP teaching. Furthermore, her home language is Afrikaans and she also teaches in Afrikaans in her ELE.

Teacher 3
This female teacher has been teaching Grade R learners for six years. There are 18 Grade R learners in this teacher's ELE. She has a degree in ECD and FP teaching. Moreover, her home language is Afrikaans and she also teaches in Afrikaans in her ELE.

Teacher 4
This 35-year-old female teacher has been teaching Grade R learners for 12 years. She has 18 learners in her ELE. She has an education qualification in ECD and FP teaching. Both her home language and LoLT is Afrikaans.

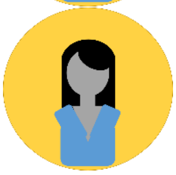
Teacher 5
This female teacher has been teaching Grade R learners for ten years. She obtained a Grade R certification and is currently busy with a degree in early childhood education at a private tertiary institution. The LoLT at her school is English and Afrikaans. Her home language is Afrikaans.

Teacher 6
This female teacher has been teaching Grade R learners for seven years. She is currently busy with her BEd degree specialising in FP. Her home language is Sepedi but the LoLT at her school is English and Afrikaans.

Teacher 7
This female teacher has been teaching Grade R learners for eight years and six months. She has 27 learners in her ELE and there are two Grade R ELEs at her school. She has a degree in ECD. This teacher's home language is Afrikaans, which is also the LoLT at her school.

Teacher 8
This female teacher has been teaching Grade R learners for six months. She was previously employed as a Grade 1 teacher for six years. There are 54 Grade R learners enrolled at this teacher's ELE. She has a degree in ECD and FP teaching. Furthermore, her home language is Afrikaans and she also teaches in Afrikaans in her ELE.

Teacher 9
This female teacher has been teaching Grade R learners for 22 years. She has a higher diploma in education that focused on pre-primary learners. Her home language is English and she also teaches in English in her ELE.



Teacher 10
This female teacher has experience in teaching Grade R for 19 years. The Grade R learners are taught together with the Grade RR learners. This teacher obtained a higher diploma in education. Her home language is English, which is also the LoLT in her ELE.

External participant
The external participant is a female with 19 years of expertise. In 2016, she earned a doctorate in ECE and FP with an emphasis on technology-based teaching and learning in the Foundation Phase. She has also authored multiple articles on ECE and technology in national and international journals. Moreover, she has presented at a few international conferences. She is currently working as a programme and qualification manager at an HEI (not the University of Pretoria), where she is primarily responsible for curriculum planning and development. She also supervises doctoral and master's students.

Figure 4.1: Description of the participants

As seen in Figure 4.1 above, the study involved ten Grade R teachers, all female. Their years of experience vary, ranging from 6 months to 22 years, and they have different qualifications, including degrees and diplomas in ECD and FP teaching. Most of the teachers' home language is either English or Afrikaans, except for one who speaks Sepedi. The EP is a female with 19 years of experience, a doctorate in ECE and FP, and a focus on technology-based teaching and learning in the Foundation Phase. She works as a programme and qualification manager at an HEI, supervising doctoral and master's students. The background information and a description of each school that the teacher participants are from, are shown in Figure 4.2. The objective was to provide more information about the types of schools I contacted to generate data.

School 1		**Preschool** This preschool caters for learners from babies to Grade R. This preschool opened in 2004.The LoLT is Afrikaans, however, the school also accommodates English home language learners. On Wednesdays, the school encourages both Grade RR and Grade R learners to speak only English. The school follows the National Curriculum Framework (NCF) curriculum for learners up to Grade RR and implements CAPS for learners in Grade R.
School 2		**Grade R pre-primary school** This pre-primary school is connected to a primary school and caters for learners from 3 years old. Learners can attend the primary school until Grade 7. The LoLT is Afrikaans, however, learners have the opportunity to engage in language lessons that include English and Sepedi as well. The pre-primary school follows a play-based approach to teaching and learning. The school opened in 1928.
School 3		**Preschool** Since 1984, this preschool has provided high-quality care and education to young learners. They facilitate a developmentally-appropriate environment for learners from 3 months old to Grade R. This preschool also caters for both English and Afrikaans learners. The subjects that are included in the daily programme are art, language, music, mathematics, sport, and computer literacy.
School 4		**Grade R pre-primary school** Learners from the age of 18 months are accommodated at this pre-primary school. Afrikaans is utilised as the medium of instruction to teach and refine basic skills in the three learning areas, namely language, mathematics, and life skills. English as a first additional language receives constant attention. The same can be said about Sepedi as a second language. Learners are expected to hear and speak Sepedi.
School 5		**Preschool** This preschool opened in January 1937, and they have worked hard every day to maintain the school's legacy by aiming to maintain the high academic standards envisioned by the founder. They believe that learners learn through play and strive to achieve a healthy balance of learning and playtime. Learners can attend this preschool from three months old.

Figure 4.2: Description of the schools

The information provided in Figure 4.2 describes five different preschools that offer education to learners from babies up to Grade R. Each preschool follows a different approach to teaching and learning, with some offering both Afrikaans and English as the language of instruction. Two of the pre-primary schools are connected to primary schools where learners can continue their education up to Grade 7. In the next section, I discuss a pseudonym system that is used to protect the privacy of the participants in the study.

4.3 PSEUDONYM SYSTEM

I used pseudonyms to protect the participants' identities, the names of the teachers, schools, and the EP. Schools, for instance, were designated as S1, S2, S3, S4, and S5, while participants were designated as T1, T2, and so forth. The observations in the respective teachers' learning environment are indicated as TO1, TO2, and so on. The external participant was coded as EP. Any name mentioned during the interviews or discussion groups was replaced with a pseudonym during transcribing. All of the codes for participants and schools are shown in Table 4.1.

Table 4.1: Pseudonym system

SCHOOL CODE	PARTICIPANTS	TRANSCRIPTION CODE	SEMI-STRUCTURED INDIVIDUAL INTERVIEW	OBSERVATION
S1	Teacher 1	T1	TI1	TO1
S2	Teacher 2	T2	TI2	TO2
	Teacher 3	T3	TI3	TO3
	Teacher 4	T4	TI4	TO4
S3	Teacher 5	T5	TI5	TO5
	Teacher 6	T6	TI6	TO6
S4	Teacher 7	T7	TI7	TO7
	Teacher 8	T8	TI8	TO8
S5	Teacher 9	T9	TI9	TO9
	Teacher 10	T10	TI10	TO10
-	External participant	EP	-	-

In order to maintain confidentiality, a pseudonym system was introduced for the participants in this study. In the following section, I discuss the PAR cycles that were conducted with the participants.

4.4 PARTICIPATORY ACTION RESEARCH PROCESS DESCRIPTION

This section addresses each cycle of PAR in terms of its cyclical process. The data generation process was carried out over the course of ten inconsecutive weeks spread approximately over a one-year period. Each participant's availability as well as the public school recess influenced when data generation could take place. Figure 4.3 visually presents a simplified version of these research cycles.

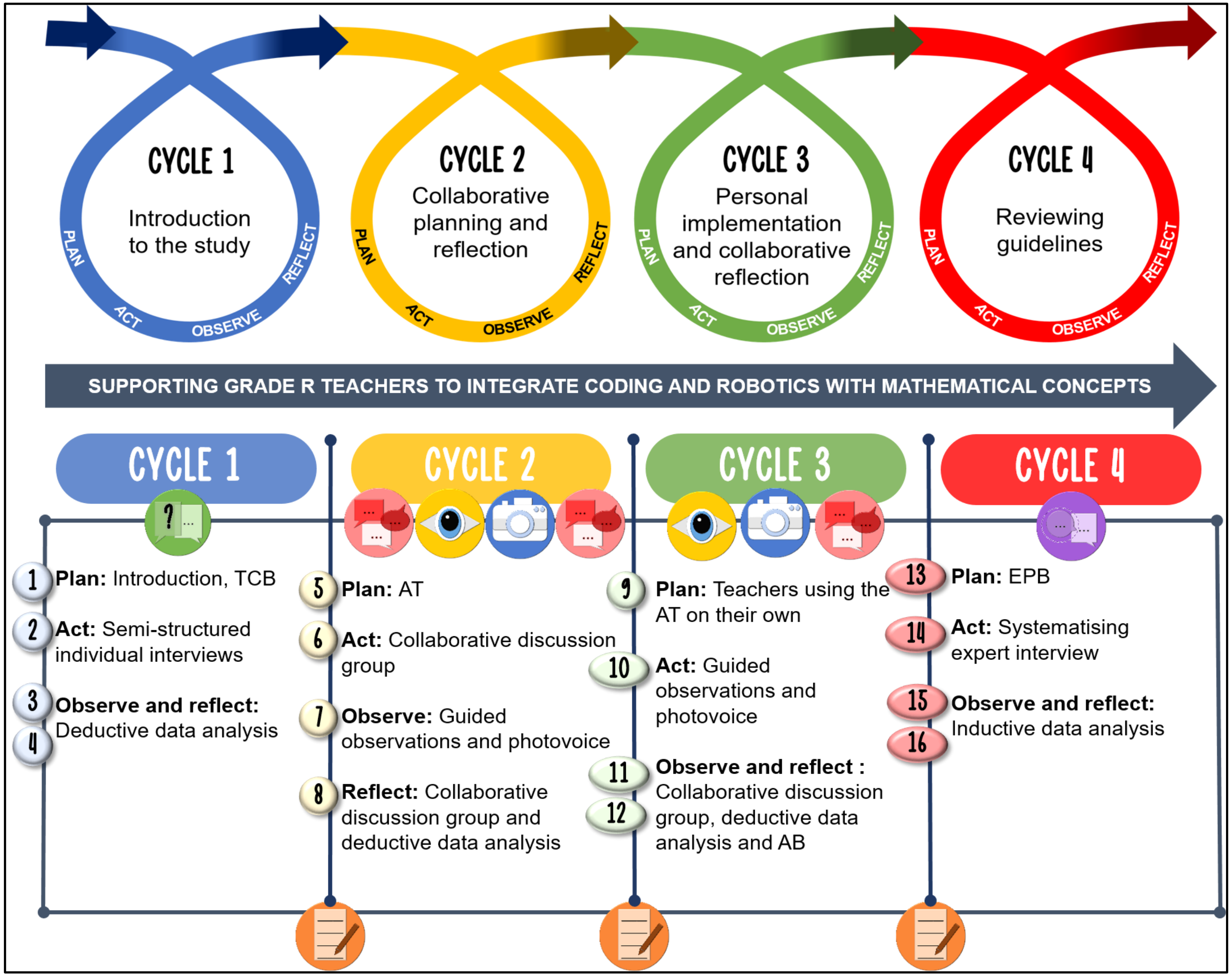


Figure 4.3: A simplified visual representation of PAR

As mentioned before and indicated in Figure 4.3, this study consisted of four PAR cycles, each with four phases: planning, action, observation, and reflection (see 3.4.3 Research Type). The first cycle introduced the study, while the second cycle focused on collaborative planning and reflection. The third cycle involved personal implementation and collaborative reflection, and the fourth cycle reviewed guidelines. These cycles were designed to create a collaborative environment where teachers could work together to improve their teaching practices and integrate technology effectively with mathematics. The planning phases involved identifying the goals for each cycle and outlining the specific activities that would be undertaken. During the action phases, the planned activities were implemented, and the participants' progress was observed during the observation phases. Finally, the reflection phases allowed for discussion and evaluation of the results, leading to adjustments and improvements for the next cycle. This iterative process aimed to improve the quality of teaching and learning in the Grade R LE by empowering teachers to take ownership of their professional development and to collaborate with their peers.

4.4.1 Participatory action research process description: Data analysis

During the first three cycles of PAR, deductive data analysis took place in order to inform the subsequent cycle of PAR. However, after cycle 3, inductive data analysis and interpretation took place before I invited the EP. When analysing data, a researcher could instinctively look for information that supports personal experience and opinions and miss information that conflicts with those beliefs (Azungah, 2018). Thus, an EP was tasked with evaluating the preliminary framework created from the first three cycles of PAR in order to reduce the likelihood of personal bias and improve the reliability and rigour of the analysis and interpretation (ibid.). The analysis and interpretation required by the EP only related to the guidelines of the framework. The steps I followed to generate the data for each cycle are described in the following section.

As discussed in Chapter 3 (see 3.6.1 Data analysis of this study), I developed a start list derived from the organisation of the literature reviewed through TPACK by using deductive reasoning. All data generation instruments were also developed to be used in each category. In the following section, I discuss each cycle of PAR as well as the preliminary data process that took place. It is worthy to mention that each of the PAR cycles emphasised the significance of understanding the participants' subjective experiences, interpretations and meanings.

4.4.2 Cycle 1: Introduction to the study

The first cycle of PAR, which aimed to introduce the study to the participants, is visually presented in Figure 4.4.

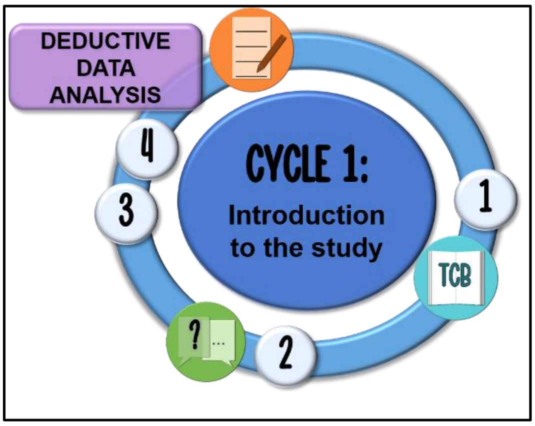


Figure 4.4: Visual representation of Cycle 1

In the first cycle, I developed a booklet (see Appendix F) to support the participants who had no prior experience with coding and robotics (number 1 – plan). The booklet included but was not limited to literature-based information, note-taking pages, and an introduction to Bee-Bot. I also conducted a semi-structured individual interview (see Appendix G) with each participant (number 2 – act) to gather their views on technology integration in ELCs. The interviews focused on pedagogy, technology, and the understanding of educational theories and international practices. The data generated from the interviews was analysed deductively by highlighting important passages and pasting them onto A2 pages (number 3 – observe).

4.4.2.1 Introduction to the study: Plan

Figure 4.5 visually represents the planning phase of Cycle 1.

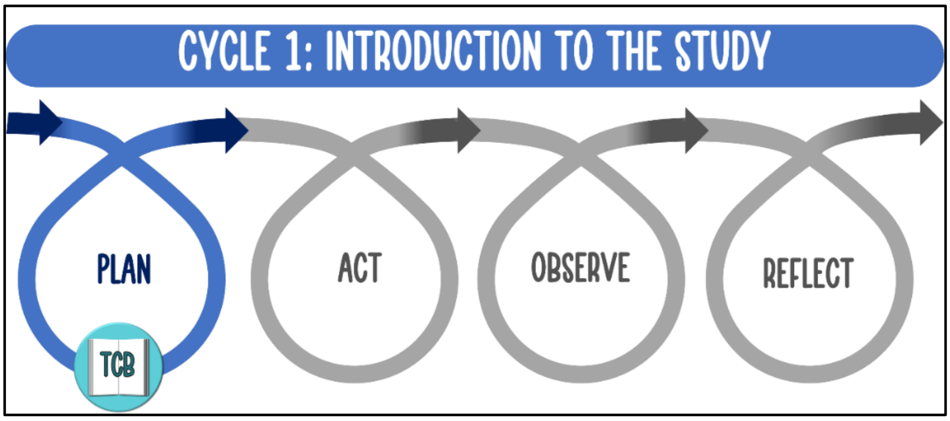


Figure 4.5: Visual representation of Cycle 1's planning phase

When data generation commenced, I realised that the participants, who had no prior exposure to using or integrating coding and robotics, had to be supported in some way to have a understanding of this. For this reason, as seen in Figure 4.5, I decided to develop the TCB (see Appendix F). The TCB was titled 'co-researcher booklet' and I gave each teacher a bound printed copy when I met with them for the first time. The booklet, consisting of 12 pages, includes front matter; a timeline; the PAR cycles; and a short introduction. The subsequent pages consist of literature-substantiated information and two pages that participants could use for note-taking. The first of these information pages has a table that summarises the pedagogical theories as well as the international practices reviewed in this study. The table was divided to indicate to the teachers what their roles would be to implement the theories and/or practices as well as how this could be accomplished. While acknowledging that the TCB alone does not provide a guarantee for teachers' adoption of theories and/or practices, its purpose lies in contextualising the study within the TPACK framework. Following this page, I summarised the content area of numbers, operations, and relationships from CAPS (DBE, 2011b). On the next page, I visually illustrated the KCRA approach. The last three pages were dedicated to coding and robotics, which included pictures of the Bee-Bot as well as the Bee-Bot coding cards that I designed. The information presented in the TCB was discussed with each teacher and during the first meeting, I also introduced the teachers to the Bee-Bot to familiarise them with its functions. The TCB included the constructs of PK, PCK, CK, and TK.

4.4.2.2 Introduction to the study: Act

In Figure 4.6, the first cycle's action phase is visually represented.

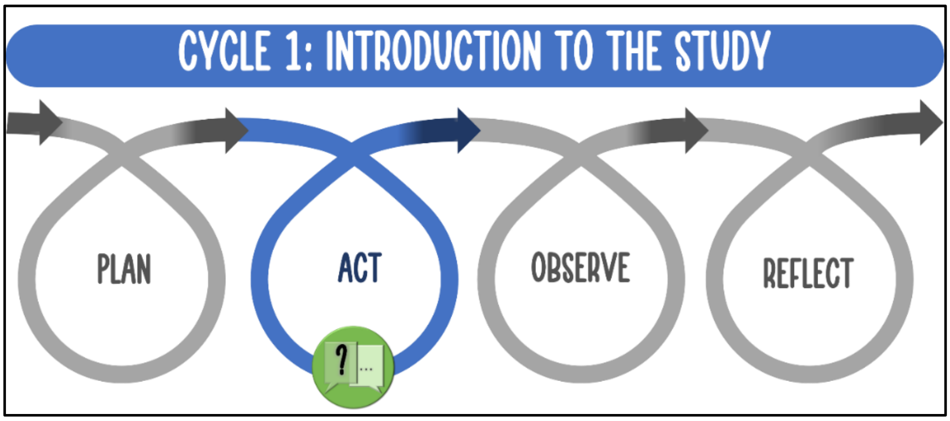


Figure 4.6: Visual representation of Cycle 1's action phase

After the introductory session, a semi-structured individual interview was held with each individual participant. The interview questions were open-ended, allowing the teachers to voice their views on technology integration with mathematics. I used these interviews to elicit information from the participants on their knowledge of coding, robotics, and the advantages and disadvantages of using it. Additionally, I gave them the chance to express what they thought about the use of coding and robotics in Grade R and how it may affect learners' learning and teachers' practices. With this tool, the questions also targeted the teachers' understanding of mathematical concepts stipulated in CAPS, the KCRA approach, as well as educational theories and international practices. The questions have been provided in Appendix G, however, the following section summarises these questions.

The questions included the following content:

- To what extent the learners were exposed to technology as well as to coding and robotics;
- Training opportunities for teachers in the implementation of coding and robotics or any other technology-enhanced tools;
- To what extent coding and robotics or any other technology-enhanced tools influence the learners' learning and the teachers' teaching;

- The possible advantages and disadvantages that can be observed in the implementation of coding and robotics;
- The teachers' dispositions and opinions regarding the implementation of coding and robotics in Grade R;
- The constructs of the KCRA approach;
- Numbers, operations, and relationships;
- Play-based teaching and learning; and
- Grand theorists and international best practices.

Although I acknowledge that certain questions fell outside the specific scope of this study, the inclusion of additional inquiries allowed participants to delve into aspects they may not have previously considered. I typed the participants' replies by using *Qualtrics* and each interview lasted more or less 30 minutes. Five participants requested to be interviewed in Afrikaans, which meant that I had to transcribe these interviews before I could read, digest, and make sense of the data.

4.4.2.3 Introduction to the study: Observe and reflect

During the observation and reflection phases of cycle 1, deductive data analysis was employed, as seen in Figure 4.7.

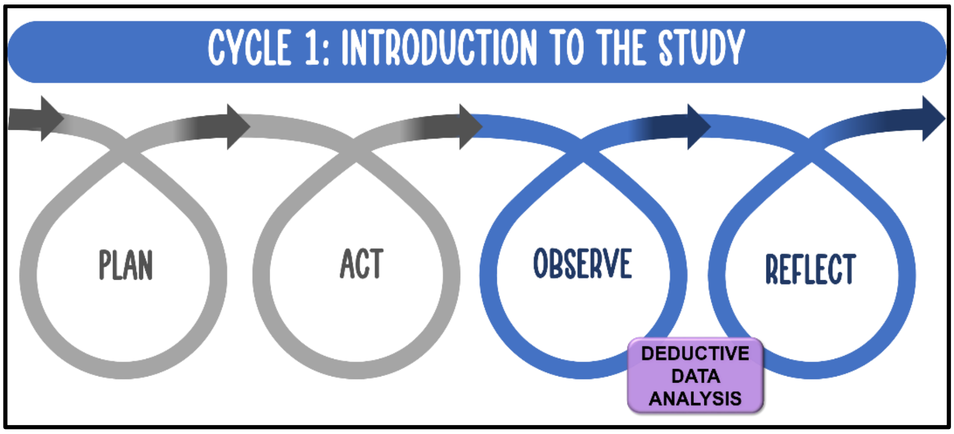


Figure 4.7: Visual representation of Cycle 1's observation and reflection phase

The semi-structured individual interview was the first data generation instrument that I analysed through deductive reasoning. I started by immersing myself in each interview, ensuring that I understood what the teacher was saying when I posed a question. In a few instances, I reverted back to the teacher to ensure that my interpretation was correct. I highlighted passages of importance according to the start list, cut out the passages and pasted them onto an A2 page. Figure 4.8 visually represents how I implemented deductive reasoning for the interviews, however, this was employed for all textual data.

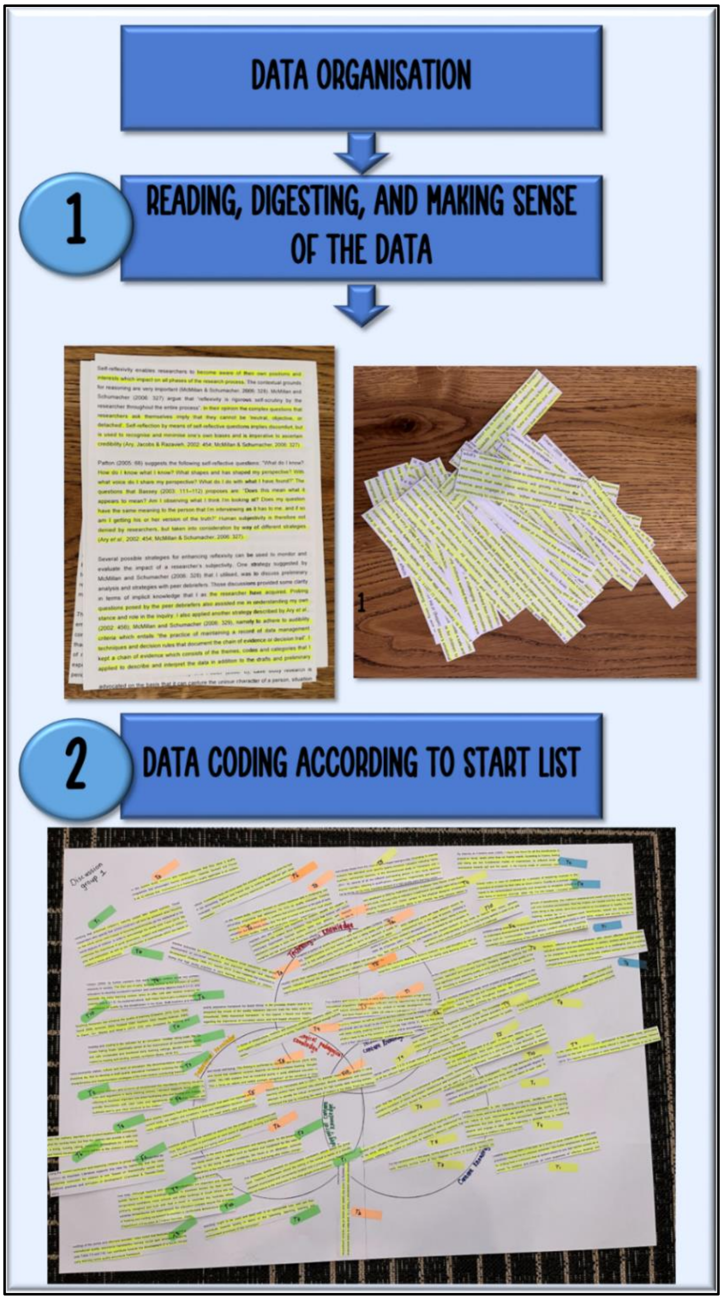


Figure 4.8: Deductive reasoning implemented in the study of textual data

As seen in Figure 4.8, I highlighted important passages that linked to the start list. These passages were then cut out and pasted onto an A2 page consisting of the constructs of the TPACK framework. This ensured that I had an understanding of what transpired during each interview and supported the planning of Cycle 2. During deductive thematic data analysis of the semi-structured individual interviews, the findings indicated that the teachers felt that they still did not possess sufficient knowledge on how to use coding and/or robotics which was addressed by developing the AT. I also completed an entry in the reflection journal regarding the first cycle. The entry was also analysed by using the last two steps of deductive reasoning, as indicated in Figure 4.4.

4.4.3 Cycle 2: Collaborative planning and reflection

Figure 4.9 visually presents Cycle 2.

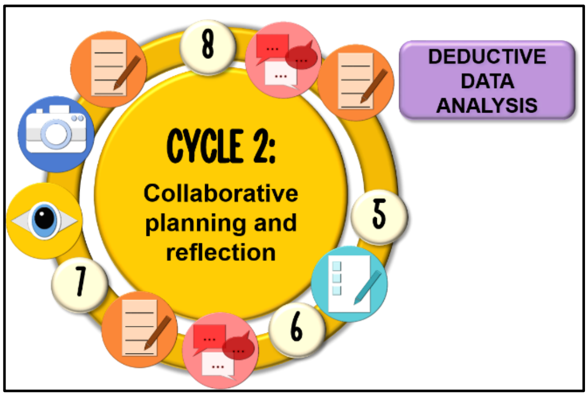


Figure 4.9: Visual representation of Cycle 2

Since the teachers felt that they did not have enough knowledge of how to use coding and/or robotics, I developed the AT (number 5 – plan). The first collaborative discussion groups were then held by drawing on the information from number 5 (number 6 – act). Although I planned for only one discussion group to take place, two teachers were involved in a separate discussion as they could not attend the other one. I then observed the first activity which integrated coding and robotics with specific mathematical concepts in each participant's respective ELE (number 7 – observe). The second collaborative discussion group as well as deductive thematic data analysis were then conducted (number 8 – reflect).

4.4.3.1 Collaborative planning and reflection: Plan

Figure 4.10 visually represents the planning phase of Cycle 2.

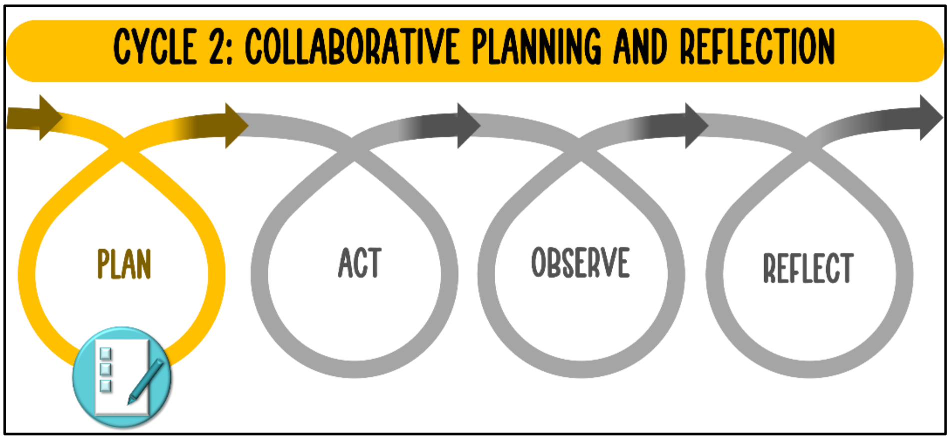


Figure 4.10: Visual representation of Cycle 2's planning phase

For the planning of the first collaborative discussion group, I developed the AT seen in Figure 4.10. The AT aimed to provide teachers with an understanding of how they can integrate coding and robotics with specific mathematical concepts by including the following imperative aspects, as seen in Figure 4.11:

- The topic taken from the Mathematics CAPS for Grade R learners;
- The theme that they had at school for that week;
- The lesson time that they would need as well as the resources;
- The aims of the activity;
- The plan that included the introduction, development, and consolidation – these sections also provided the teachers to tick which aspect(s) of the KCRA approach they used;
- The mathematical skills it included; and
- The last two sections provided the teachers with an option to choose which theories and/or practices they implemented and to justify their choice.

<table>
<tr><td rowspan="4">CONTEXT</td><td>Topic</td><td colspan="4"></td></tr>
<tr><td>Theme</td><td colspan="4"></td></tr>
<tr><td>Total activity time</td><td colspan="4"></td></tr>
<tr><td>Resources</td><td colspan="4"></td></tr>
<tr><td>AIMS</td><td colspan="5"></td></tr>
<tr><td rowspan="9">PLAN</td><td colspan="5">INTRODUCTION (___ MINUTES)</td></tr>
<tr><td colspan="2">☐ K</td><td>☐ C</td><td>☐ R</td><td>☐ A</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="5">DEVELOPMENT (___ MINUTES)</td></tr>
<tr><td colspan="2">☐ K</td><td>☐ C</td><td>☐ R</td><td>☐ A</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="5">CONSOLIDATION (___ MINUTES)</td></tr>
<tr><td colspan="2">☐ K</td><td>☐ C</td><td>☐ R</td><td>☐ A</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="7">MATHEMATICAL SKILLS</td><td colspan="2">☐ Counting objects</td><td colspan="3">☐ Addition and subtraction</td></tr>
<tr><td colspan="2">☐ Counting forwards and backwards</td><td colspan="3">☐ Grouping and sharing leading to division</td></tr>
<tr><td colspan="2">☐ Number symbols and number names</td><td colspan="3">☐ Money</td></tr>
<tr><td colspan="2">☐ Describe, compare, and order numbers</td><td colspan="3">☐ Mental mathematics</td></tr>
<tr><td colspan="2">☐ Problem-solving techniques</td><td colspan="3">☐ Other: ______________________</td></tr>
<tr><td colspan="5">Elaboration and justification</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="3">THEORIES</td><td colspan="2">☐ Lev Vygotsky</td><td colspan="3">☐ Jean Piaget</td></tr>
<tr><td colspan="5">Elaboration and justification</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="3">BEST PRACTICES</td><td colspan="2">☐ Montessori</td><td colspan="3">☐ Reggio Emilia</td></tr>
<tr><td colspan="5">Elaboration and justification</td></tr>
<tr><td colspan="5"></td></tr>
</table>

Figure 4.11: Activity template

The AT was developed as an appropriate tool for supporting teachers to plan for the integration of coding and robotics with mathematics (Webb & Cox, 2007). It served as a platform for teachers to engage in discussions and reflections regarding their teaching objectives, learning outcomes, and strategies to accomplish them. The AT functioned as the teacher's roadmap, outlining what activities the learners would engage in and how it could be effectively achieved. In line with the TPACK framework, which emphasises the successful integration of pedagogy, technology, and content, the AT incorporated play-based theories and practices. Additionally, it facilitated the integration of coding and robotics with pre-existing mathematical skills. By incorporating these elements, the AT aimed to provide teachers with comprehensive support in delivering effective and meaningful instruction that combined both technology-enhanced learning experiences and mathematical concepts. The AT was specifically designed solely for the purpose of supporting teachers' planning and did not constitute a component of the data analysis process. The analysis was solely based on the actual occurrences and observations during the presentation and implementation of the activities. The AT served as a planning aid and did not directly contribute to the data analysis procedure.

The AT was provided to each teacher in hard copy format and I also sent it to them electronically. I provided the teachers with the hard copy before the first guided observation took place, which meant that I had to visit some teachers outside of the scheduled data generation cycles.

4.4.3.2 Collaborative planning and reflection: Act

Figure 4.12 visually represents the action phase of Cycle 2.

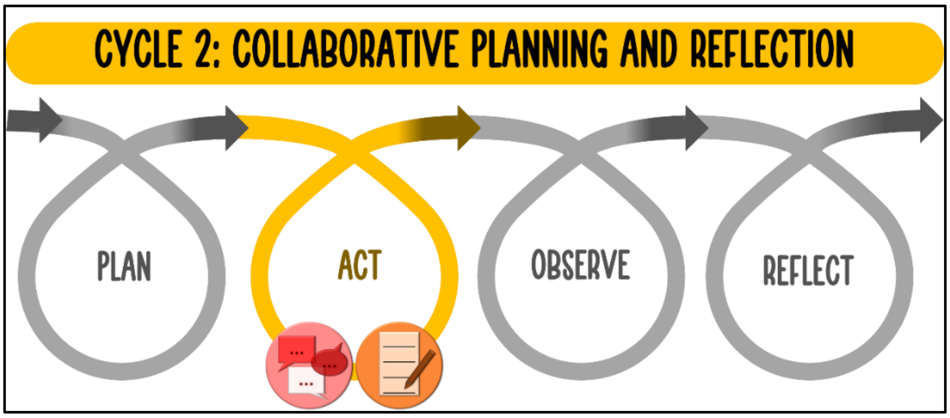


Figure 4.12: Visual representation of Cycle 2's action phase

Before the teachers started with the discussion, I referred back to the TCB that I developed. Firstly, I indicated to them which session we were busy with during PAR. I also elaborated on the functions of the Bee-Bot again. Since the teachers indicated that they do make use of the KCRA approach, even though it is not necessarily in that specific order, I also discussed this part again since the activities would be based on this. All the teachers also indicated that learning and teaching should take place through a play-based approach in Grade R, which supported the use of the pedagogical theories and best practices.

For the first collaborative discussion group, T9 and T10 were included. The reason that these two teachers could not join the collaborative discussion group with T1 – T8, was due to other obligations. I conducted a session with these two teachers first where they developed their own activity and a day later, I conducted another session with the other teachers. The teachers had to develop one activity that they would implement for the first guided observation. As they discussed different activities that can be implemented to integrate coding and robotics with specific mathematical concepts, I typed what they said on the AT for them to see. After the session, I sent each of them a completed electronic version to use during the guided observation.

4.4.3.3 Collaborative planning and reflection: Observe

In Cycle 2's observation phase, I conducted guided observations and used photographs to capture the data, as seen in Figure 4.13.

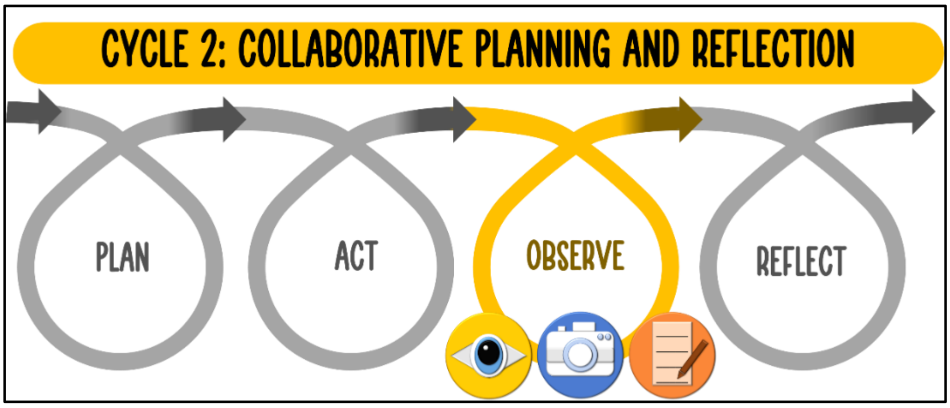


Figure 4.13: Visual representation of Cycle 2's observation phase

T9 and T10 developed an activity that focused on integrating coding with counting skills and number recognition. The aims of the activity were that the learners had to follow and remember instructions; practise their listening and counting skills; and recognise number symbols and number names from 1 – 10. The rest of the teachers, T1 – T8, developed an activity that also focused on integrating coding with counting skills and number recognition. The aims of the activity were the same except that the learners only had to recognise number symbols and number names from 1 – 8. The outcome of the first collaborative discussion group was also analysed by using deductive reasoning, however, the discussion elicited minimal rich data since the teachers only had to develop an activity. However, the discussion with T1-T8 was lengthy since the teachers all had different ideas for activities, which they had to organise to reach an agreement on focusing on a particular objective.

4.4.3.4 Collaborative planning and reflection: Reflect

As depicted in Figure 4.14, the second collaborative discussion group was held with eight teachers. Two teachers (T5 and T7) could not join the discussion due to other obligations.

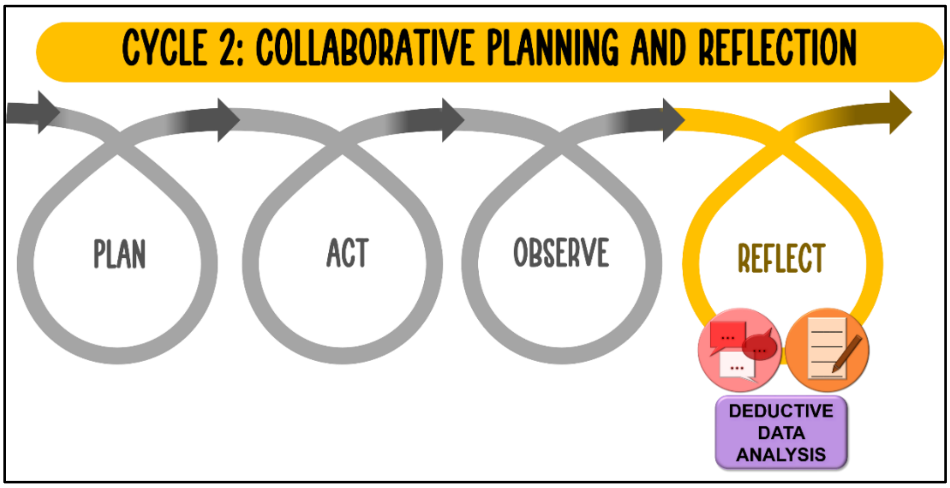


Figure 4.14: Visual representation of Cycle 2's reflection phase

During this discussion, the teachers were asked to reflect on the different activities that they had presented. The first question that I asked the teachers was to elaborate on both their positive and negative experiences of the activities they offered to the learners. The second question that was addressed in the collaborative discussion group related to the integration of coding and robotics with numbers, operations, and/or relationships. The teachers then elaborated on how they thought their activity developed the learners' coding skills. At the end of the discussion, the teachers were reminded that the next activity had to be developed by themselves, and that they were encouraged to use the AT to plan their activity.

I then started deductive data analysis by immersing myself in each photograph and responses from the teachers to ensure that I understood what had transpired. I pasted these photographs onto an A2 page as visually represented in Figure 4.15. All photographs related to a specific teacher's activity were analysed in this manner and I also shared these observations with the teachers.

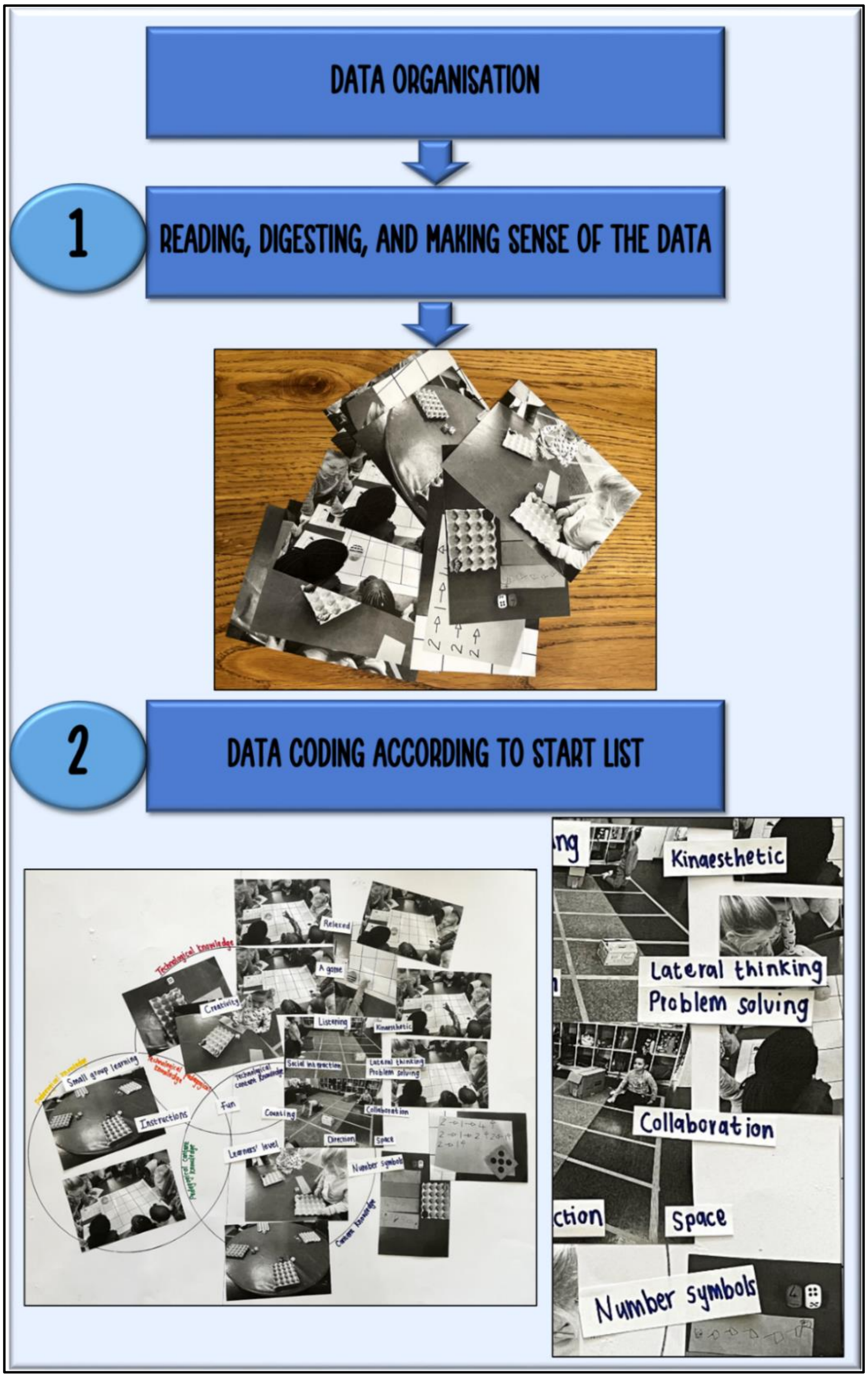


Figure 4.15: Deductive reasoning implemented in the study of photovoice

Ten researcher reflection journal entries were completed during this cycle. The first nine were completed after the guided observations, and the last after the second collaborative discussion group. The outcome of the second collaborative discussion group as well as the entries were analysed by using deductive reasoning and provided a platform to commence with Cycle 3.

4.4.4 Cycle 3: Personal implementation and collaborative reflection

Figure 4.16 visually represents Cycle 3.

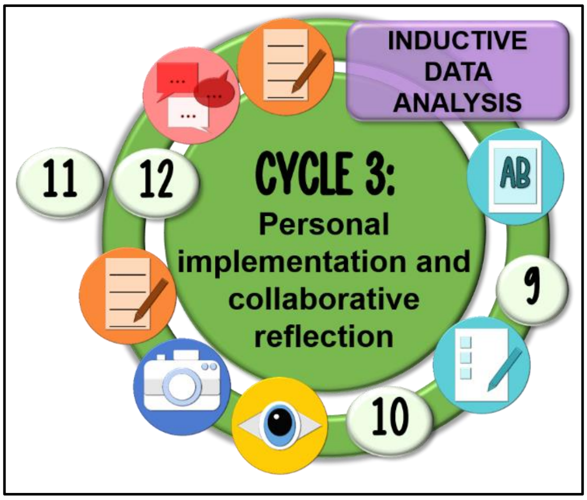


Figure 4.16: Visual representation of Cycle 3

In Cycle 3, teachers were required to develop their own activity that integrated coding and/or robotics with specific mathematical concepts. The teachers used the AT to plan their activities and were observed during their lessons. After each observation, a journal entry was compiled, and a collaborative discussion group was held with all ten teachers to reflect on their experiences and discuss the implementation of coding and robotics in a Grade R learning environment. The discussion covered topics, such as the integration of other subject areas, implementation and dispositions towards the KCRA approach, assessment, and experiences of integrating coding and robotics with specific mathematical concepts. The data from the observations and discussions were analysed using deductive reasoning, and the teachers were provided with an activity booklet containing all of their planned activities.

4.4.4.1 Personal implementation and collaborative reflection: Plan

Cycle 4’s planning phase is visually represented in Figure 4.17.

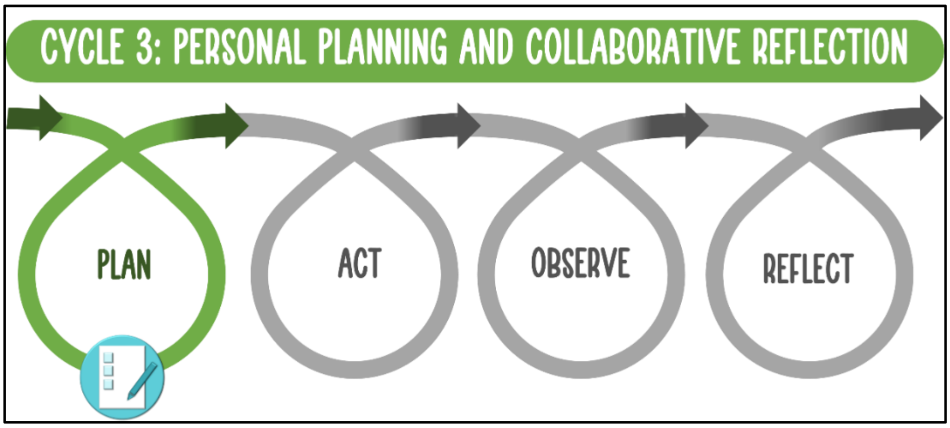


Figure 4.17: Visual representation of Cycle 3’s planning phase

The planning of Cycle 3 required the teachers to develop an activity of their own to engage learners in integrating coding and robotics with specific mathematical concepts. The teachers were provided with the AT to plan their activities.

4.4.4.2 Personal implementation and collaborative reflection: Act

The action phase of Cycle 3 is depicted in Figure 4.18.

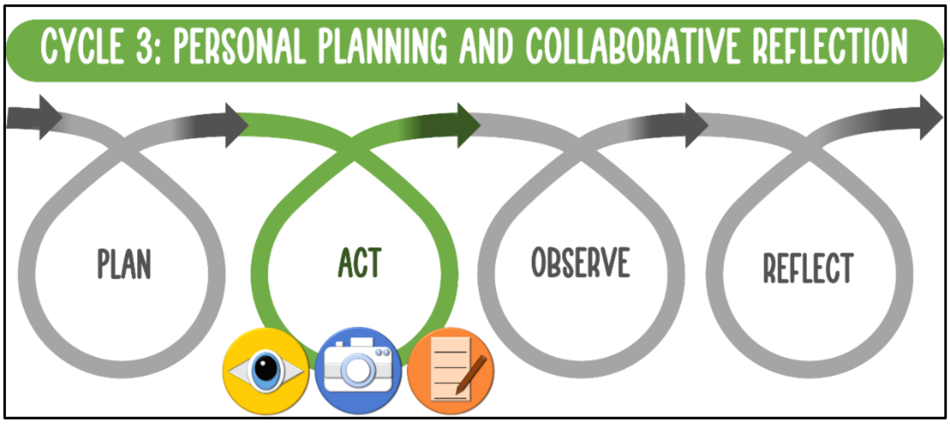


Figure 4.18: Visual representation of Cycle 3’s action phase

I conducted one observation in each teacher’s respective ELE. I observed T9 and T10’s activity together, therefore, I had a total of nine observations. All ten teachers used the AT to plan their activities and provided me with a hard copy or an electronic copy of their activity on the day of their observation. I compiled a journal entry after each guided observation.

4.4.4.3 Personal implementation and collaborative reflection: Observe and reflect

The last two phases, namely observation and reflection are depicted in Figure 4.19. While I am aware that these two phases have different implications and serve different purposes, I chose to combine them since the data generation methods had both the outcome of analysing and observing patterns as well as discussing and reflecting.

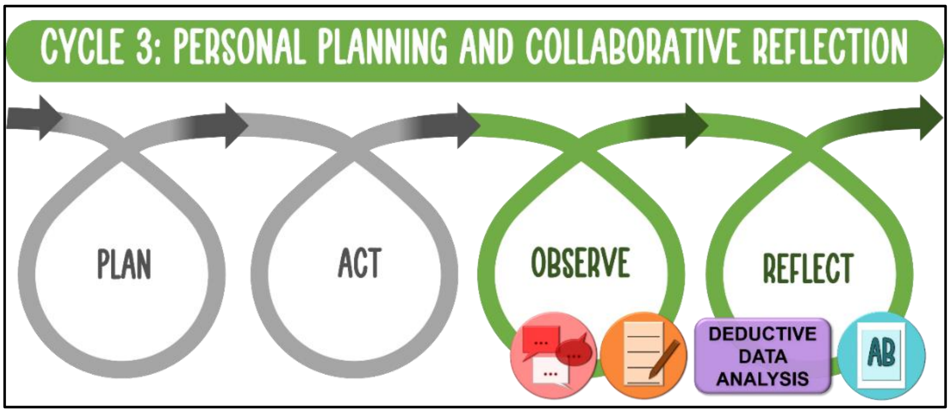


Figure 4.19: Visual representation of Cycle 3's observation and reflection phase

The last collaborative discussion group was then held with all ten participants. During this discussion, the teachers were provided with an opportunity to not only reflect on the previous activity they presented but on the journey as a whole. The first aspect that was discussed during the discussion was the teachers' experiences regarding the activity that they presented. The second aspect discussed related to the integration of coding and robotics in a Grade R learning environment. The teachers then discussed the integration of coding and robotics with numbers, operations and relationships. I then asked the teachers whether they think that their activities integrated with any other subject areas or content areas of mathematics. Following this, teachers' implementation and dispositions regarding the use of the KCRA approach were elucidated. The next aspect that was discussed related to the assessment of integrating coding and robotics with numbers, operations, and relationships. The last part that formed part of the discussion related to the teachers' experiences and/or dispositions of integrating coding and robotics with specific mathematical concepts.

I reflected on the last collaborative discussion group by completing a final journal entry. For each observation, entry, as well as the last collaborative discussion group, the data was analysed by using deductive reasoning. The teachers were also provided with an activity booklet (AB) that contained all of the activities that they had planned.

4.5 INDUCTIVE THEMATIC DATA ANALYSIS

Before the last cycle of PAR, I had to employ inductive data analysis. As seen in Figure 3.3, it supported me to develop sub-themes and a main theme by using open coding and categories. I used Microsoft Excel and the inductive approach (see Figure 4.20) to identify themes from the raw data without running the risk of imposing a predetermined result (Azungah, 2018).

Interview question		Verbatim transcripts	Open coding	Category	Sub-theme
Do you think coding and robotics should be used in Grade R? Please motivate your answer.	T1	*Yes, this gives learners the opportunity to discover learning and problem solving on their own.*	Learning through discovery	Lateral thinking	Teachers' attitudes and dispositions regarding the implementation of coding and robotics
	T2	*Yes, it can be integrated in different subjects and used to create variety in the way a concept is explained and shown.*	Problem solving	Critical thinking	
	T3	*I do not know.*	Integration	Teachers' views regarding the integration of subject areas	Integration of subject areas
	T4	*Yes, each learner will keep on trying until they can do it.*	Encourages determination	Innovation	Teachers' attitudes and dispositions regarding the implementation of coding and robotics
	T5	*Definitely in moderation and in an interactive fun way.*	Moderation	Moderation	
	T6	*Yes, it will be an enjoyable teaching tool and the learners will be able to relate and use it in their everyday life.*	Interactive	Collaboration	
	T7	*Yes, some students [learners] are ready.*	Fun	Enjoyment	
	T8	*Yes, so that learners can be technologically equipped before they [the learners] start with Grade 1. They will be well developed*	Enjoyable teaching tool		
	T9	*Yes, if it will make a positive difference.*	Equipping learners for formal schooling	Exposure to technology	
	T10	*Yes, learning environments need to keep up with new developments.*	New developments	Teachers keeping abreast with new developments	Benefits of using coding and robotics

Figure 4.20: An example of how I employed inductive data analysis of one question from the semi-structured interview schedule

Overlapping categories were discovered, refined, and reduced using clustering (ibid.). Before creating categories, a separate analysis was conducted for each data instrument I used. I triangulated data from all the data generation instruments to group data that had a similar significance in order to generate categories (Neeley & Dumas, 2016; Vuori and Huy, 2016; Azungah, 2018). Additionally, this iterative phase of the analysis alternated between the categories and changing data patterns until conceptual patterns for sub-themes were identified. Table 4.3 represents how one of the questions in the semi-structured interview schedule was analysed through inductive reasoning. For each data generation instrument, a separate Microsoft Excel spreadsheet tab was created to enable me to code the data, create categories, as well as to develop categories. Each of the codes was colour-coded. A total of 114 codes were created from all the data generation instruments (some of the codes were used for more than one instrument or participant). The codes were then used to develop 36 categories. Finally, these categories developed four sub-themes. These codes, categories, and sub-themes are discussed in detail in Chapter 5.

As part of my research, I wanted to develop guidelines for a framework that would guide a particular process. To do this, I conducted inductive thematic data analysis to identify patterns and themes in the qualitative data I collected. One of the later stages of the research process involved reviewing and refining these guidelines (Cycle 4). However, because this stage was dependent on the insights gained from analysing and interpreting the data, I decided to delay discussing Cycle 4 until after I have presented and interpreted the results in Chapter 5 (see Figure 2.21). By doing this, I can provide a clearer understanding of the factors that influenced the development of the framework guidelines. This makes it easier to discuss Cycle 4 in more detail and explain how the insights gained from the data analysis influenced the refinement of the guidelines for the framework (see Figure 2.21).

4.6 SUMMARY OF CHAPTER 4

I began this chapter by introducing the participants involved in the study. I provided some details about their backgrounds and characteristics to give context to the data generated. To generate data for the study, I employed PAR. This involved engaging with the participants throughout the research process to collaboratively identify and address issues relevant to their experiences. As part of the PAR process, I also used deductive thematic data analysis. This helped me to organise and analyse the qualitative data collected during the PAR cycles based on a pre-existing start list. In the next chapter, I focus on the inductive analysis of the data generated through the PAR cycles. This type of analysis involves starting with the data and allowing themes and patterns to emerge through careful analysis. By presenting the results of the inductive analysis, I can provide a deeper understanding of the experiences and perspectives of the participants, and how they relate to the research questions.

CHAPTER 5: DATA RESULTS AND INDUCTIVE ANALYSIS OF THE FIRST THREE CYCLES

5.1 INTRODUCTION

In the previous chapter, I provided an overview of the participants that took part in this study. I also summarised the data generation procedures implemented within the cycles of PAR. I furthermore indicated how deductive thematic data analysis was used to preliminarily analyse the data and gave a short introduction to how inductive reasoning was employed. In this chapter, I focus on the inductive analysis of data generation and the results which are presented and discussed in detail. The primary research question "*How can Grade R teachers be supported to integrate coding and robotics with mathematical concepts?*" formed the foundation of how data was analysed. All data analysis strategies explicated in Chapter 3 were implemented and ethical considerations were upheld during this research study.

The following section presents the sub-themes and categories that were found during inductive data analysis. When I first began to analyse the data, I understood that it would be difficult to group the data because of the interrelated nature of the TPACK framework (see 2.2.3 The Application of TPACK in this study), which informed the data generation instruments. Therefore, a certain conclusion could conceivably be divided into more than one category during analysis, however, I chose to just include each finding once in a single category. Where necessary I mentioned its applicability in the other TPACK constructs.

Deductive and inductive thematic data analysis were employed in this study. Before data analysis commenced, I had already established a start list (see 3.6 Deductive and inductive thematic data analysis and interpretation), which was imperative to understand the topic of this study. All data generation instruments were developed by considering these categories. When I read through the transcripts of the data and looked at the pictures, I started to group it according to the different constructs of TPACK. This was done, manually, by printing the data; highlighting (only textual data); and, grouping it. This formed the first step of how I employed deductive thematic data analysis. The data grouped according to each construct was then analysed again, this time I identified keywords to indicate the main idea of the specific transcript extract. These keywords formed codes applicable to this study. This process was employed electronically by using Microsoft Excel. Following this, I reviewed the keywords that I had highlighted and grouped them according to possible categories. This process was implemented three times to ensure that I fully immersed myself in the data. I then proceeded to identify categories from the codes, this process was done twice. Finally, I identified sub-themes emerging from the categories.

Figure 5.1 visually presents the icons I used in this section to denote the research question each category addressed.

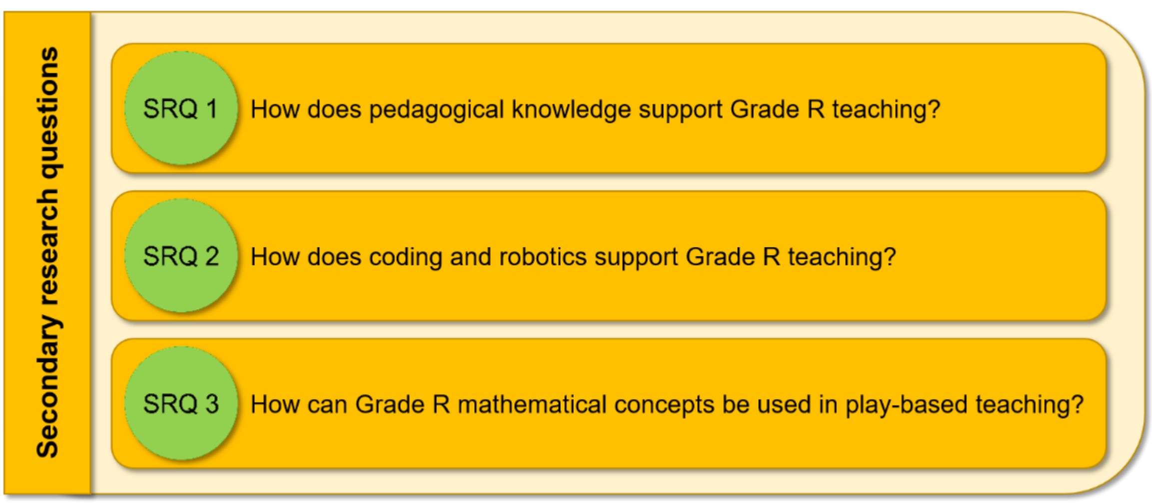


Figure 5.1: List of icons for secondary research questions

The primary research question was not included in the list of icons because the interpretation of the three secondary research questions was used, collectively, to answer the primary research question in Chapter 6. To provide a deeper understanding of the findings, I divided the themes and sub-themes into separate sections, and explained each one in the context of the teachers in this study. This will allow readers to gain a better understanding of the nuances and complexities of the teachers' experiences and perspectives related to the integration of coding and robotics with mathematical concepts. In the summary of the chapter, I present a summarised overview of the themes, sub-themes, and categories in table format to make it easier for readers to see the connections between the different elements of the study and to understand the overall implications of the findings.

5.2 MAIN THEME: INTEGRATING CODING AND ROBOTICS WITH GRADE R MATHEMATICAL CONCEPTS

The primary goal of the main theme was to address the integration of coding and robots with mathematical concepts. According to the findings, the main objective of play-based teaching and learning approaches employed by teachers is to address the integration of coding and robots with mathematical concepts. Finally, the study informs readers of the difficulties and advantages associated with the integration of coding and robotics with numbers, operations, and relationships.

5.2.1 Theme 1: How teaching occurs in Grade R

The first theme explored how teaching occurs in Grade R. This theme shed light on how learning experiences are structured in Grade R ELEs. The findings ultimately reveal the most important aspects of teaching in Grade R as perceived by the teachers. The sub-themes supporting the theme are: play-based teaching and learning, the integration of the three subject areas in Grade R (language, mathematics, and life skills) as well as using the pedagogical theories and international best practices. I begin this section by presenting the teachers' perceptions about play in Grade R.

5.2.1.1 Sub-theme 1.1 Play-based teaching and learning

All ten teachers had a positive perception of play in Grade R. During the semi-structured interviews, the teachers were specifically asked whether learning and teaching in Grade R should be implemented through a play-based approach. Furthermore, when the teachers participated in the collaborative discussion groups, they developed activities that were playful in nature and reflected on these as well. Moments of play-based teaching and learning were captured during the guided observations by means of photographs. I also reflected on the outcomes of these activities by writing in a reflection journal and noting whether the content and context promoted playful pedagogies.

All ten teachers indicated that they believe learners learn best while they are playing. TI1 and TI7 mentioned that "*when learners think it is a game they do not worry about making mistakes"* and that *"learners need to learn and understand work without putting them under pressure to perform at a certain level – they* [the learners] *retry in a relaxed manner when they are not worried about being wrong*". T10 noted that "*learning through play is effortless because if they* [the learners] *enjoy an activity they participate willingly and learn*" and T4 supported this by indicating that playing is how "*learners learn the easiest*". T2 and T6 also supported these statements, specifically T6 stated that play "*resonates with children* [learners] *on their own level, makes it fun and then as a result helps children* [learners] *to absorb what they hear much easier*". Furthermore, T2 mentioned that play "*invites learners to participate and makes them willing and enthusiastic to participate*". T7 stated that "*we strongly support whole brain learning at our school and steer away from worksheets in order to have a strong focus on interactive, learner-centred learning experiences*" and that "*learners actually learn and discover by playing, and that one should guide the play minimally, which can leave a lot to the learners by means of open questions, as an example*". Thus, it is evident that the teachers view play as being effortless as well as promoting participation and understanding in Grade R.

5.2.1.2 Sub-theme 1.2 Integration of subject areas

Throughout data generation, it was clear that the integration of all three subject areas took place without necessarily placing a specific focus on language and life skills. The integration of the subject areas was unconsciously implemented by the teachers during the activities and when they reflected on it they were able to identify the areas that were integrated. The three subject areas formed the development of the three categories below, namely, language, life skills, and mathematics. The last category focuses on the teachers' views regarding the integration of the subject areas.

5.2.1.2.1 Category 1.2.1 Language

SRQ 1

Language integration was present in each activity and reflection. The two most prominent language aspects that were integrated were listening and speaking skills. T9 mentioned that her "*learners had to listen to instructions, process and plan in order to be able to participate. They learnt to wait for their turn even though they were very excited*". T10 opined that her "*learners had to listen to follow instructions and vocabulary about spatial awareness were tested, such as using the words forwards, backwards, to the side, up, down and so forth*". T8 and T6 concurred with these statements by positing that the "*learners had to listen to specific instructions to execute the activity successfully*" and T8 also mentioned that English as a first additional language was integrated when she played a video for the learners. The photographs below in Figure 5.2 visually support the teachers' statements regarding the integration of language in their activities that were captured during the guided observations by means of photographs.

TO1

Translation:
Insekte: Insects

TO2

Translation:
By: Bee

TO1

TO6

TO7

Figure 5.2: Photographs indicating language integration

T1 opined that in her lesson the "*learners used language to describe insects*", which was supported by T7 who indicated that "*the learners' speaking skills were also developed in my lesson because the learners had to explain where the other* [learners] *had to move to*". Other language skills that were mentioned by two teachers were reading and handwriting. T7 specifically mentioned that the learners practised their reading skills "*when they coded the Bee-Bot and looked at the path that they wrote by using arrows*". T6 mentioned that learners' handwriting skills were supported when they "*drew shapes*".

5.2.1.2.2 Category 1.2.2 Life skills

SRQ 1

Each activity and reflection integrated the application of some life skills. Beginning knowledge, creative arts, and physical development were mentioned the most. T2, T7, T8, and T10 opined that their lessons integrated with physical development since "*the* *learners had to move from block to block on the carpet*" (T2); "*the learners moved on the chessboard with a specific focus on spatial orientation*" (T7); "*understand the space around their bodies*" (T8); and "*concepts were taught* [used] *by using learners' gross motor skills*" (T10). T2, T3 and T1 indicated that their lessons integrated beginning knowledge with a specific focus on "*Natural Science concepts, such as*": "*insects*" (T2); "*animals*" (T3); and "*farming*" (T1). Lastly, creative arts were integrated as suggested by T2 and T4 when the "*learners built their own insects and painted it"* (T2) and when they "*danced to the song I created*" (T4).

The photographs below in Figure 5.2 substantiate the responses above regarding the integration of life skills.

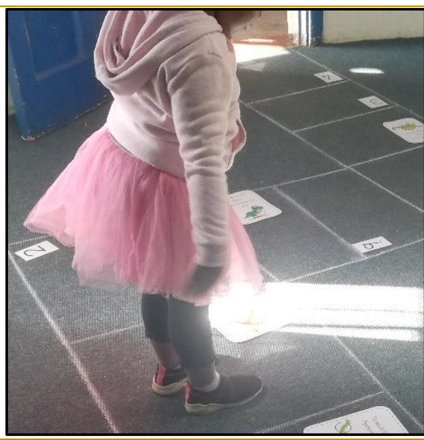
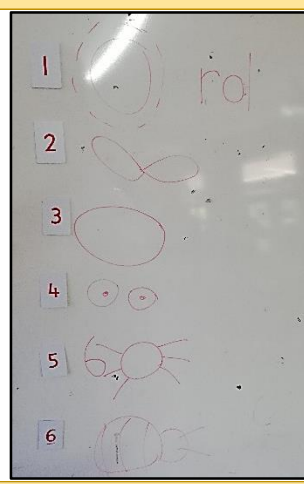
	
TO10	**TO7**
	 
TO2	**TO4**

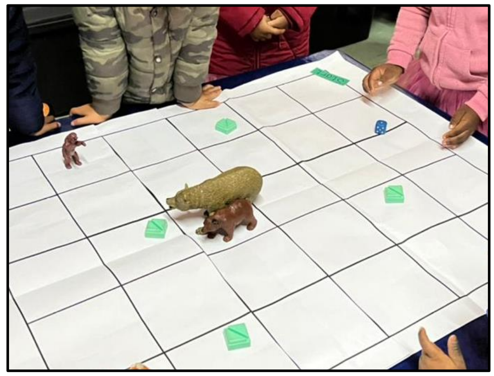
Figure 5.3: Photographs indicating life skills integration

The photographs presented above serve as visual evidence to support the teachers' responses that physical development and creative arts were integrated into their lessons. Each image captures a different moment where the teacher has incorporated physical or creative activities to enhance learning. For instance, in the first picture (TO10), the teacher is integrating the use of learners' gross motor skills with coding and robotics as well as mathematical concepts. By incorporating physical movement into the lesson, the teacher is engaging the learners in a fun and interactive way, making the learning experience more enjoyable and memorable. In the second picture (TO7), the learners are seen moving on a chessboard with a specific focus on spatial orientation. This activity not only strengthens their physical development but also develops their spatial awareness and critical-thinking skills. In TO2's activity, the teacher has included creative arts by having the learners build their own insects and paint them. This not only fosters creativity but also encourages the learners to use their imagination and problem-solving skills. Finally, in TO10's lesson, the teacher created a song for the learners to dance to, which is another way to incorporate creative arts into the classroom. This activity helps to develop the learners' coordination, rhythm, and musicality, while also promoting teamwork and collaboration. Overall, these photographs provide a compelling visual representation of how physical development and creative arts are being integrated, and how this integration can enhance the learning experience for young learners.

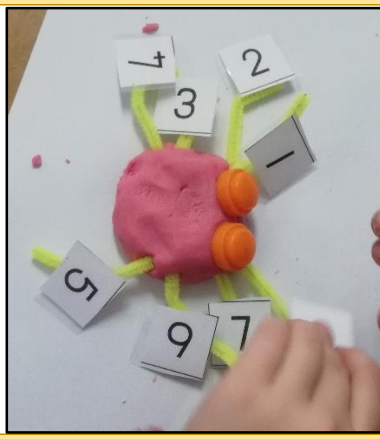
5.2.1.2.3 Category 1.2.3 Mathematics

Even though the focus of this study is on numbers, operations, and relationships, the content area of space and shape was also integrated. T4 indicated that her lessons supported the "*learners to recognise and write numbers as well as doing simple operations*". Moreover, the learners were able to use ordinal numbers to show order, place or position by following "*the instructions, they can learn* [use] *ordinals and describe objects from first, second, third, and so forth*". T10 opined that her lessons integrated "*learners' counting skills especially when they had to count according to the dice*". T9 supported the previous statement by also indicating that her lessons integrated "*learners' basic counting skills as well as learners' understanding of direction*". Direction forms part of space and shape (DBE, 2011:27). T7 suggested that her lessons integrated the use of "*patterns, functions and algebra since the squares on the chessboard is* [are] *exposure to numbers and letters. The pawns move forward in a pattern and were strategically moved. It requires planning as well as spatial understanding* [by the learners]." T8 agreed with T7's account by indicating "*my lesson also incorporated space since the learners had to be aware of the space on the chessboard*". T6 indicated that in her first activity the learners "*were exposed to the concept of symmetry which had been discussed previously*". Symmetry forms part of space and shape (ibid.). T6 also mentioned integrating space and shape in her second activity since the learners used "*different shapes and measurement by thinking of the length that have* [had] *to be taken by the Bee-Bot to reach the relevant shape chosen*". T5 indicated that her lessons integrated counting, shapes, symmetry and writing numbers since "*they* [the learners] *counted step-by-step how many balls and little snakes they had to make and also revised shapes that way. In the process, they also saw … that a butterfly is symmetrical. After they made the bee with the clay, they wrote a number next to the different amounts of legs, and so forth".* Lastly, T2 concluded that, in her lessons, *"mathematical language was reinforced as were spatial skills"*.

The photographs below in Figure 5.2 substantiate the responses above regarding the integration of mathematics.



TO4	TO10



TO6

Figure 5.4: **Photographs indicating mathematics integration**

The photographs presented provide visual evidence of how mathematics was integrated into the activities of different teachers. In the first picture, which depicts an activity from TO4, it is evident that the learners were already able to recognise and write numbers, and perform simple operations. In addition to this, the learners were able to use ordinal numbers to show order, place or position using instructions. By using ordinal numbers, the learners were able to describe objects in terms of their position, such as first, second, third, and so forth. In TO10's activity, the focus was on integrating counting skills, especially when they had to count according to the dice. The teacher designed an activity that provided learners with an opportunity to practice their counting skills in a fun and engaging way.

TO6 used space and shape in her activity, where the learners used their own knowledge of shapes and measurement concepts by thinking of the length that would be taken by the Bee-Bot to reach the relevant shape chosen. This activity allowed learners to apply their knowledge of shapes and measurement in a practical context, which helped to reinforce their understanding of the concepts. Overall, these photographs provide concrete examples of how mathematics was integrated into the activities of different teachers in this study.

5.2.1.2.4 Category 1.2.4 Teachers' views regarding the integration of the subject areas

SRQ 1

This category focuses on the teachers' views regarding the integration of the subject areas as a way to teach in Grade R. Five teachers viewed integration positively, however, T1 indicated that even though "*it is important to integrate subject areas but integrating too many aspects can complicate the lesson unnecessarily*". T8 postulated that "*all subject areas together form the overall picture for a child's* [learner's] *life. One cannot stand apart from the other, for example, language is necessary to understand mathematics and mathematics is necessary to master certain life skills, such as using money, and so forth*". T7 agreed with T8's statement and indicated that "*learners must understand the application of everything they learn and everything in their life world must be integrated*". T7 furthermore disclosed "*mathematics can be integrated with all learning areas and themes and I actually think we live in a time where technology is developing so quickly that we cannot afford not to do it*". T2 and T4 indicated that "*we incorporate mathematics into everyday tasks and all our subjects in a very informal way*" so that "*we can apply it during any time of the daily programme*". T3 indicated that without integrating the subject areas "*you will not be able to cope with the workload*". T10 also advocated the use of integration in her statement "*the integrated approach is effective in order to reinforce skills and concepts, especially in younger learners. They are more likely to retain information if encountering and practising it more than once*".

5.2.1.3 Sub-theme 1.3 Pedagogical theories and international best practices

The categories below consist of the pedagogical theories of Lev Vygotsky and Jean Piaget as well as the best practices from Maria Montessori and Reggio Emilia. The last category focuses on the teachers' views regarding the integration of the subject areas. As mentioned previously, I chose these two theorists and two practices due to the considerable contributions these individuals have made to EC, nonetheless, I do acknowledge the possibility that other theories or practices may also be present in this study. I found it difficult to separate the teachers' accounts and opinions into the four categories because there are many overlapping concepts between Vygotsky, Piaget, Montessori, and Reggio Emilia. Nonetheless, I opted to include a specific finding in one single category but I also mentioned, where necessary, if it can be grouped into another category.

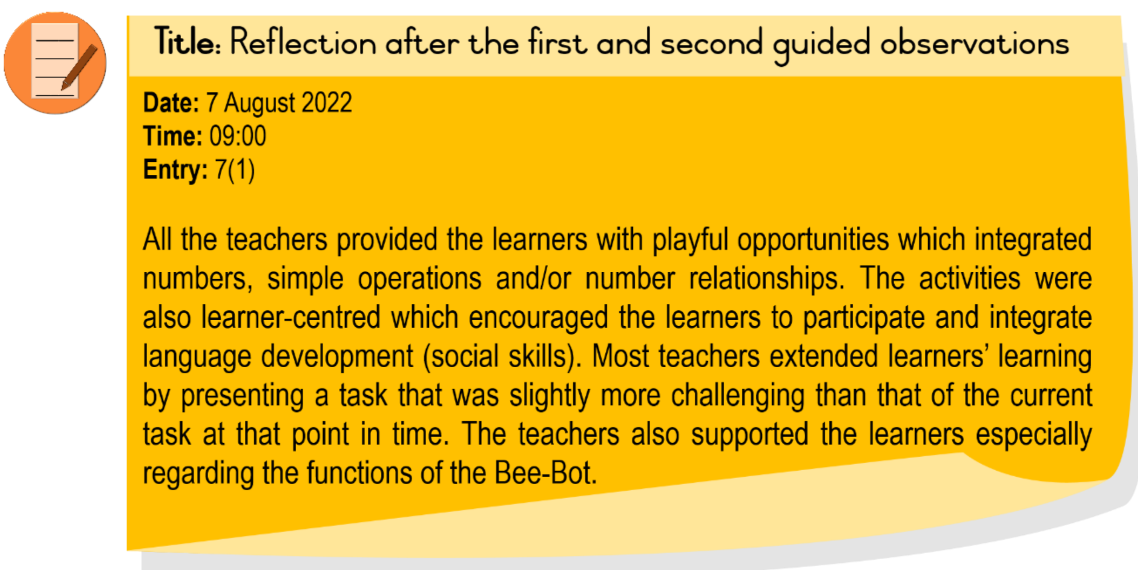
It is important to acknowledge that expressing capability in performing a task and objectively assessing that capability are distinct realms. In my study, I did not quantify the extent to which teachers effectively incorporated theories and practices, using a predetermined metric. Instead, my objective was to ascertain whether teachers demonstrated the ability to incorporate the foundational principles of these theories and practices within the framework of TPACK. To determine whether these activities effectively translated the theories and practices into practice, further research will be necessary to conduct thorough measurements.

5.2.1.3.1 Category 1.3.1 Lev Vygotsky

Six teachers indicated that they had made use of some constructs of Vygotsky's theory during the presentation of their activities.

T1 posited that she provided the learners with "*different activities with differing degrees of difficulty; in some situations, they* [the learners] *were given instructions, while in other circumstances, they were permitted to progress on their own*". T2 stated that "*We* [the teacher and the learners] *had previously discussed different types of animals so we started the lesson with animals we knew. We looked at pictures of different insects and named them. While I did give instructions for them to complete a bee, each learner still interpreted it in their own way and they could look at each other's work if they were unsure*". T5 and T6 indicated that they "*led the learners*" by *"guiding and explaining instructions to them"* and *"providing them with steps that they all had to follow*". T7 and T8 explained that their activities were focused on learners' social engagement. T7's viewpoint was "*children* [learners] *learn best from their peers, therefore, in order for optimal learning to take place, I allowed the children* [learners] *to be socially interactive*". T8 postulated that "*the learners worked in a big group and then individually. There were* [was] *a lot of social interaction during this lesson*". In this specific data set it may be said that these teachers integrated some constructs of Vygotsky's theory, such as the ZPD, cooperative learning opportunities, and scaffolding.

Journal entry 7(1) in Figure 5.5 supports the teachers' views regarding their integration of some constructs of Vygotsky's theory.


Title: Reflection after the first and second guided observations

Date: 7 August 2022
Time: 09:00
Entry: 7(1)

All the teachers provided the learners with playful opportunities which integrated numbers, simple operations and/or number relationships. The activities were also learner-centred which encouraged the learners to participate and integrate language development (social skills). Most teachers extended learners' learning by presenting a task that was slightly more challenging than that of the current task at that point in time. The teachers also supported the learners especially regarding the functions of the Bee-Bot.

Figure 5.5: Journal entry 7(1)

5.2.1.3.2 Category 1.3.2 Jean Piaget

SRQ 1

Six teachers indicated that they had integrated some constructs of Piaget's theory during the presentation of their activities.

T1 reported that she "*planned for each learner's developmental stage, watched how they were learning, and encouraged them to share what they have learned with one another*". T10 concurred with the previous statement and said "*I also checked the learners' developmental stages and monitored their progress in order to broaden their own experiences and inspire others to share what they have learned*". T2 added that "*the learning environment in my class was planned. It consisted of a wide variety of activities and resources that provide the children* [learners] *with opportunities to learn while still having fun*". T3 explained that "*the learners did more than one activity. I showed and explained to them what each learner did so that they could learn from each other*". T5 "*encouraged the learners to be included and let them also be who they are or present what they have learnt themselves. I encouraged learner-centred activities*". Lastly, T7 noted that in her activities "*the learners were physically involved and interacting* [with each other]". The previous statement can also be grouped according to Montessori's practices since it focuses on the importance of using kinaesthetic learning experiences. Constructs of Piaget's theory has been integrated by these teachers since they mentioned that they offered a variety of activities, the learning opportunities were based on the developmental level of each learner, and the learners' gross and fine motor skills were supported. However, as the teachers paid attention to the learners' developmental stages, this may also be categorised in accordance with any of the pedagogical theories or Reggio Emilia practices.

Journal entry 7(2) in Figure 5.6 contrasts some of the teachers' perspectives on Piaget's theory implementation.

Title: Reflection after the first and second guided observations

Date: 7 August 2022
Time: 09:00
Entry: 7(2)

Only during the first observations of T2-T8, did teachers provide opportunities for learners to explore and discover by providing them with a variety of resources.

Figure 5.6: Journal entry 7(2)

5.2.1.3.3 Category 1.3.3 Maria Montessori

Three teachers mentioned integrating the practices of Montessori, however, TI9's comment can be grouped either according to Montessori or Reggio Emilia. She stated that "*I plan a learning environment that is suitable for the specific class (age and ability) and making it fun and interactive where they learn by 'doing' and learn from repetition and from each other*". T7 reported that "*Montessori came in where* [when] *learners could decide for themselves which insect they wanted to make first and the resources were just provided for them to do with it what they wanted*". T6 concluded that "*I used Montessori since my activities were appropriate according to the learners' developmental levels and focused on their enjoyment*". However, since she focused on the learners' development levels, this could also be grouped according to any of the pedagogical theories or the practices of Reggio Emilia. Practices of Montessori were integrated into these teachers' activities since they were appropriate to learners' developmental levels, the teachers prepared and directed the learning opportunities, and it focused on learners' interests.

Journal entry 7(3) in Figure 5.7 corroborates the teachers' assertions about how they applied Montessori principles.

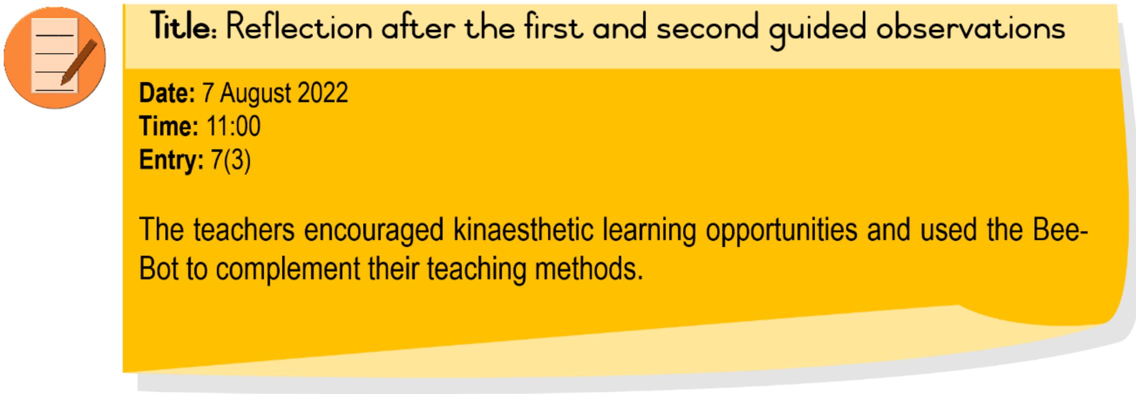


Figure 5.7: Journal entry 7(3)

5.2.1.3.4 Category 1.3.4 Reggio Emilia

SRQ 1

T1 and T2 indicated that they had integrated practices of Reggio Emilia since they observed the learners' learning to extend individual experiences and encouraged the learners to learn from one another as well. T1 specifically stated that "*I ensured that* [the] *activities were easy enough to encourage learners to participate but at the same time the activities were difficult enough to provide a different learning experience for some learners*". T2 indicated that she "*provided the learners with a space to learn and to explore on their own as well*". Regarding their integration of Reggio Emilia practices, the teachers' observations are contrasted by journal entry 7(4) in Figure 5.8.

Title: Reflection after the first and second guided observations

Date: 7 August 2022
Time: 11:00
Entry: 7(4)

The literature review of my study indicates very specific Reggio Emilia teacher practices. In my opinion I do not believe that the teachers' activities were specifically based on Reggio Emilia. Reggio Emilia views the environment as one of the most important aspects in learners' play, however, the activities developed did not allow the learners to learn through the environment. The activities had specific outcomes that had to be achieved and as such the teachers provided particular resources. Although the teachers were with the learners during the presentation of these activities, it is unknown whether the teacher stays with the learners throughout the day. The teachers discussed their observations with each other during the collaborative discussion groups, however, after the activities they did not discuss their observations but continued with the daily programme. Nevertheless, the teachers did incorporate the interests of the learners and most were eager to introduce the learners to coding and robotics.

Figure 5.8: Journal entry 7(4)

5.2.1.3.5 Category 1.3.5 Teachers' views regarding the use of the pedagogical theories and/or international practices

SRQ 1

It was evident throughout data generation that constructs of pedagogical theories and aspects of international best practices were integrated by the teachers without necessarily giving them much attention. During the activities, the teachers unconsciously integrated these in their instruction, however, upon reflection and questioning, the teachers were able to explain how their activities integrated some constructs and aspects as seen in the categories above. Teachers' unconscious use of the theories and/or practices is reiterated in statements made by T5, T9, and T10. T5 indicated she does "*not implement it* [theories or practices] *intentionally but I am sure that I use many of them without even realising* [it]". T9 argued that "*as preschool teachers, I think we have been using a good* *number of these methods, theories and skills in other ways. It is important to keep abreast of new teaching methods and also be reminded of theories. Sharing knowledge across the educational sector is important and training should be a continuous process*". T10 concluded that "*teachers instinctively apply the theories that have been learnt without having to name them. You use what you know will work and do so with whichever resources are at your disposal depending on what you are trying to teach*".

5.2.1.4 Summary of Theme 1: How teaching occurs in Grade R

The data indicates that all ten Grade R teachers had a positive perception of play-based learning. The integration of language, life skills, and mathematics occurred unconsciously in the activities and reflections, with language integration being the most prominent. Five teachers viewed integration positively, while one indicated that too much integration can complicate the lesson unnecessarily. The teachers unconsciously used constructs of pedagogical theories and spects of international best practices in their instruction, and upon reflection, they were able to explain how their activities integrated these theories and practices. However, to measure the teachers' successful implementation of these has not been discussed in this study. Overall, the teachers believed in the effectiveness of an integrated approach to teaching, and the use of pedagogical theories and best practices without necessarily giving them much attention.

5.2.2 Theme 2: The integration of mathematics in Grade R

The second theme centres on exploring how mathematics is integrated in Grade R. Findings of this theme revealed the teaching techniques that teachers used to integrate mathematics. The KCRA approach was identified as a sub-theme of integrating mathematics in Grade R, however, this sub-theme could also have been grouped under integrating coding and robotics in Grade R (Theme 4) since some of the activities focused on how coding and robotics can be integrated by using the KCRA approach. Nonetheless, I still grouped it under this theme because even though some of the activities were focused on coding and robotics, they still integrated numbers, operations, and relationships.

5.2.2.1 Sub-theme 2.1 The KCRA approach

SRQ 3

All ten teachers indicated that they use some or all of the constructs of the KCRA approach, even though it might not necessarily be in that specific order. T2 mentioned the importance of following the KCRA approach since "*a concept is better captured when you move through the different steps from kinaesthetic to abstract learning*". T10 added that with this "*younger age group* [Grade R learners] the *kinaesthetic approach is of utmost importance* [because the] *learners are constantly physically involved and need to experience as much as possible*". T1 concurred with T10 by adding that "*this age group learns most effectively when physically involved and interacting* – [they are] *less likely to be distracted and also view such activities and games as enjoyable*". T5 concurred with the previous statement by stating that "*learners enjoy doing rather than listening*". T9 emphasised the use of concrete learning by stating that "*when teaching any concept to the kids* [learners]*, whether it is letter forming, mathematics patterns or counting, we always start concrete, using objects or sensory experiences to introduce what we want to teach them*". Furthermore, TI2 indicated that only after kinaesthetic and concrete learning has taken place, they move to representational and abstract learning since "*we* [the teachers] *let them* [the learners] *draw numbers in sand, flour or slime then we let them form it with their bodies, walk on numbers drawn large on the ground, form it with playdough and so on. We start concrete and sensory, then on 2D or paperwork and end with talking about and testing the abstract concept*". TI6 also stated that she starts with concrete or representational learning by using "*objects (counters) and number cards with pictures display or dots*". Since all the teachers advocated the use of the KCRA approach in some way, they used these constructs to integrate coding and robotics with numbers, operations, and relationships. It is evident that the teachers view the constructs of the KCRA approach as being valuable in the context of Grade R learning and teaching.

The pictures captured during the guided observations in Figure 5.3 note how the KCRA approach was implemented during the teachers' activities.

SRQ 3

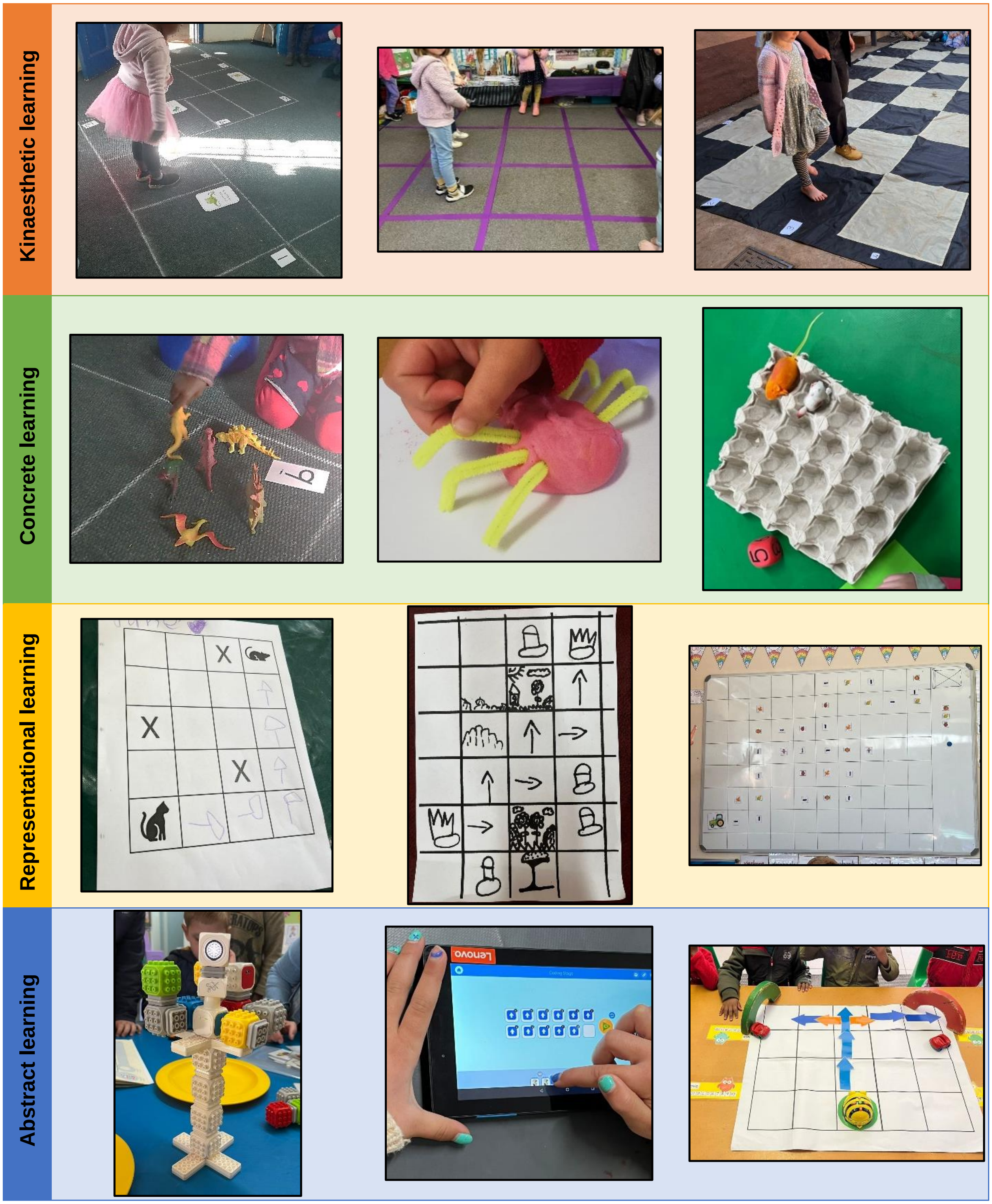


Figure 5.9: The KCRA approach used during the presentation of activities

The first three images present activities that were observed in ELEs of TO9, TO10, TO4 and TO8 that integrated kinaesthetic learning. TO9 and TO10's activity shows the squares of a hop-scotch grid that included either action pictures or number symbols that the learners had to read out loud. TO4's activity indicated a 4x5 grid where the learners had to move to specific squares. TO8 also supported learning through movement by using the squares on a human-sized chessboard consisting of numbers (horizontally) and letters (vertically) on which the learners had to move. The second row of pictures presents how TO9, TO10, TO5, and TO2 integrated concrete learning in their activities by allowing the learners to count by using concrete objects as well as integrating coding skills by means of concrete materials. Representational learning is visually presented through TO2, TO8, and TO1's activities in the third row. These activities all made use of pictures to integrate coding and counting skills. The last row, namely, abstract learning, indicates how TO4, TO3, and TO5 integrated robotics and coding in an abstract way with coding as well counting skills.

In accordance with the teachers' accounts, the extract from journal entry 7(5) in Figure 5.10 below also indicates that the teachers used the constructs of the KCRA approach in their activities.

Title: Reflection after the first and second guided observations

Date: 7 August 2022
Time: 11:00
Entry: 7(5)

The activities incorporated various aspects of the KCRA approach and allowed learners to learn through play. Each teacher used one of the constructs of the KCRA approach or implemented the steps in sequence. These activities definitely supported learners' abilities, interests, and stages of development.

Figure 5.10: Journal entry 7(5)

5.2.2.2 Summary of Theme 2: The integration of mathematics in Grade R

All ten teachers in the study reported integrating some or all of the constructs of the KCRA approach, with T2 and T4 emphasising the importance of following the approach in a specific order. T10 noted that the kinaesthetic approach is particularly important for Grade R learners, who benefit from physical involvement and sensory experiences. T1 and T5 also agreed that physical involvement and interaction are effective for this age group, while T9 stressed the importance of starting with concrete learning experiences. T2 and T6 explained how they progress from kinaesthetic and concrete learning to representational and abstract learning. The teachers used the KCRA approach to integrate coding and robotics with mathematical concepts. Overall, the teachers found the constructs of the KCRA approach to be valuable for Grade R learning and teaching.

5.2.3 Theme 3: Integrating coding and robotics with mathematics

The third theme explored how teachers integrate coding and robotics with mathematics. The use of numbers, operations, and relationships were mostly integrated.

5.2.3.1 Sub-theme 3.1 Integrating coding and robotics with mathematical concepts

The following sub-theme focuses on the integration of coding and robotics with mathematical skills and knowledge, specifically related to numbers, operations, and the relationships between numbers. The sub-theme is explained by using a table to elicit thorough comprehension.

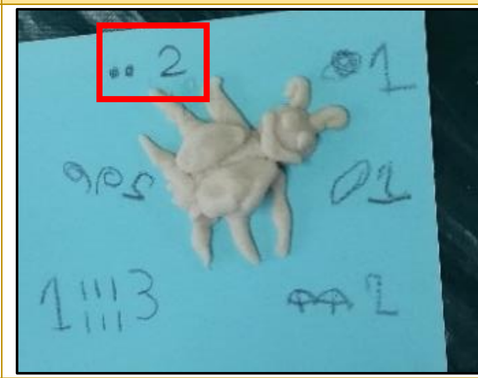
Table 5.2 summarises the integration of coding and robotics with numbers, operations, and relationships. In the first column, the teacher’s pseudonym is presented. The two subsequent columns indicate which mathematical concept had been used in the teacher’s activity, which is substantiated by either a verbatim transcript and/or an explanation substantiated by photographs (or both). All ten teachers integrated coding and robotics with either numbers, operations, or relationships (or integrated more than one concept).

Through the analysis presented in the table, it is evident that the activities focused primarily on the use of counting; number symbols and number names; describing, ordering and comparing numbers; and simple addition, which are all categories within the content area of numbers, operations, and relationships.

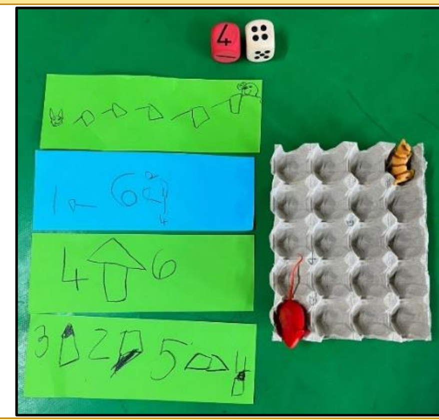
SRQ 2

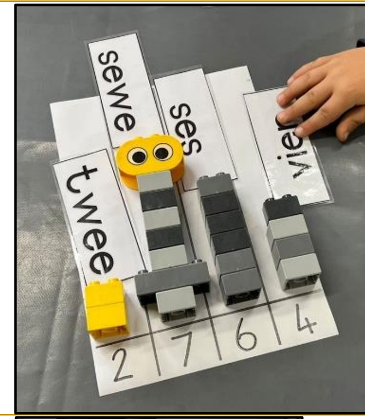
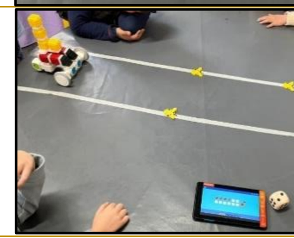
SRQ 3

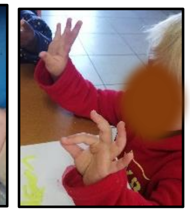
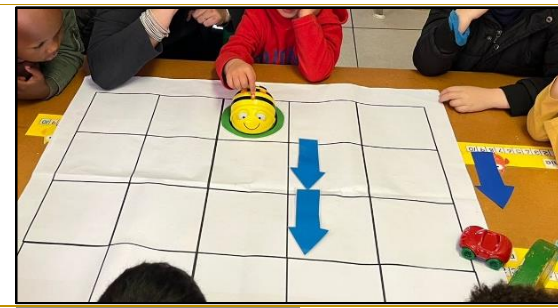
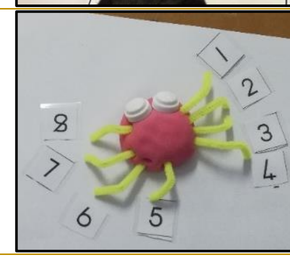
Table 5.1: Teachers integrating coding and robotics with Grade R mathematical concepts

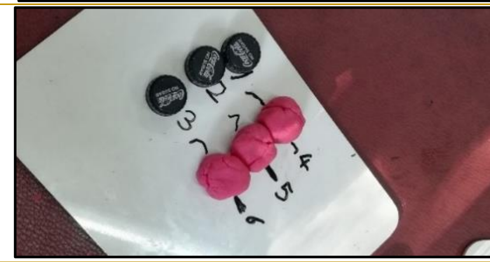
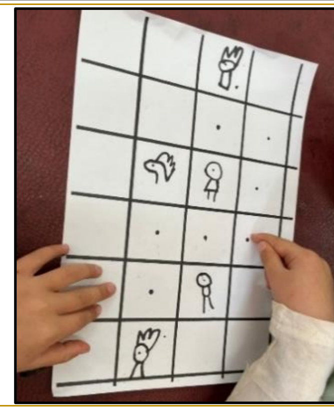
	Mathematical concept(s) integrated	Verbatim transcript and/or explanation	Photovoice
T1/TO1	• Counting (DBE, 2011b) • Number symbols and number names (DBE, 2011b)	In this CRA activity, the learners first had to 'build' a spider by using play dough. The teacher provided the learners with specific instructions to follow. When they had completed it, the learners then had to indicate how many parts of the spider they could recognise by writing the number symbol as well as indicating the part it referred to. For example, this learner's spider had two eyes.	
TI2/TO2	Number symbols and number names (DBE, 2011b)	<u>Question from semi-structured interview:</u> **When I met you, I introduced you to the KCRA approach. How do you use the constructs (kinaesthetic learning, concrete learning, representational learning, and/or abstract learning) of this approach in your learning environment (if at all)?** "*We* [the teachers] *let them* [the learners] *draw numbers in sand, flour or slime then we let them form it with their bodies, walk on numbers drawn large on the ground, form it with playdough and so on*".	

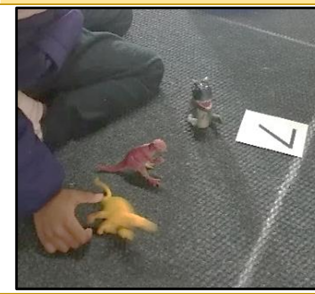
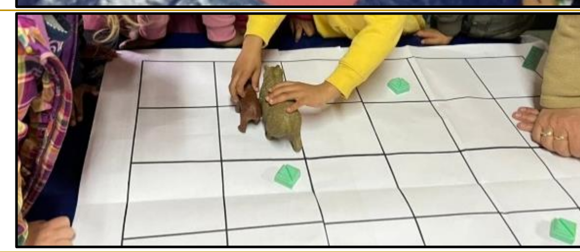
Mathematical concept(s) integrated	**Verbatim transcript and/or explanation**	**Photovoice**
• Counting (DBE, 2011b) • Number symbols and number names (DBE, 2011b)	"*Learners could recognise numbers and build shapes*". In this activity, the learners had to build an insect of their choice by using play dough. They then had to indicate how many legs the insect had by writing the number symbol – which in this case was six. This activity is, therefore, a CRA activity.	
Counting (DBE, 2011b)	The learners had to roll a die, count the number of dots they had thrown and then move their own bodies on the grid to the selected number. This is an example of a KR activity.	
	In this KCA activity, the learners first had to roll a die and count the number of dots to know how many places they should move. They then counted the number of blocks on the grid in the right direction – to get to the end of the grid. Afterwards, they pressed the correct buttons on the Bee-Bot to move it.	

	Mathematical concept(s) integrated	Verbatim transcript and/or explanation	Photovoice
	• Counting (DBE, 2011b) • Number symbols and number names (DBE, 2011b)	This activity required the learners to roll a die and move the cat figurine in the right direction towards the mouse figurine. The learners either had a die containing dots or number symbols – this was provided to the learners at the teacher's discretion. While the learners were moving the cat figurine, they had to plot their moves on a piece of coloured paper to indicate how the figurine had moved. This activity is, therefore, an example of KCRA learning.	
T3/TO3	Number symbols and number names (DBE, 2011b)	"*It leads the kids [learners] to follow the correct way of numbering the spider legs with* [the] *information provided.*" In this CA activity, the learners had to construct a spider using play dough and then they had to write the number symbols (1-6) in the correct order with a whiteboard marker.	
	• Counting (DBE, 2011b) • Describe, compare, and order numbers (DBE, 2011b)	In this KR activity, each learner stood at the back of a row of circles and threw the die to jump the number of times represented by the dots on the die. They had to indicate the number and name of the position they held.	

	Mathematical concept(s) integrated	Verbatim transcript and/or explanation	Photovoice
	• Counting (DBE, 2011b) • Addition (DBE, 2011b) • Number symbols and number names (DBE, 2011b) • Describe, compare, and order numbers (DBE, 2011b)	"*The learners to recognise and write numbers as well as doing simple operations. With the instructions, they can learn* [use] *ordinals and describe objects from first, second, third, and so forth*". This KCRA activity required the learners to pick up a certain amount of blocks according to a pair of dice (they had to add the numbers). They then placed these blocks flat on the piece of paper to recognise the number name of the position they held.	 Translation: *Twee*: Two *Sewe*: Seven *Ses*: Six *Vier*: Four
	• Addition (DBE, 2011b) • Describe, compare, and order numbers (DBE, 2011b)	This RA activity required the learners to throw a die and count the number of dots. They then had to move the Cubroid giraffe robot by inserting the correct number of times the robot had to move by using a coding application on a tablet.	 
T4/TO4	Counting (DBE, 2011b)	In this CRA activity, the learners had to use the Cubroid coding blocks to design a flashlight. They had to count the number of blocks required in each step of the building process by following the coding cards.	

	Mathematical concept(s) integrated	Verbatim transcript and/or explanation	Photovoice
T5/TO5	Counting (DBE, 2011b)	"*They* [the learners] *counted step-by-step how many balls and little snakes they had to make*".	 
		Each learner had the opportunity to move the Bee-Bot in a desired direction. The learners had to count the number of blocks they wanted to move, use directional arrows to indicate the path, and move the Bee-Bot. This activity represents KCRA learning.	
T6/TO6	• Counting (DBE, 2011b) • Number symbols and number names (DBE, 2011b)	In this CA activity, the learners had to construct a spider using play dough and then they had to put number symbol cards (1-8) in the correct order according to the feet of the spider.	 
	Counting (DBE, 2011b)	"*Objects* (counters) *and number cards with pictures display or dots*".	

	Mathematical concept(s) integrated	Verbatim transcript and/or explanation 	Photovoice 
T7/TO7	• Counting (DBE, 2011b) • Number symbols and number names (DBE, 2011b)	“*The squares on the chessboard is exposure to numbers and letters*”. Two learners were provided with an opportunity to move other learners seated on the chessboard. The learners that had to move the other learners had to be very specific when providing instructions and had to read the name of each individual block, for example, “B2 move to B3”. The learners were only allowed to move forwards. This activity presents KA learning.	
T8/TO8	• Counting (DBE, 2011b) • Number symbols and number names (DBE, 2011b)	In this CA activity, the learners had to construct a spider using play dough and then they had to write the number symbols (1-6) in the correct order with a whiteboard marker.	
	Counting (DBE, 2011b)	This RA activity required the learners to draw a king and queen on a 6x4 grid and then indicate the path that the queen had to move to reach the king by working in pairs. They also had to draw obstacles.	

Mathematical concept(s) integrated		Verbatim transcript and/or explanation	Photovoice
T9/TO9	• Counting (DBE, 2011b) • Number symbols and number names (DBE, 2011b) • Describe, compare, and order numbers (DBE, 2011b)	In this CA activity, the learners had to match the correct number of dinosaur figurines to a number symbol card. They then had to say who had the greatest and least number of figurines.	 
T10/TO10	Counting (DBE, 2011b)	"*Learners' counting skills especially when they had to count according to the dice* [die]". This activity required the learners to count the dots on a die and move the dinosaur figurine in the right direction by avoiding certain obstacles. This activity is, therefore, an example of CA learning.	
		This activity required the learners to count the dots on a die and move the bear figurines in the right direction by avoiding certain obstacles. This activity is, therefore, an example of CA learning.	

5.2.3.2 Summary of Theme 3: Integrating coding and robotics with mathematics

All ten teachers integrated coding and robotics with numbers, operations, and relationships, with activities focused primarily on counting, number symbols and names, describing, ordering and comparing numbers, and simple addition. The mathematical skills were already developed before the start of these activities.

TK

5.2.4 Theme 4: The effect and integration of coding and robotics in Grade R

The last theme explored the benefits of using coding and robotics; the difficulties that arise in the integration of using coding and robotics; how integrating coding and robotics with specific mathematical concepts should be assessed; and, teachers' attitudes and dispositions regarding the integration of coding and robotics. In this section, I report on the most important aspects of integrating coding and robotics in Grade R. The sub-themes supporting the main theme are: the benefits of integrating coding and robotics, difficulties that arise in the integration of using coding and robotics; the assessment of coding and robotics; as well as, teachers' attitudes and dispositions. I begin this section by presenting the teachers' perceptions about the benefits of using coding and robotics.

5.2.4.1 Sub-theme 4.1 Benefits of using coding and robotics

The categories below consist of the benefits of using coding and robotics as perceived by the teachers during the collaborative discussion groups. I asked the teachers "*What do you think are the possible advantages of using coding and robotics (or other technology-enhanced tools)?*" during the semi-structured interview, however, since none of them had had any previous experience in using coding and/or robotics, I opted to ask this question during the collaborative discussion groups again in order for the teachers to reflect on the activities they had presented.

5.2.4.1.1 Category 4.1.1 Equipping learners for formal schooling

SRQ 2

T6 indicated that "*coding and robotics equip learners for formal school so that they can be technologically equipped before they start with Grade 1. They will be well* *equipped*". T7 and T8 replied to this statement by adding "*we offer coding and robotics as an extramural activity but only from Grade 1 upwards*". T10 concluded the discussion by stating "*coding and robotics and technology, in general, has become very prevalent and learners are becoming very visual learners*". In these statements, it is evident that these four teachers view the integration of coding and robotics as beneficial since it will equip the Grade R learners for formal schooling (Grade 1).

5.4.4.1.2 Category 4.1.2 Equipping learners for life after school

SRQ 2

Four teachers believe that the integration of coding and robotics will prepare Grade R learners for life after school. T1 reported that "*Children* [learners] *are now growing up with technology and by using coding and robotics they can immediately be taught at a level where they are comfortable with new information*". T5 concurred with the previous statement and stated that "*it prepares them for their future to learn new things, words, numbers and so on*". T7 added that "*in moderation and applied in the correct way, I believe robotics and coding can have an excellent influence and is absolutely necessary in* [for] *our day and age. This will also teach children* [learners] *ethics and discipline in regards with* [to] *using technology in our fast developing world*". The discussion was concluded by T8 who opined that "*I now realise that coding and robotics are such a big part of our children's* [learners'] *future and we need to equip them with it*".

5.2.4.1.3 Category 4.1.3 Supporting learners' understanding

SRQ 2

Three teachers were of the opinion that coding and robotics have the potential to support learners' understanding. T6 started the conversation by stating "*teaching using technology-enhanced tools make the lessons easier to be understandable to learners* [using technology-enhanced tools as integration with other subjects; supports learners' understanding]. *As some learners are learning using different styles of learning, for example, auditory, kinaesthetic (touching), visual (using images)*". T5 added "*yes, it helps children* [learners] *think differently*". T1 ended the conversation by adding "*it also helps to keep busy learners engaged. Learners tend to focus more as it is something new and exciting*".

5.2.4.1.4 Category 4.1.4 Teachers keeping abreast with new developments

SRQ 2

In the last category, all ten teachers agreed that they have to keep abreast with new developments, however, only three teachers provided their opinions. T8's statement "*it would be beneficial for me to learn a new skill and teaching method in order to broaden the children's* [learners'] *horizons*" indicates that she believes her teaching impacts learners' learning. T9 agreed by indicating that "*I would like to keep abreast of enhancements and changes to the way children* [learners] *learn*". T10 concurred "*I would like to keep abreast of new developments in education and be knowledgeable as to how they can be used to improve my teaching. Learning environments need to keep up with new developments*".

5.2.4.2 Sub-theme 4.2 Difficulties that arise in the integration of coding and robotics

The teachers said that a few issues need to be resolved before they can successfully deploy the integration of coding and robotics. Verbatim transcripts that were obtained throughout the data generation process are provided in the section below and are used to discuss these issues. It includes challenges like the requirement for teacher training, dealing with issues brought on by having a large number of learners, needing a robot, having limited resources, and integrating robotics and coding into the curriculum.

5.2.4.2.1 Category 4.2.1 Teachers' needs

All ten teachers indicated that certain aspects would need to be addressed before coding and robotics can be successfully integrated in their ELEs. T10, the conversation starter, stated "*I do have a very basic idea of what coding and robotics is all about but am by no means content with the knowledge I have. I certainly feel that I would need a manual or textbook with clear aims and objectives, which I can use in my time to plan my lessons accordingly. Teachers would need some form of training or guidelines or manuals to help them*". T3's comment also addressed the need for training "*I am still very unsure because I don't* [do not] *quite know how to apply it in my everyday teaching. I would definitely need training in using coding and robotics as well* *as worked out lesson plans*". T4, T5, T6, T7, T8, T9 and T10 acknowledged that they would also need training and completed lesson plans to implement the use of coding and robotics successfully. Furthermore, T1 indicated "*I would also need a robot*" to which T2 agreed. T9 and T10 further elaborated on the issue of needing more information for successful implementation. T9 stated that "*if you are using coding and robotics for the first time, I believe you would require more background information, especially if you are expected to continue presenting further lessons*". T10 concurred by adding "*yes, there is a great deal of general information that needs to be given: Why? Where to begin? How? It* [coding and robotics] *has some value but is a very unknown field for me and I would still continue using methods, which I know do have value*".

T7 added "*I would like to learn how to incorporate coding and robotics into our very busy programme and adjust my teaching to adapt to our fast-developing world. Also, how to effectively give children exposure in the classroom and set up my class in such a way that they can play and discover for themselves*". T2 concurred in her statement "*yes, it will definitely be challenging to make time for it. Can work once a week in place of a normal mathematics lesson*". The discussion concluded after T4 mentioned that "*I would have liked another opportunity to present an activity, I think it would have gone better*".

5.2.4.2.2 Category 4.2.2 External factors influencing successful integration

T10 stated, "*large classes would also obviously need careful class management, which inexperienced teachers would have to work on*". T3 also explicated the issue of overcrowded classes in her comment "*yes, I would like to see how it will work with a full class of 30 learners and how you will get everyone involved to get a turn and get to their other work*". Furthermore, T10 argued that a "*lack of finances due to the current economic times will* [also] *pose a challenge*".

5.2.4.3 Sub-theme 4.3 Assessment of coding and robotics

SRQ 2

All ten teachers agreed that the assessment of coding and robotics should be implemented through informal observation as part of "*general assessments during the* *school year*" (T9). T1 reiterated the importance of assessment by reporting "*assessment remains important so that one can see where the learners are and where they still need help. Assessment of coding and robotics should be done through informal observation so that we can still lead our learners to think in other ways*". T2 added that "*through observation, you will be able to assess many objectives and implement the necessary interventions*". T6 concurred and added that "*…yeah, definitely, you will then be able to see if the learner struggles*". T10 concluded the discussion "*yes, you need to know how successful, or not, you were in conveying your objectives. As a teacher, you should quickly be able to see how effective the activity has been by observing*".

5.2.4.4 Sub-theme 4.4 Teachers' attitudes and dispositions

This sub-theme elucidates teachers' attitudes and dispositions related to the integration of coding and robotics. It is evident that the teachers' views were mostly positive and focused on innovation, enjoyment, collaboration, creativity, lateral thinking, exposure to technology, critical thinking, and the understanding of algorithms (coding skills). Negative attitudes and dispositions related to other learning areas that could be neglected, the replacement of traditional teaching methods, basic issues in education, learners' dependency on technology, and the influence of the Bee-Bot's simplistic design. Tables 5.2 and 5.3 provides these attitudes and dispositions by referring to verbatim transcripts of the teachers as well as the categories that these transcripts belong to. A statement made by T7 also form part of this sub-theme but were not categorised. T7 mentioned that "*coding and robotics seem like novel concepts until you see how it is applied in practice. Then you realise that is not that unknown and that it is just a new concept used as the end project*".

To make Tables 5.2 and 5.3 stand out, it has been formatted differently from the other tables in the chapter, with green representing teacher's positive views (Table 5.2) and red representing teacher's negative views (Table 5.3).

Table 5.2: Teachers' positive attitudes and dispositions regarding the integration of coding and robotics

SRQ 2

Positive attitudes and dispositions		
Category		**Verbatim transcript**
Category 4.4.1 Innovation	T9	"*A different way of learning made available to the children* [learners]". "*It would open up a new area of learning*".
	T8	"*This is a way to encourage children* [learners] *to solve problems and think creatively and innovatively*".
	T2	"*It speaks to the children on another level, excites them and helps to let the information sink in much quicker. It makes teaching new and exciting*".
	T10	"*Learners would respond well as many of them are already technologically adept. Anything that is different and likely to capture their attention is advantageous to their learning*".
Category 4.4.2 Enjoyment	T8	"*An enjoyable teaching tool and the learners will be able to relate and use it in their everyday life*".
	T10	"*Captures learner attention, adds interest, allows for learner involvement*".
	T2	"*Learners participated enthusiastically, understood everything well and just really enjoyed it*". "*Children* [learners] *are naturally interested in any type of technology and you'll have their attention right away. They will also want to participate*".
	T6	"*Makes learning fun and interesting*".
	T7	"*Coding and robotics … gives meaning to number relationships and complements mathematics*".
Category 4.4.3 Collaboration	T2	"*It helps learners to work together in a group*".
	T9	"*I think it is useful in teaching children* [learners] *about working together*".
Category 4.4.4 Creativity	T4	"*It was fun to see the children's* [learners'] *different creative ideas and how everyone interprets the activities*".
	T2	"*Improves creativity*".
	T9	*"I think it is useful in teaching children* [learners] *about creative thinking.*"
Category 4.4.5 Lateral thinking	T1	"*I could see how the learners think in different ways*".
	T10	"*Learners had to use cognitive skills and find a creative solution in the game*".
Category 4.4.6 Exposure to technology	T2	"*Equipping children* [learners] *for the future. Introducing them to the technology world at an early age*".
	T4	"*The learner is able to learn through screen time, which is part of their daily lives. Learners are more exposed to new technology every day*".
	T8	"*Technology is a part of every person's everyday life, therefore, the learners must be equipped with tools in order to use technology correctly, but also to be able to invent new technology for the future".*
Category 4.4.7 Critical thinking	T2	"*Improves critical thinking, analytics and planning*".
	T6	"*It encourages learners to learn* [use] *the concepts in an easier way and this stays in their long-term memory*".
	T7	"*I could see the children enjoying it and I experienced how some of them made the connection between the grid on the chessboard and the Bee-Bot's grid, as well as giving and carrying out instructions. For the children who did not get it, it was also good exposure*".
	T9	"*I think it is useful in teaching children* [learners] *about problem-solving and so on*".
Coding skills – **Category 4.4.8 Algorithms**	T4	"*It is [*These are] *simple tasks and steps each learner is able to learn on* [in] *his or her own way*".
	T2	"*By following a set of steps so that the end product forms an overall image*".

Positive attitudes and dispositions			
Category		Verbatim transcript	
			"*The instructions had to be applied one hundred per cent correctly, so that the end product could be a success*".
		T5	"*It* [the activities] *teaches* [supports] *them* [the learners] *to follow steps*".
		T6	"*Steps helped learners complete the task more efficiently*".
		T7	"*By following the instructions or steps, the lesson was a success*".

Category 4.4.1, innovation, was established because teachers saw the integration of coding and robotics with mathematics as new and exciting ways for learners to engage in problem-solving. This innovative approach engages learners who are already technologically savvy, making teaching more exciting and effective. The use of technology is advantageous to their learning, as it captures their attention and helps information to sink in more quickly.

Category 4.4.2, enjoyment, refers to how teachers view coding and robotics as an enjoyable teaching tool that captures learners' attention and allows for the learners' involvement. Category 4.4.3, collaboration, refers to how coding and robotics can help learners work together in a group and learn about teamwork. Category 4.4.4, creativity, refers to how teachers find it enjoyable to see learners' different creative ideas and how the learners interpret the activities. The teachers believe that coding and robotics improve creativity and can teach learners about creative thinking.

Category 4.4.5, lateral thinking, refers to how coding and robotics encourage learners to think creatively and find innovative solutions to problems. Category 4.4.6, exposure to technology, emphasises the importance of introducing learners to technology at an early age and equipping them with the tools to use and potentially create new technology in the future. This exposure to technology is beneficial since technology is now an integral part of daily life. Category 4.4.7, critical thinking, highlights how coding and robotics can improve learners' critical thinking, analytical and planning skills. Teachers have observed learners enjoying the activities, making connections between the chessboard and Bee-Bot's grid, and carrying out instructions. It helps support learners' problem-solving skills and stays in their long-term memory.

Category 4.4.8, algorithms, focuses on how coding and robotics activities support learners to follow a set of steps or instructions in order to achieve an overall goal or image. Teachers have observed that these activities help learners to complete tasks more efficiently and learn to follow steps accurately. It encourages learners to learn at their own pace and helps them to understand the importance of following instructions correctly to achieve success.

Table 5.3 presents teachers' negative attitudes and dispositions regarding the integration of coding and robotics.

Table 5.3: Teachers' negative attitudes and dispositions regarding the integration of coding and robotics

SRQ 2

Negative attitudes and dispositions		
Category	**Teacher**	**Verbatim transcript**
Category 4.4.9 Neglected learning areas	T10	"*Listening skills and gross motor skills will be compromised*". "*Learners become passive rather than active learners, other areas of learning, such as gross motor skills are neglected*". "*Sadly, many of the learners today are exposed to too much technology from a very young age and miss out on the foundations that are so important in their development*".
	T7	"*The use of technology can be addictive to children and cause them not to play outside, influence their social skills and have an impact on their normal development*". "*I firmly believe that active play, social interaction and exercise outdoors is* [are] *fundamental, especially at an early age*".
Category 4.4.10 Replacement of traditional methods	T10	"*I think that there is always [a] place for new ideas but these should not necessarily replace tried and tested methods*".
	T8	"*Technology cannot replace all teaching methods. If used too frequently and if it is the only teaching tool that is used, optimal learning will not be able to take place*".
Category 4.4.11 Basic issues in education	T9	"*I think there is a place for this once other basic issues like teacher training and supply of traditional equipment has* [have] *been met*".
Category 4.4.12 Dependency	T1	"*Learners may not want to participate in lessons if technology aspects are not present*".
		"*The bigger problem comes from not being dependent on technology to solve problems*".
Category 4.4.13 Simplicity	T9	"*The Bee-Bot is cute but I fear that once its limited functions has* [have] *been discovered and mastered by the children* [learners] *they will quickly become bored by it. Modern children* [learners] *are already handling far more sophisticated technology*".

Category 4.4.9 discusses the potential negative effects of using too much technology on learners' listening and gross motor skills, as well as their overall development. Category 4.4.10 cautions against replacing traditional teaching methods with technology, and emphasises the need for a balance. Category 4.4.11 suggests that technology can be introduced once other basic education issues have been addressed. Category 4.4.12 highlights the potential issue of learners becoming

dependent on technology, and Category 4.4.13 raises concerns about the limited functionality of certain technology tools and the potential for learners to become uninterested.

Categories 4.4.1 to 4.4.13 cover various aspects of integrating coding and robotics in education, including enjoyment, collaboration, creativity, lateral thinking, exposure to technology, critical thinking, algorithms, neglected learning areas, replacement of traditional methods, basic issues in education, dependency, and simplicity. However, there are also concerns regarding over-reliance on technology, neglect of traditional learning methods, and potential negative impacts on learners' development.

One of the negative attitudes and dispositions presented by the teachers was that the integration of coding and robotics could neglect other learning areas, such as physical development. In contrast to this, the excerpt from journal entry 4 in Figure 5.11 indicates that during my observation I did not view the implementation of these activities to interfere with learners' natural play patterns or their learning possibilities.

Title: Reflection after the first guided observations

Date: 19 June 2022
Time: 10:00
Entry: 4

I believe that the content presented in all the activities supported the learners to learn, engage with one another and explore the topic of 'coding'. Although coding is associated with DT, these activities did not take away from learners' learning opportunities or their natural play patterns.

Figure 5.11: Journal entry 4

Furthermore, journal entry 6 in Figure 5.12 supports the teachers' positive attitudes and dispositions towards the integration of coding and robotics. In the entry, categories, such as collaboration and enjoyment correlate with the teachers' accounts, however, other aspects that were also mentioned are imagination and exploration.

Title: Reflection after the second guided observations

Date: 7 August 2022
Time: 09:00
Entry: 6

I thoroughly enjoyed to observe each teacher's lesson during these observations. It was wonderful to see how innovative and interesting their activities were and how they incorporated coding, robotics, and mathematics. I learnt a lot and I also realised that there are various daily activities (such as playing chess) that can also develop coding skills. All the activities presented by the teachers supported the learners to learn, engage, express, imagine and explore. The kinds of social interactions that occurred were cooperative in nature since the learners and the respective teacher worked together to achieve a specific goal. All these interactions added to the learners' learning opportunities and natural play patterns. The coding and or robotics activities used by each teacher is a good fit for learners' needs, abilities, interests, and stage of development.

Figure 5.12: Journal entry 6

5.2.4.5 Summary of Theme 4: The effect and use of coding and robotics in Grade R

The teachers engaged in a discussion about the integration of coding and robotics. The teachers generally agreed that the integration of coding and robotics can be beneficial for learners, as it can prepare them for future learning and equip them with important technological skills. However, they also recognised the need for training and resources to successfully integrate coding and robotics in their classrooms. In addition, the teachers discussed issues, such as time management, class size, and assessment methods. They suggested that informal observation and general assessments during the school year could be used to evaluate learners' progress. In summary, the teachers' views on the integration of coding and robotics in Grade R were mostly positive, with a focus on innovation, enjoyment, collaboration, creativity, lateral thinking, exposure to technology, critical thinking, and coding skills. However, there were some negative attitudes towards potential neglect of other learning areas, replacement of traditional teaching methods, basic issues in education, learners' dependency on technology, and limitations of the Bee-Bot's design.

5.3 SUMMARY OF CHAPTER 5

The purpose of this chapter was to employ inductive thematic data analysis to analyse the various data generation techniques in light of the themes, sub-themes, and categories. The participant responses, photovoice, guided observations, and a reflection journal all contributed to validate the findings. After analysing the data, the identified categories, sub-themes and themes, as well as their correlation with the literature, are presented in Table 5.1. All categories, sub-themes, and main themes are numbered in accordance with their presentation and numbering in this chapter.

Table 5.4: An overview of the categories, sub-themes and theme

START LIST	TPACK CONSTRUCT	CATEGORY	SUB-THEME	THEME	RESEARCH QUESTION ADDRESSED
5.2 Main theme: Integrating coding and robotics with Grade R mathematical concepts					
Grade R teaching	PK	Benefits of play	**5.2.1.1 Sub-theme 1.1** Play-based teaching and learning	**5.2.1 THEME 1:** How teaching occurs in Grade R	SRQ 1
New information not explicitly focused on in Chapter 2		**5.2.1.2.1 Category 1.2.1** Language	**5.2.1.2 Sub-theme 1.2** Integration of subject areas		
		5.2.1.2.2 Category 1.2.2 Life skills			
	PCK	**5.2.1.2.3 Category 1.2.3** Mathematics			
		5.2.1.2.4 Category 1.2.4 Teachers' views regarding the integration of subject areas			
Grade R teaching	PK	**5.2.1.3.1 Category 1.3.1** Lev Vygotsky	**5.2.1.3 Sub-theme 1.3** Pedagogical theories and/or international practices		
		5.2.1.3.2 Category 1.3.2 Jean Piaget			
		5.2.1.3.3 Category 1.3.3 Maria Montessori			
		5.2.1.3.4 Category 1.3.4 Reggio Emilia			
New information not explicitly focused on in Chapter 2		**5.2.1.3.5 Category 1.3.5** Teachers' views regarding the use of the pedagogical theories and/or international practices			

START LIST	TPACK CONSTRUCT	CATEGORY	SUB-THEME	THEME	RESEARCH QUESTION ADDRESSED
5.2 Main theme: Integrating coding and robotics with Grade R mathematical concepts					
Mathematics in Grade R teaching	PCK	Kinaesthetic	**5.2.2.1 Sub-theme 2.1** KCRA approach *[categories discussed in sub-theme]*	**5.2.2 THEME 2:** The integration of mathematics in Grade R	SRQ 3
		Concrete			
		Representational			
		Abstract			
Integrating coding and robotics with mathematics	TCK CK TPK	Skill and knowledge development *[category discussed in sub-theme]*	**5.2.3.1 Sub-theme 3.1** Integrating coding and robotics with mathematical concepts	**5.2.3 THEME 3:** Integrating coding and robotics with mathematics	SRQ 2
Coding and robotics	TPK TK	**5.2.4.1.1** **Category 4.1.1** Equipping learners for formal schooling *[category discussed in sub-theme]*	**5.2.4.1 Sub-theme 4.1** Benefits of integrating coding and robotics	**5.2.4 THEME 4:** The effect and use of coding and robotics in Grade R	
		5.2.4.1.2 **Category 4.1.2** Equipping learners for life after school			
		5.2.4.1.3 **Category 4.1.3** Supporting learners' understanding			
		5.2.4.1.4 **Category 4.1.4** Teachers keeping abreast with new developments *[category discussed in sub-theme]*			

START LIST	TPACK CONSTRUCT	CATEGORY	SUB-THEME	THEME	RESEARCH QUESTION ADDRESSED
5.2 Main theme: Integrating coding and robotics with Grade R mathematical concepts					
New information not explicitly focused on in Chapter 2		**5.2.4.2.1** **Category 4.2.1** Teachers' needs	**5.2.4.2** **Sub-theme 4.2** Difficulties that arise in the integration of coding and robotics		
		5.2.4.2.2 **Category 4.2.2** External factors influencing successful implementation			
		Assessment *[category discussed in sub-theme]*	**5.2.4.3** **Sub-theme 4.3** Assessment of coding and robotics		
Coding and robotics		**Category 4.4.1** Innovation	**5.2.4.4** **Sub-theme 4.4** Teachers' attitudes and dispositions regarding the integration of coding and robotics		
		Category 4.4.2 Enjoyment			
		Category 4.4.3 Collaboration			
		Category 4.4.4 Creativity			
		Category 4.4.5 Lateral thinking			
		Category 4.4.6 Exposure to technology			
		Category 4.4.7 Critical thinking			
		Category 4.4.8 Algorithms			
New information not explicitly focused on in Chapter 2		**Category 4.4.9** Neglect of other learning areas			
		Category 4.4.10 Replacement of traditional methods			
		Category 4.4.11 Basic issues in education			
		Category 4.4.12 Dependency			
		Category 4.4.13 Simplicity			

Table 5.3 presents the start list of literature as well as new information that was not originally included in the start list, which is highlighted in red. The first newly discovered information pertains to the integration of subject areas in Grade R. Although the literature reviewed did not focus on subject areas other than the mathematical content area of numbers, operations, and relationships, it became evident during the review of the results that the other subject areas also played a significant role.

The second newly discovered information pertains to teachers' views on the use of pedagogical theories and/or international practices in Grade R. While the literature discussed how these theories and practices, it did not focus on how teachers view their implementation. The third newly discovered information concerns the integration of coding and robotics with mathematics. While this was briefly explored in Chapter 2, its importance and potential difficulties were not discussed. Fourthly, the difficulties that arise in the integration of coding and robotics were also briefly mentioned, but not with a specific focus on their implementation in South African schools.

Fifth, while the assessment of coding and robotics was not a necessity in the literature as the focus is on the process rather than the product in Grade R, teachers' views highlighted the importance of assessing coding and robotics as part of informal observations. Finally, teachers' negative attitudes and dispositions regarding the integration of coding and robotics were also not discussed in Chapter 2.

For a more comprehensive understanding of the codes, categories, sub-themes and themes, a thorough overview is provided in Appendix L. In the subsequent chapter, I interpret the data findings and also provide the preliminary framework that was reviewed by the EP.

CHAPTER 6: DATA INTERPRETATION AND PRELIMINARY FRAMEWORK

6.1 INTRODUCTION

In the previous chapter, I presented the sub-themes, categories and codes that were found during inductive data analysis. The data sets are centred on the research questions since the study explored the integration of coding and robotics with specific Grade R mathematical concepts. This chapter is dedicated to interpreting the data presented in the previous chapter. Data interpretation, in the words of Bogdan (2003:147), "refers to developing ideas about your findings and relating them to the literature". Additionally, according to Madjitey (2014), the main goal of information clarification is to provide the data context and importance. This chapter concentrates on the interpretation of the main themes and sub-themes illustrated in Table 6.1 below.

Table 6.1: A simplified overview of the categories, sub-themes and theme

CATEGORY	SUB-THEME	THEME
Main theme: Integrating coding and robotics with Grade R mathematical concepts		
Benefits of play	Play-based teaching and learning	**THEME 1:** How teaching occurs in Grade R
Language	Integration of subject areas	
Life skills		
Mathematics		
Teachers' views regarding the integration of subject areas		
Lev Vygotsky	Pedagogical theories and/or international practices	
Jean Piaget		
Maria Montessori		
Reggio Emilia		
Teachers' views regarding the use of the pedagogical theories and/or international practices		
Kinaesthetic	KCRA approach	**THEME 2:** Matematics in Grade R teaching
Concrete		
Representational		
Abstract		
Skill and knowledge development	Integrating coding and robotics with mathematical concepts	
Equipping learners for formal schooling	Benefits of using coding and robotics	**THEME 4:** The effect and use of coding and robotics in Grade R
Equipping learners for life after school		
Supporting learners' understanding		
Teachers keeping abreast with new developments		
Teachers' needs	Difficulties that arise in the integration of using coding and robotics	
External factors influencing successful integration		
Assessment	Assessment of coding and robotics	
Innovation	Teachers' attitudes and dispositions regarding the integration of coding and robotics	
Enjoyment		
Collaboration		
Creativity		
Lateral thinking		
Exposure to technology		

CATEGORY	SUB-THEME	THEME
Main theme: Integrating coding and robotics with Grade R mathematical concepts		
Critical thinking		
Algorithms		
Neglect of other learning areas		
Replacement of traditional methods		
Basic issues in education		
Dependency		
Simplicity		

The guidelines for the preliminary framework reviewed by the EP were developed using Table 6.1, and their application is extensively discussed in 6.6 Preliminary framework and external review. Additionally, Section 6.6 also describes the events that occurred during each phase of Cycle 4 of PAR, which included the EP review.

6.2 Theme 1: How teaching occurs in Grade R

In this section, I evaluate the data findings linked to play-based teaching and learning, the integration of three subject areas in Grade R (language, mathematics, and life skills), and the use of pedagogical theories and international best practices.

6.2.1 Play-based teaching and learning

All of the participants agreed that playing is the best way for learners to learn, which is supported by Moyles (2012) who believes that playing is important for learners' neurological development and promotes mental flexibility. Furthermore, the data indicated that participants believe that when learners play, they are free to make mistakes and are not pressured to perform at a fixed level. The views of the participants are supported by literature by Smith and Vollstedt (1985), The LEGO Foundation (2017), and Stach and Veldsman (2021), who believe that playful activities should be joyful and flexible rather than focused on a specific result. The participants also agreed that learners learn easily and eagerly through play since they are motivated to learn and take part in educational activities because they experience play as being joyful. Joyfulness is a play-based learning characteristic associated with most types of play; it includes feelings of excitement, surprise, and learning from the unexpected (Stach & Veldsman, 2021).

6.2.2 Integration of subject areas

It is common knowledge that learners in Grade R learn through "integration and play-based learning" (DBE, 2011a:9). The participants unconsciously integrated language, life skills, and mathematics during the activities, and when they reflected during the collaborative discussion groups, they were able to identify the subject areas that were integrated. Green, Parker, Deacon and Hall (2011:118) believe that in order to improve quality teaching in the FP, an integrated approach must be used, and "the right people" must be appointed to teach in the grade.

Literacy in Grade R focuses on emergent language skills as determined by the school community's LoLT. Listening and speaking, reading and phonics, writing, and handwriting skills are the areas or topics of literacy, according to Joubert (2015). Play facilitates the integration of these skills, resulting in the development of emergent language in its entirety. The DE (2003) supports the aforementioned by stating that although presented as separate outcomes, listening and speaking; reading and viewing; writing; thinking and reasoning; and knowledge of sounds, words, and grammar should all be integrated into teaching and assessment. Each activity and reflection of the participants included language integration of which speaking and listening skills were the two language-related skills that were integrated most prominently. According to Segura Alonso (2012), integrating listening and speaking is the best way to practise them. Speaking is the simplest skill to integrate with other subject areas because almost every lesson begins with a speaking task to introduce new vocabulary, elicit what the learners already know about the topic, get their attention, or make them think about a new topic (ibid.).

Life skills was also incorporated into each activity and reflection with a focus on beginning knowledge, creative arts, and physical development. Life skills is "central to the holistic development of learners" (DBE, 2011a:8). It is concerned with how various aspects of learners' development – their social, psychological, intellectual, emotional, and physical growth – are integrated (ibid.). According to the DBE (2011a:8), the teaching of the other two subjects, mathematics and language, should be supported and strengthened by the "cross-cutting subject" of life skills.

Although the focus of this study is on numbers, operations, and relationships, the participants also unconsciously incorporated other content areas of mathematics. The use of ordinal numbers to indicate order, place, or position; learners' grasp of direction; the application of patterns, functions, and algebra; and a comprehension of spatial awareness, symmetry, shapes, and measurement are the most notable of these mathematics skills. According to Excell and Linington (2015), an integrated and play-based approach is most efficient for Grade R mathematics development because it promotes problem-solving, logical thinking, and reasoning.

According to the DBE (2023), the subjects of life skills, specifically beginning knowledge, as well as personal and social relationships, language, and mathematics are all interconnected and strengthened by the study of coding and robotics.

Furthermore, the participants believed that the integration of subject areas is successful in reinforcing concepts and abilities, particularly with younger learners because they are more likely to remember information if they encounter and practice it often. The DE (2003) agrees with the participants' perspectives on subject integration. According to the DE (2003), the principle of integrated learning is essential to outcomes-based education because it supports and expands learners' opportunities to acquire skills, acquire knowledge, and develop attitudes and values across the curriculum.

6.2.3 Pedagogical theories and international best practices

The participants were effective in identifying constructs and aspects of the pedagogical theories and/or international practices in their activities. When interpreting theories and concepts, we consider their impact on the quality and care provided to young learners in the early years (Conkbayir & Pascal, 2016).

Most participants indicated that they integrated Vygotsky's ZPD as well as scaffolding because they allowed learners to advance independently while yet receiving guidance, when necessary (Wood *et al*., 1976; Rogoff, 2003; Slavin, 2006; Berk, 2018). The activities were also designed to emphasise learners' social interaction with peers (Slavin, 2006). Peer collaboration promotes assisted discovery by allowing learners of varying abilities to work together in groups, teaching and supporting one another (Berk, 2018).

Some participants were also of the opinion that they integrated Piaget's theory. Firstly, these participants indicated that they provided a variety of activities for the learners to engage in. As mentioned previously, in a Piagetian learning environment, ready-made knowledge is minimised, and learners are encouraged to learn for themselves through spontaneous engagement with their surroundings. As a result, rather than direct instruction, teachers should provide a variety of activities that allow learners to act directly in the physical world. However, during the guided observations it was evident that most teachers used direct instruction rather than guided play or free play. Only during the guided observations of the first activity that T2–T8 developed, guided play was evident since the teachers encouraged learners to engage in play by being involved, expressing interest in what they are doing, and participating in learners' play when asked or at an opportune time to further their learning (Excell & Linington, 2015; Stach & Veldsman, 2021).

According to the teachers, their learning opportunities were also centred on the learners' developmental stage. According to Berk (2001 cited in Slavin, 2006), Piagetian learning experiences build on a learner's present level of cognitive functioning. During the guided observations, most teachers built on learners' prior knowledge by providing them with opportunities to orally share ideas and discuss opinions. T1 also used a theme table to explore what learners already knew during the first guided observations.

Lastly, the teachers opined that they used aspects of Piaget's theory since their activities reinforced the learners' gross and fine motor skills. According to Janse van Rensburg (2015), learners in Grade R are in the preoperational stage of development of Piaget. One of the characteristics of these learners is that they acquire gross and fine motor skills to experience the world around them (Doherty & Hughes, 2014). Photovoice captured during the guided observations substantiate the teachers' opinions since in all the activities the learners' gross motor and/or fine motor skills were supported.

Some participants mentioned incorporating Montessori practices as well, such as planning learning opportunities that were appropriate for the learners' developmental stages and that it centred on the interests of the learners. The Montessori method is distinguished by the development of activities based on the developmental levels of the learners (Doherty & Hughes, 2014; Van Heerden & Du Preez, 2021). Furthermore, these participants also indicated that they planned and oversaw the learning opportunities. The primary tool of the teacher's evaluation of the learning process in all Montessori LEs is observation (Isaacs, 2018). In journal entry 7(3) (see Figure 5.7), I indicated two other aspects of Montessori practices that were implemented, firstly, most teachers encouraged the learners to engage in kinaesthetic activities, and secondly, the use of the Bee-Bot was used to complement their teaching in most instances.

Two participants stated that they had used Reggio Emilia practices because they witnessed the learners' learning to extend individual experiences and encouraged the learners to also learn from one another. Nevertheless, in my journal entry, I did not regard any of the teachers to having explicitly implemented Reggio Emilia practices. As mentioned previously, this practice emphasises self-directed and experiential learning in natural settings through a learner-centred self-guided curriculum (Van Heerden & Du Preez, 2021:103).

Despite being able to name the specific theories and/or practices the participants used, the participants agreed that they unintentionally used constructs and aspects of these pedagogical theories and/or international practices in their instruction.

6.3 Theme 2: Mathematics in Grade R teaching

This section focuses on the KCRA approach's data interpretation.

6.3.1 KCRA approach

All the participants advocated the use of the KCRA approach in some way since they used these constructs to develop activities that integrated coding and robotics with numbers, operations, and relationships. It is clear that the participants valued the KCRA approach's constructs in the context of teaching and learning in Grade R, however, the participants felt that when teaching Grade R learners (in general), kinaesthetic and concrete learning is of the utmost significance since the learners need to experience as much as possible by engaging all of their senses. Literature shows that employing the KCRA approach improves learner performance (Wolf, 2017); enables learners to create their own unique interpretations of concepts (Tranquillo, 2008); supports learners to retain practical alternatives (Witzel, 2005); and helps learners to conceptualise foundational operations (Mancl *et al.*, 2012). Furthermore, the DBE (2011b) stresses the importance of kinaesthetic learning before concrete and representational or semi-concrete learning.

6.4 Theme 3: Integrating coding and robotics with mathematics

The data interpretation for this theme emphasises the integration of coding and robotics with mathematical concepts.

6.4.1 Integrating coding and robotics with mathematical concepts

The teachers' activities included counting; identifying and reading number names and symbols; describing, ordering, and comparing numbers; as well as simple addition, all of which belong under the topic of numbers, operations, and relationships. In the literature review, the following skills of numbers, operations, and relationships were argued to be integrated with the use of coding and robotics: (1) counting (Highfield, 2010; Gura, 2012; Samuels & Haapasalo, 2012); (2) addition and subtraction (Kazakoff *et al.*, 2013; Ardito *et al.*, 2014; Sullivan & Bers, 2016); (3) number recognition (Lydon, 2007); (4) mental mathematics (ibid.); describing, comparing, and ordering numbers as well as recognising, identifying, and reading number symbols and number names (Highfield, 2010; Khanlari, 2014). As a result, the literature and data in the study concur.

6.5 Theme 4: The effect and use of coding and robotics in Grade R

The benefits of coding and robotics use, integration challenges, assessment of coding and robotics, and teachers' attitudes and dispositions are the focus areas of data interpretation in this section.

6.5.1 Benefits of using coding and robotics

The participants were of the opinion that coding and robotics will support learners' ethical use and discipline in using technology in the future, as well as to assist learners in comprehending DT and prepare them for life after school. Individuals must have knowledge of ethical use and discipline when using technology in the 21st century (Binkley *et al.*, 2012). Kazakoff *et al*. (2013) the DBE (2023) agree with teachers that coding and robotics will prepare learners for life after school by assisting them in addressing problems in their daily lives.

The participants concluded that using coding and robotics will improve their teaching and help them to stay current with educational developments. Sapounidis and Alimisis (2021) and the DBE (2023) also emphasise the importance of teachers staying current with educational advancements, such as coding and robotics.

6.5.2 Difficulties that arise in the integration of using coding and robotics

The participants stated that a few issues must be addressed before they can successfully integrate coding and robotics. It includes challenges, such as the need for training, dealing with issues caused by having overcrowded LEs, requiring a robot, having limited resources, and incorporating robotics and coding into the curriculum.

Participants must be trained in the integration of coding and robotics in order to understand why and how it should be implemented, where to begin with integration, and how to integrate coding and robotics with mathematics. Bers *et al*. (2013) contend that providing teachers with professional development opportunities will improve their knowledge of coding and robotics and how to integrate it. Further to that, the participants indicated that they would require a manual or textbook with clear aims and objectives in order to plan lessons or lesson plans that are already completed; information on how to integrate coding and robotics into the daily programme; and information on how to set up the learning environment for free play with coding and robotics. According to Savard and Highfield (2015), when teachers lack sufficient knowledge of coding and robotics, they will focus on how to use it rather than integrate it with mathematics.

According to the participants, class management, when integrating coding and robotics, would be critical in a learning environment with a high teacher-to-learner ratio. This point was raised by the participants even though none of them teach in overcrowded LEs. The issue of overcrowded LEs in some South African schools is confirmed by literature (Naudé & Meier, 2019; West & Meier, 2020; Zulu, 2020). According to the findings of a study conducted by West and Meier (2020), teachers perceived the implementation of efficient discipline practices as necessary but challenging in overcrowded LEs. Similarly, Zulu (2020) discovered that teachers face challenges when integrating technology with mathematics in overcrowded LEs. Cortes, Moussa and Weinstein (2012), Marais (2016) and West and Meier (2020) also mention that overcrowded LEs are one of the most frequent causes of didactic neglect, which is when a teacher is unable to adequately attend to each learner's educational needs. Overcrowding has also been linked to neurobiological impacts, such as acute stress, hypertension, cognitive impairment, and psychosocial issues in both learners and teachers (West & Meier, 2020). According to the findings of a study conducted by Kanadlı (2019), STEM education integration is difficult as it is costly since adequate equipment and materials are required, and teachers cannot apply them in overcrowded LEs. However, the literature suggests that teachers should be involved in professional development opportunities and given support material in order to increase the integration of STEM education (ibid.). Sisman, Kucuk and Yaman (2020) affirm that it is inconvenient in overcrowded LEs for the successful integration of coding and robotics.

As a final point, the participants mentioned the need for a robot in order to successfully integrate robotics. Khanlari's (2014) findings reveal that teachers experience a lack of educational robots as the most significant barrier to integrating robotics in ELEs.

6.5.3 Assessment of coding and robotics

The participants stated that the integration of coding and robotics with specific mathematical concepts should be assessed as part of the general assessments administered by Grade R teachers through informal observations. The CAPS documents support the notion that assessment in Grade R is informal and that teacher observations should be the primary assessment technique (DBE 2011a; 2011b; 2011c). Since observation is the main tool for assessment in Montessori learning contexts, this has a link to those settings as well (Isaacs, 2018).

6.5.4 Teachers' attitudes and dispositions

The participants stated that coding and robotics has the potential to improve learners' collaboration skills (supported by Fernandes *et al.*, 2006; Chambers, 2015), creativity skills (supported by Adams, Kaczmarczyk, Picton & Demian, 2010; Sullivan & Bers, 2018, Alves-Oliveira, 2020), lateral and critical thinking (supported by Clements, Battista & Sarama, 2001; Hoyles & Noss, 2003; Fernandes *et al.*, 2006; Highfield *et al.*, 2008; Highfield, 2010; Chalmers *et al.*, 2012; Allen, 2013; Ardito *et al.,* 2014; Chambers, 2015; Angeli & Valanides, 2020; Govind *et al.*, 2020; Diago *et al.*, 2022), and algorithm understanding (supported by DBE, 2023).

Negative attitudes and dispositions related to other areas of learning that may be overlooked, the replacement of traditional teaching methods, fundamental issues in education, and learners' reliance on technology.

The participants were concerned that the integration of technology would have a negative impact on learning areas, such as language (listening skills) and physical education (gross motor skills). Alhumaid (2019) and Strom (2021) affirm the previous by stating that technology does in fact have a negative impact on learners' language and physical skills. However, in the context of this study, participants discovered that coding and robotics can improve learners' language skills and can also be taught through kinaesthetic activities with mathematical skills.

The participants also advocated for the use of traditional teaching methods, claiming that coding and robotics should not be used to replace these methods but rather as a tool to enhance learners' learning. Furthermore, the participants stated that learners should not become overly reliant on coding and robotics, or technology in general, to solve problems. In contrast, an entry from my reflection journal stated that during my observation, I did not believe the implementation of these activities interfered with learners' natural play patterns or learning opportunities. In response to the participants' views, Nel *et al*. (2021) state that coding and robotics can be used as supportive tools to achieve a learning objective.

6.6 PRELIMINARY FRAMEWORK AND EXTERNAL REVIEW

Once the data was organised and categorised into themes, I used inductive data analysis to develop guidelines based on teachers' perspectives and diverse contexts (Fulton & Britton, 2011). To create these guidelines, I delved back into the data, reviewing codes, categories, sub-themes, and themes to understand the overarching idea. As a result, I identified four main focus areas that produced knowledge of what is needed, what needs to be addressed, how teaching and learning should unfold, and the possible outcomes when integrating coding and robotics with Grade R mathematical concepts. To categorise the themes into guidelines, I returned to Microsoft Excel. However, I encountered some instances where one theme could overlap with two or more guidelines. In these cases, I split the theme to accommodate the overlap. The resulting guidelines and when they should be addressed during the integration of coding and robotics with Grade R mathematical concepts can be seen in columns 4 and 5, respectively, of Table 6.2.

Table 6.2: Using Microsoft Excel to develop the guidelines according to the themes, sub-themes and categories

CATEGORY	SUB-THEME	THEME	GUIDELINE	IMPLEMENTATION
Main theme: Using coding and robotics to teach Grade R mathematical concepts				
Benefits of play	Play-based teaching and learning	**THEME 1:** How teaching occurs in Grade R	Learning process	During
Language	Integration of subject areas		Learning process	During
Life skills			Learning process	During
Mathematics			Learning process	During
Teachers' views regarding the integration of subject areas			Learning process	During
Lev Vygotsky	Pedagogical theories and/or international practices		Learning process	During
Jean Piaget			Learning process	During
Maria Montessori			Learning process	During
Reggio Emilia			Learning process	During
Teachers' views regarding the use of the pedagogical theories and/or international practices			Learning process	During
Kinaesthetic	KCRA approach	**THEME 2:** The teaching of mathematics in Grade R	Learning process	During
Concrete			Learning process	During
Representational			Learning process	During
Abstract			Learning process	During
Keeping the focus on mathematics when using coding and robotics	Keeping the focus on mathematics	**THEME 3:** Using coding and robotics to teach mathematics	Learning process	During
Skill and knowledge development	Mathematical skills developed when using coding and robotics		Outcomes	During/after
Equipping learners for formal schooling	Benefits of using coding and robotics	**THEME 4:** The effect and use of coding and robotics in Grade R	Outcomes	During/after
Equipping learners for life after school			Outcomes	During/after
Supporting learners' understanding			Outcomes	During/after
Teachers keeping abreast with new developments			Outcomes	During/after
Teachers' needs	Difficulties that arise in the implementation of using coding and robotics		Needs	Before
External factors influencing successful implementation			External factors	Before

CATEGORY	SUB-THEME	THEME	GUIDELINE	IMPLEMENTATION
Main theme: Using coding and robotics to teach Grade R mathematical concepts				
Assessment	Assessment of coding and robotics		Learning process	During
Innovation	Teachers' attitudes and dispositions regarding the implementation of coding and robotics		Outcomes	During/after
Enjoyment			Outcomes	During/after
Collaboration			Outcomes	During/after
Creativity			Outcomes	During/after
Lateral thinking			Outcomes	During/after
Exposure to technology			Outcomes	During/after
Critical thinking			Outcomes	During/after
Algorithms			Outcomes	During/after
Neglect of other learning areas			Needs	Before
Replacement of traditional methods			Needs	Before
Basic issues in education			External factors	Before
Dependency			Needs	Before
Simplicity			Needs	Before

In developing these guidelines, I hope to support teachers to create more effective and engaging learning experiences that meet the diverse needs of Grade R learners (Stephen & Plowman, 2013). It is also based on integrating technology, more specifically coding and robotics, and its possible anticipated outcomes as well as how it should be used during the learning process. The four guidelines I developed were crucial in developing a preliminary framework for the EP to review.

6.6.1 The rationale for developing the guidelines

In this study, developing guidelines was a crucial step in interpreting and analysing the data. It provided a structured approach to understanding the generated data. In my view, developing guidelines from already-vast themes is an essential step to creating a practical resource that can be used by teachers and researchers alike. By condensing the data and identifying the most relevant themes, a set of guidelines can be created that is easy to understand and implement in practice (see Figure 2.21).

However, creating the guidelines required condensing a vast amount of information into a set of clear and concise guidelines. While this approach provides an overview of what is needed and how the process should occur, it can potentially result in the loss of the essence of each sub-theme and theme. It is important to note that developing guidelines is not a replacement for the underlying themes but a higher level of explanation and understanding. As a researcher or teacher, it can be challenging to sift through a vast volume of information and extract what is most relevant. By creating guidelines that focus on the themes, a practical resource is provided that can be easily applied in a classroom setting or used as a framework for further research.

Moreover, to ensure that the data is properly explained according to the teachers' lived experiences, the focus was primarily on the first set of four themes, as seen in the interpretation of data and the comparison in the next chapter. While the guidelines provide a comprehensive understanding of the data, it is essential to acknowledge that it is not a replacement for the themes. Instead, the guidelines should be complemented by the underlying sub-themes and themes to gain a complete understanding of the data.

6.6.1.1 The development and importance of each guideline

The subsequent section delves into the development and significance of every guideline, with each guideline and its corresponding title highlighted in **grey**. The content of each guideline is briefly explained, followed by a turquoise block that provides a summary of the rationale and importance of including the guideline and its contents.

6.6.1.1.1 Needs

The **first guideline** focuses on the **needs** of teachers regarding the successful integration of coding and robotics with Grade R mathematical concepts. As part of the preparation for integrating coding and robotics with numbers, operations, and relationships in Grade R, I chose to group certain information under the category of 'needs'. This grouping allowed me to identify specific areas where teachers may require support and guidance to ensure successful implementation.

The first information category I included was the **difficulties that may arise during the integration of using coding and robotics**, specifically related to teachers' needs. This information was important to consider as it allowed me to anticipate potential challenges. By understanding the needs of the teachers, I could provide an overview of any barriers experienced by the teachers in this study for the successful integration of coding and robotics with Grade R mathematical concepts.

The second category I included was the **training needs** of teachers to understand the integration of coding and robotics. This information was important to consider as it allowed me to ensure that teachers may have a clear understanding of the integration of coding and robotics with mathematical concepts, as well as how they could be used in conjunction with traditional teaching methods. By highlighting this need, teachers may feel confident and empowered to integrate coding and robotics as a complementary tool in their teaching practice.

In summary, the above-mentioned elements are essential for identifying and addressing the needs of teachers in integrating coding and robotics with mathematical concepts in Grade R. These elements include considering potential difficulties and providing appropriate support, as well as addressing the need for teacher training to understand the integration of coding and robotics in Grade R.

6.6.1.1.2 External factors

The **second guideline** encompassed the **external factors** that needed to be addressed before integrating coding and robotics with Grade R mathematical concepts. As part of the preparation for integrating coding and robotics with numbers, operations, and relationships in Grade R, I chose to group certain information under the category of ‘external factors’. This grouping allowed me to identify specific contextual factors outside of the immediate classroom environment that could influence the success of the integration.

The first category I included was the information on the various **external factors** that could impact successful integration. This information was important to consider as it allowed me to anticipate potential barriers. The second category I included was the **basic issues in education** that may impact successful integration. This information was important to consider as it allowed me to highlight any broader issues that could have an impact on the success of the integration.

In summary, the above-mentioned categories are essential to consider before integrating coding and robotics with numbers, operations, and relationships in Grade R. It allowed for the identification of potential barriers and highlighted broader issues that may impact the success of the integration.

6.6.1.1.3 Learning process

The **third guideline** focused on the **learning process** of integrating coding and robotics with Grade R mathematical concepts. This involved identifying the specific steps involved in the learning process and how they could be optimised to achieve the desired outcomes.

I grouped the following information under the title ‘learning process’ during the integration of coding and robotics with numbers, operations, and relationships in Grade R because these elements are integral to the process of learning and development of young learners.

- Firstly, **play-based teaching and learning** can promote active learning and problem-solving skills.
- Secondly, the **integration of subject areas** can aid in the development of cognitive abilities.
- Thirdly, incorporating **pedagogical theories and/or international practices** can enhance teaching effectiveness.
- Fourthly, the **KCRA approach** to teaching and learning can facilitate a deeper understanding of coding and robotics with mathematical concepts.
- Lastly**, assessment** of coding and robotics with mathematics can help monitor learner progress and provide feedback for improvement.

In summary, the above-mentioned elements are essential to the learning process during the integration of coding and robotics with numbers, operations, and relationships in Grade R. Grouping them under the title ‘learning process’ can aid in organising the information and highlighting their importance in facilitating effective teaching and learning for young learners.

6.6.1.1.4 Outcomes

Finally, the **fourth guideline** was focused on the possible positive **outcomes** that could be anticipated when integrating coding and robotics with Grade R mathematical concepts. I chose to group the information on **mathematical skills used** when integrating coding and robotics, the **benefits** of integrating coding and robotics, and **teachers' positive attitudes and dispositions** regarding the integration of coding and robotics, and title it ‘outcomes’ during the integration of numbers, operations, and relationships in Grade R using these tools. I made this choice because I wanted to focus on the potential results of integrating coding and robotics with mathematical concepts to young learners.

By grouping the information under the 'outcomes' heading, I aimed to highlight the tangible benefits and skills that learners could gain, as well as the positive attitudes and beliefs that teachers held towards it. This grouping helped me to emphasise the potential impact that the integration of coding and robotics with mathematics could have.

Overall, using these four guidelines helped me to develop a preliminary framework that was comprehensive and covered all aspects of integrating coding and robotics with Grade R mathematical concepts as identified in this study.

6.6.1.1.5 The guidelines and the preliminary framework

The four guidelines and how they emerged from the data generation are visually represented in Figure 6.1.

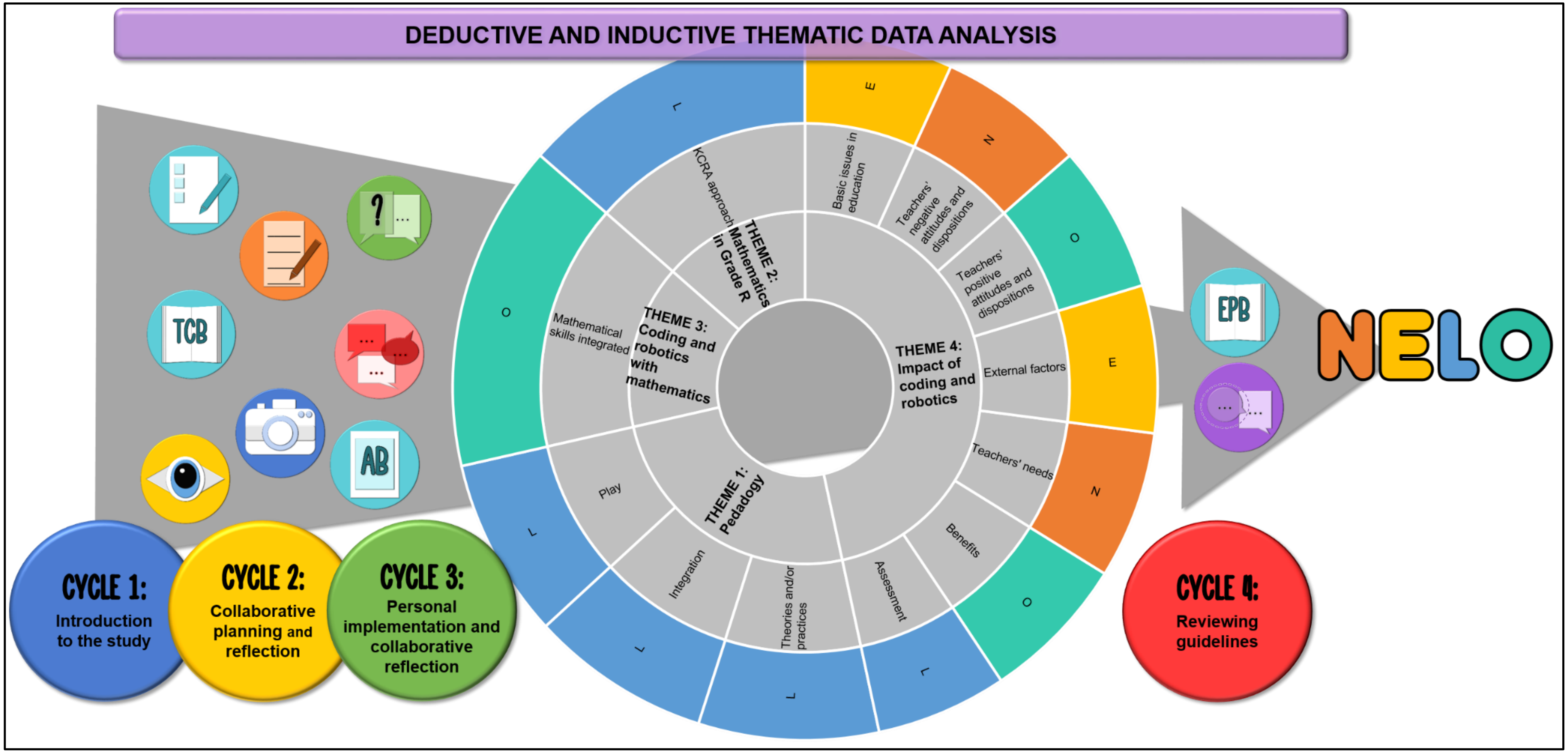


Figure 6.1: Visual representation of the sub-themes, themes and guidelines

In Figure 6.1, the four themes and their accompanying guidelines developed through inductive data analysis are presented. ***Theme 1*** focuses on the ***learning process during integration*** of coding and robotics with Grade R mathematical concepts, specifically the integration of subject areas, the benefits of play, and the integration of pedagogical theories and/or international best practices. ***Theme 2*** also focuses on the ***learning process*** by employing the KCRA approach ***during implementation***. ***Theme 3*** was split into two guidelines: one focused on the ***learning process during implementation*** and the other on the possible anticipated ***outcomes during or after implementation***. ***Theme 4*** is the broadest theme, encompassing all four guidelines. It includes ***teachers' needs*** and ***external factors*** as separate guidelines that need to be addressed ***before integration***, with the former referring to aspects that can be addressed within the school environment (such as teacher training) and the latter requiring support from other role players (such as addressing overcrowded LEs). This theme also covers the ***learning process*** of using assessment of coding and robotics with mathematics ***during implementation***, as well as the possible ***outcomes*** for both teachers' and learners' development. These four themes were used to develop a preliminary framework for review by the EP, aiming to support teachers in creating effective and engaging learning experiences for Grade R learners that meet their diverse needs.

The next section discusses the final cycle of PAR, namely, Cycle 4.

6.6.2 Cycle 4: Reviewing guidelines

Figure 6.2 visually represents Cycle 4.

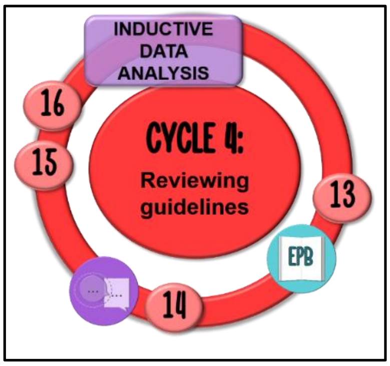


Figure 6.2: A visual representation of Cycle 4

Cycle 4 required me to complete thematic data analysis as well as data interpretation of the first three cycles in order to develop a preliminary framework. I then contacted the EP to confirm her availability and obtain informed consent. I decided to design an external participant booklet (EPB), to condense the guidelines for a preliminary framework and provided this to the EP in electronic format before employing a systematising expert interview during the action phase of this cycle. The interview lasted 90 minutes and was conducted on Microsoft Teams. The EP was required to review the preliminary framework. During the observation phase of PAR, I noted differences and similarities between the initial data and the data obtained from the systematising expert interview. Lastly, I organised this new information in order to develop the finalised framework.

6.6.2.1 Reviewing guidelines: Plan

The EPB was part of Cycle 4's planning phase (see Figure 6.3). To develop the EPB, I employed inductive data analysis to understand the themes and generate four guidelines (see Figure 6.1).

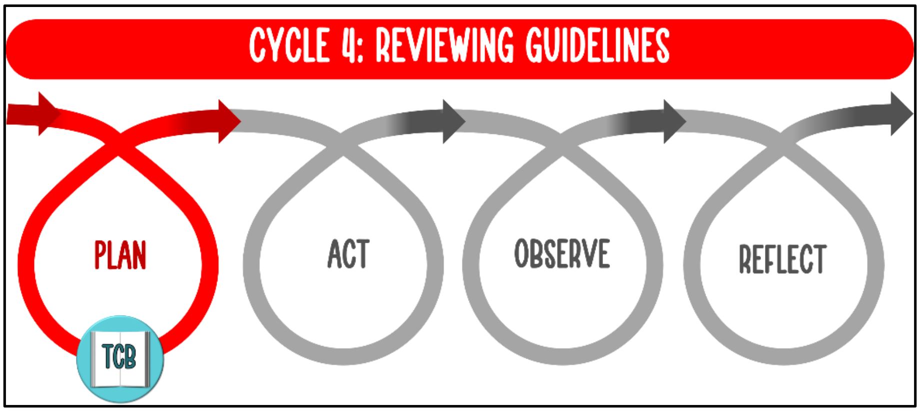


Figure 6.3: Visual representation of Cycle 4's planning phase

Before interviewing the EP, I visually represented the preliminary guidelines, the purpose of the study, the research questions, how PAR was employed, how TPACK informed the study, as well as the themes, sub-themes, and categories (see Appendix M). The reason for this was to enable the EP to familiarise herself with the study before providing feedback. I then contacted the EP to confirm her availability and obtain informed consent. The EPB was provided to the EP in electronic format before employing the systematising expert interview.

6.6.2.2 Reviewing guidelines: Act

During the action phase of Cycle 4, as seen in Figure 6.4, the systematising expert interview was held.

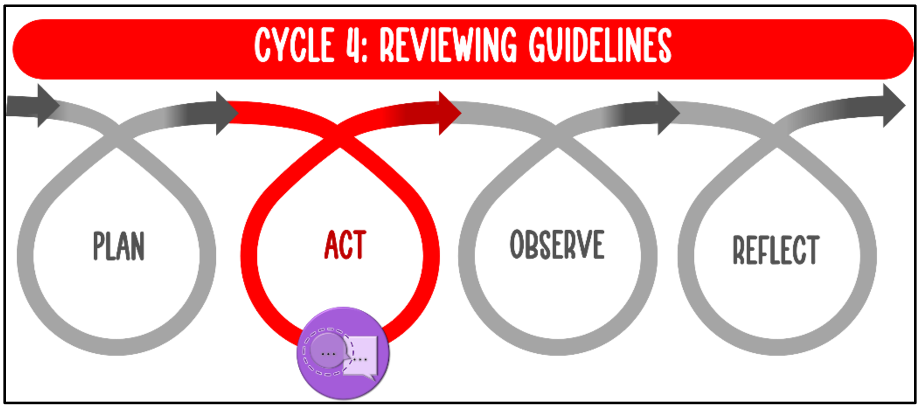


Figure 6.4: Visual representation of Cycle 4's action phase

The interview lasted 90 minutes and was conducted on Microsoft Teams. The main purpose of the interview was for the EP to review the preliminary framework. The interview contained ten open-ended questions, which allowed the EP to provide sufficient feedback on each guideline that related to its content, organisation, and presentation (see Appendix H). Each guideline was discussed with the EP, by providing information on how the data was analysed to get to that specific guideline as well as what it meant in the context of the study. The EP was also asked to comment on each guideline's applicability to be used in the framework. Figure 6.5 is a visual representation of the preliminary guidelines.

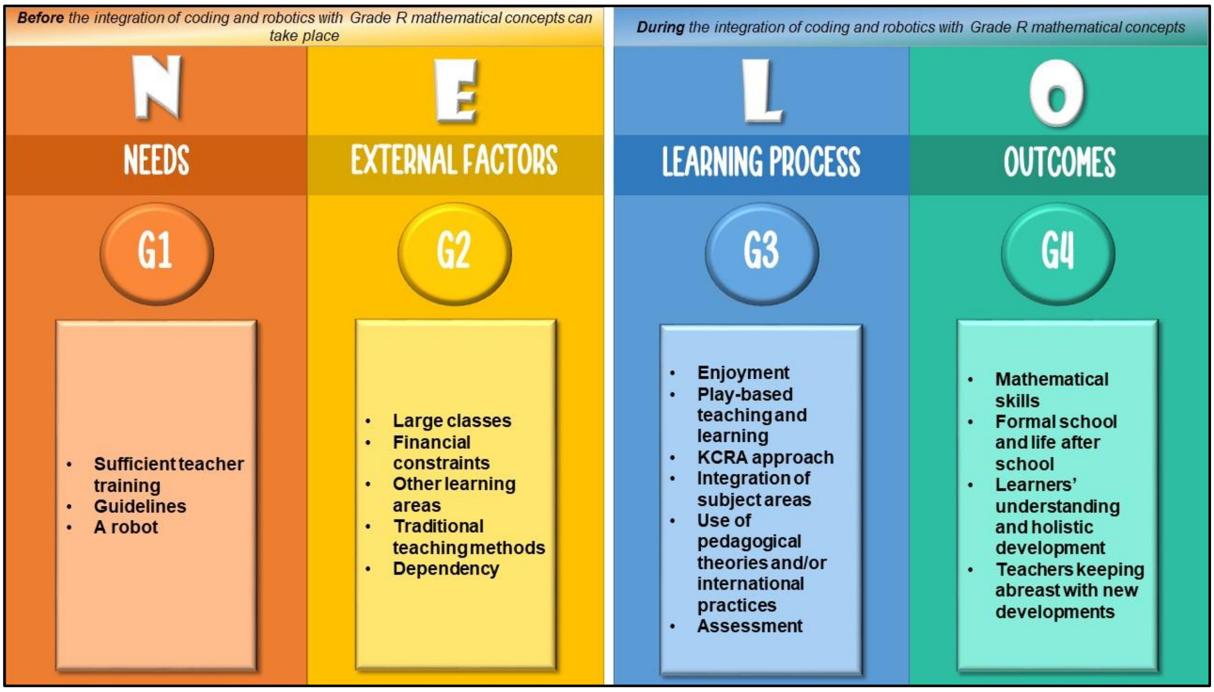


Figure 6.5: A preliminary framework to integrate coding and robotics with Grade R mathematical concepts

The first two guidelines must be implemented before teachers can integrate coding and robotics with Grade R mathematical concepts. Teachers' needs relate to training; guidelines; and a robot. The issue of external factors also needs to be addressed. The subsequent two guidelines need to be employed during integration of coding and robotics with Grade R mathematical concepts. Firstly, learning activities supported through coding and robotics are enjoyable; and should be informed through play-based learning and teaching.

Moreover, teachers should employ the KCRA approach, or the constructs thereof, to facilitate learners' learning. Teachers already unconsciously integrate the three subject areas and use the pedagogical theories and/or international practices elucidated in this study. Furthermore, the assessment of integrating coding and robotics with Grade R mathematical concepts should form part of the general assessments in Grade R, which are informal observations. Lastly, four possible positive outcomes occur when integrating coding and robotics with Grade R mathematical concepts, namely, mathematical concepts that are included; it may prepare learners for formal schooling as well as life after school; it supports learners' understanding and holistic development; and, teachers are able to keep abreast with new developments in education.

6.6.2.3 Reviewing guidelines: Observe and reflect

During the observation and reflection phase of Cycle 4, I noted differences and similarities between the initial data and the data obtained from the systematising expert interview. Lastly, I organised this new information in order to develop the finalised framework. This is visually represented in Figure 6.6.

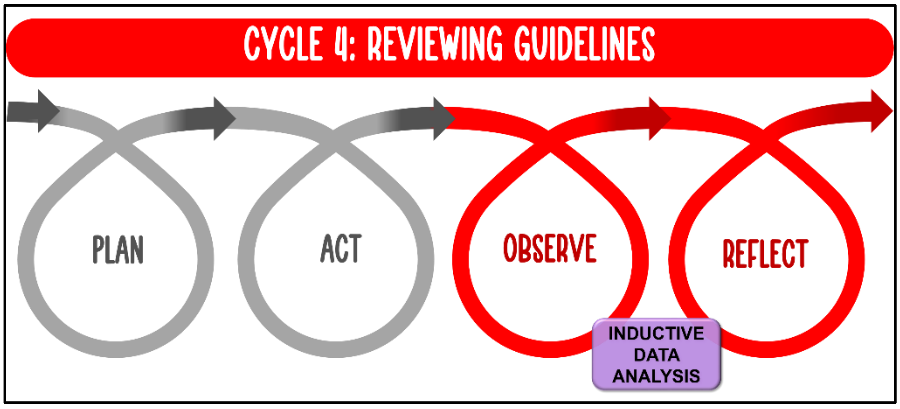


Figure 6.6: Visual representation of Cycle 4's observation and reflection phase

In the next section, the data analysis of Cycle 4 is presented by providing the results from the systematising expert interview as well as how it affected the development of the finalised framework.

6.6.3 Guidelines of preliminary framework

In this section, I present the four guidelines identified from the findings as well as the data interpretation, which was reviewed by the EP. I have provided a brief summary of each guideline, the aspects it consists of, as well as the EP's views.

6.6.3.1 Before the integration of coding and robotics with Grade R mathematical concepts can take place

As mentioned previously, two guidelines were identified that need to be addressed before the successful integration of coding and robotics with Grade R mathematical concepts can take place. These refer to teachers' needs and external factors. The EP reiterated the importance of these two guidelines preceding the actual integration of coding and robotics with Grade R mathematical concepts by stating "*I really like the way you have approached it* [the framework] *and I think specifically for … teacher education and in schools, very often you start with the L* [learning process] *and the O* [outcomes]. *And you know you dive straight into implementation* [integration] *and you fail to look at what needs to happen prior to implementation* [integration]*. And I think that is often why, you know, certain educational endeavours fail because they have not actually looked at what the prerequisites are, what prior learning is there and what needs to be built on before you can actually go into what needs to be implemented.*" The definition of a teaching framework presented in Chapter 1 (*see* 1.1 Introduction to the study) does not include factors that need to be addressed beforehand, however, the EP stated "*I think it can be justified, and you know, in order to achieve learning objectives, you have to have certain things in place. If those things are not in place, you are not going to achieve those learning objectives. So yes, it must be to align learning objectives within activities and environments and assessments and so forth* [teaching framework definition], *but, in addition to that, it is also to look at factors that are going to influence the process of aligning those learning objectives*". For this reason, I decided to include teachers' needs as well as external factors that need to be addressed in the final framework.

6.6.3.1.1 Guideline 1: Needs

It was determined that teachers needed a robot, sufficient training, and guidelines before the integration of coding and robotics with mathematical concepts can take place. Teachers noted the need to understand the rationale for integrating coding and robotics with mathematics. Teachers also expressed a need for knowledge on how to integrate coding and robotics into the daily curriculum and how to set it up for free play; a manual with goals and objectives for lesson planning; and completed lesson plans that they can follow. Last but not least, the teachers emphasised the requirement for a robot that should be equipped by a wide range of applications and features.

The starting point of the first guideline with the EP was regarding teacher training and guidelines. The EP suggested that teacher training and guidelines should be combined since "*generally in teacher training, they are going to get guidelines. …teacher training* [refers], *you know*, [to] *the more practical components of it and guidelines is a document*". Furthermore, regarding the guidelines, the EP expressed that "…*in South Africa especially, we are training technical teachers, we are training them to, you know, have a script of a lesson plan and you* [the teachers] *dare not falter from that lesson plan because that is what it says you must do. So, there is no flexibility. There is no creativity. There is no critical thinking. So, I would really like somewhere instead of saying, you know, 'worked out lesson plan' to maybe say 'an exemplar of lesson plans' or 'of possibilities', or even instead of having* [a] *lesson plan to have framework guidelines rather than a lesson plan because we know our teachers, you will have this exemplar for them and they will use it to the last full stop. They will not deviate from that. Which then, I do not think serves any purpose at the end of the day, so that is something also that you could consider*". These responses of the EP led me to divide teacher training into two parts: the training itself and the material that accompanies it. I also changed the term 'teacher training' to 'the thinking teacher' as suggested by the EP. The phrase 'the thinking teacher' is broader, embracing both professional development and basic teacher education, and incorporates the idea of allowing teachers to understand why they need to know certain things and how to accomplish certain things.

Moreover, instead of including 'worked out lesson plans' as an aspect that teachers need, I opted to remove this and rather suggest that teachers employ the framework to understand how to use coding and robotics to teach specific mathematical concepts, as the EP also advocated that through this the teachers will be able to "…*creatively, and using their thinking and applying their knowledge of everything that they have learnt, come up with their own lesson*".

Lastly, specifically regarding the robot the EP stated that robots "*can be as open-ended as you make it*" and *"that is something that could possibly go into the guidelines as well you know, the open-endedness of the robots*". As a result, I chose to merely declare that teachers would require a robot rather than that the robot's selection should also be driven by a plethora of purposes and functions.

6.6.3.1.2 Guideline 2: External factors

Learning environment overcrowding; financial constraints; the neglect of other learning areas; the replacement of traditional teaching methods; and learners developing dependencies on technology were all external problems that were highlighted.

Teachers noted that the integration of coding and robotics will require careful class management in overcrowded LEs. Regarding the inclusion of this external factor, the EP stated "…*we know the South African situation and we know what schools look like. So, I do think that* [it] *must be included and I am sure it* [the aspect of overcrowded LEs] *came out in your literature and somewhere you know that, that is the reality on the ground*". For this reason, I still included overcrowded LEs as an aspect that needs to be addressed before the integration of coding and robotics can take place. Nevertheless, it is imperative to note that although overcrowded LEs as an external factor was mentioned by the participants, I did not observe the teachers in this type of LE. All the teachers had few learners in their LEs. It might, therefore, also be important to mention that other factors such as parental involvement and attitude towards the integration of coding and robotics, could be grouped in this section. However, I kept to the scope of this study and what was found in the data by only including what the participants had stated.

Furthermore, teachers mentioned if specific equipment, such as a robot, needs to be purchased, financial restrictions could become a problem. The EP mentioned that "*I think in almost every technology education article that you will read in South Africa, this one* [financial constraints] *comes up and you know there is that whole gap between the haves and the have-nots. Those that, you know, in our schooling system if we look at, you know, government schools, the levels within the government schools and then government versus private and there definitely are huge gaps there*". The discussion then proceeded towards an explanation of integrating coding without necessarily buying any equipment, for example, kinaesthetic and concrete mathematics activities supported by the concept of coding. The EP added "*it does not mean that it* [coding and robotics] *is not doable*. *It does not mean that you cannot implement it in other ways, there is a researcher … where she for many years before, you know, the popularity of coding and robotics actually came to South Africa … she did coding and* *robotics in rural South Africa in early childhood education, using recyclable materials. You know, teaching them the concepts of it just with what they had. So, there are always ways to overcome that*". I opted to include the difficulty that might arise when certain equipment needs to be bought in the final framework, however, I also added that there are ways to overcome this, such as using recyclable materials. I also relocated this factor to teachers' needs.

The results also indicated that coding and robotics integrate with learners' language skills and physical development, however, teachers expressed their concern that technology, in general, will affect these developmental areas negatively. Moreover, teachers expressed that coding and robotics should not take the place of traditional instructional strategies but that it needs to be utilised as a tool to improve learning. Last but not least, teachers emphasised that learners must avoid becoming reliant on, coding, robotics, or technology in general to resolve problems and that it should only be employed as a means of enhancing learner comprehension. Regarding these three aspects mentioned above, the EP expressed the need of "*shifting the perception of how you think about digital, or how you think about technology, or how you think about coding and robotics, because it has always been there in some way or another. It is now just named differently and maybe the importance has escalated, but it has always been there, so, you know, we need to move with what is but also just view it differently. If you have got the correct pedagogy and the correct approach and the right way to do it, you know the benefits are limitless*". Furthermore, the EP emphasised than rather than categorising these factors as negative, we need to change our perspective because "…*there needs to be an understanding of what is required in coding and robotics and how it is changed the way we are going to educate our children to see it as part of a child's world now and then to think about how quality coding and robotics can support, you know, a playful approach to maths* [mathematical] *concepts*". As a result, I chose to transform these factors from negative to positive by categorising them as "*framing coding and robotics within learning areas*", as proposed by the EP, because "*it is not to replace anything, it is to enhance* [learning and teaching]". The EP also indicated that "*there needs to be a stronger advocacy so that it is not necessarily change management, it is you know in a way change management because it is a new way of doing things, but if there was that advocacy and that understanding then the process of implementation could be a little bit smoother. It* *would definitely be an external factor that would have to come out before the learning process and the outcomes*". The perspectives of the EP on these three areas enabled me to regroup them while also emphasising the importance of teachers having a deeper understanding of coding and robotics in the recommendations section of my study. I opted to relocate these aspects to different guidelines.

6.6.3.2 During the integration of coding and robotics with Grade R mathematical concepts

During the integration of coding and robotics with Grade R mathematical concepts, there are certain aspects addressed in the learning process as well as some possible positive outcomes that may be anticipated. The discussion with the EP commenced by focusing on what transpires during the learning process when integrating coding and robotics with specific mathematical concepts.

6.6.3.2.1 Guideline 3: Learning process

Teachers noted that play-based teaching and learning must take place during the integration of coding and robotics with Grade R mathematical concepts; the KCRA approach ought to be used; the integration of subject areas will take place; and coding and robotics may be used as an enjoyable teaching tool. Additionally, the findings clarified how teachers used international best practices and/or pedagogical theories, and the research supported their significance. Finally, teachers suggested that general informal observations should be used as assessment.

The EP emphasised that enjoyment; play-based teaching and learning; the KCRA approach; integration; and integrating coding and robotics to supplement teaching and learning; all constitute part of one feature, namely, "*Grade R pedagogy*". As a result, in the final framework, I merged these elements to form one aspect.

I also informed the EP that the teachers' utilisation of pedagogical theories and/or international practices was not explicitly implemented to which she replied "…*this is something that I think speaks to teacher training and that, like you said, even though the experienced teachers naturally and you know subconsciously integrate certain* *theories and best practices, it is not necessarily that they have that explicit knowledge. They might just be doing it through, you know, uh, almost* [an] *assimilation of working in the field for so long that, that is what they have learned to do. I do not know if you can change it or phrase it differently but you know thinking about why they are doing certain things; why they are using certain theories and practices and approaches to achieve what they need to achieve. You know where does that knowledge come from? Who says it? Why do they say it? How does it fit in the South African context?*". This statement allowed me to incorporate the application of theories and best practices as a necessary component of 'the thinking teacher' into the final framework.

The EP argued in favour of including observation as assessment in the guideline since "*assessment is very important and it is very important in early childhood education. You know, the type of assessments and the way in which we assess which you have got there through informal observations. But you know, the purpose of assessment, why do we need at the end of this learning process to assess is to make sure that, you know students* [learners] *are achieving what we as teachers have set out for them to achieve*". The EP further suggested that the purpose of assessment should also be incorporated into the framework.

6.6.3.2.2 Guideline 4: Outcomes

The possible positive outcomes that may be anticipated are learners' use of mathematical skills; preparing learners for formal school and life after school; learners' understanding and holistic development; as well as teachers keeping abreast of new developments in education. The EP suggested that I clearly state that the outcomes in this framework refer to the benefits that may be anticipated when using coding and robotics, such as "*what can be developed, and what can be enhanced, and what is being built*". The EP also recommended that the four outcomes be reordered so that attention is given first to the learners and then to the teacher. She also proposed changing the term "*learners' understanding and holistic development"* to "learners' holistic development", as "understanding" is too generic and might relate to a wide range of topics, such as an "*understanding of coding and robotics, of mathematics, or* *of everything that you have put in the subheading there that they are developing and understanding of and in collaboration, creativity, lateral thinking*".

Another aspect that was discussed is learners' ethical use of technology, which the EP viewed as "*important and it is one of the things when we discussed, you know, with people's perceptions of technology and the negative side of it. If there is ethics and ethical practice and ethical care taken around all these things, then it is fairly safe and it is quite easy to implement. But maybe it just needs to be rephrased, so, technology is part of the future and coding and robotics could support ethical use and discipline to use technology*". The EP also recommended rephrasing the term 'teachers keeping abreast of new developments' to "*teachers' professional development or teachers' upskilling or reskilling*" and to link all these aspects within the TPACK framework. The final framework included all the aspects recommended by the EP.

It is important to note that the context-specific factors identified in this study all had an impact on the aforementioned guidelines. It will require more investigation to determine whether these guidelines hold true in other situations. Nevertheless, the four guidelines identified in the preliminary framework were established and confirmed by the results, the literature, and the external review. For the development of the final framework, which is covered in Chapter 7, some components within each guideline were rearranged and/or rephrased.

6.7 SUMMARY OF CHAPTER 6

This chapter began with interpreting the findings obtained from the various data generation instruments. These findings were then utilised to construct four guidelines for a preliminary framework to integrate coding and robotics with numbers, operations, and relationships in this unique setting, which was subsequently reviewed by the EP. The recommendations and suggestions by the EP were used to create the final framework described in the following chapter. In Chapter 7, I also examine the data by comparing it to existing studies to expound on supportive and contradictory findings, as well as absences and new ideas.

CHAPTER 7: COMPARISON OF THE RESEARCH FINDINGS WITH THE LITERATURE AND THE FINAL FRAMEWORK

7.1 INTRODUCTION

This chapter presents the investigation's findings as well as a review of the literature. In four tables, the findings from the study are compared to the literature, highlighting supportive evidence, contradicting evidence, silences, and new insights. I also presented the finalised framework for integrating coding and robotics with mathematical concepts. The chapter concludes with a summary of what was covered.

7.2 Findings compared to existing knowledge

Four tables (Tables 7.1 – 7.4) have been constructed in order to convey the supporting evidence, contradictions, silences, and new insights according to the study's findings and to contrast these with the literature on the issue. The study's findings have been compared based on the identified themes (see Table 6.2 for an example) rather than relying on the higher-level summary of the four guidelines. The rationale behind this approach is to gain a more in-depth understanding of the data and explore the data in an open-ended manner, minimising any biases that may arise from a guideline-centric approach. Since the findings highlight important contributions to understanding a topic, Creswell (2014) contends that a qualitative study requires the ability to compare findings with prior literature. I weighted the findings of my study against the findings of the literature review (see Chapter 2), which focuses on understanding the components of TPACK. The tables (Tables 7.1 – 7.4) feature the icon of a TPACK construct, or its integration, along with the research question(s) it addresses, to support the presented findings and related literature.

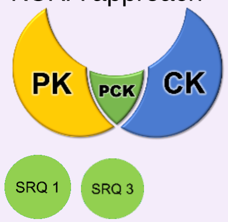
7.2.1 Supporting evidence

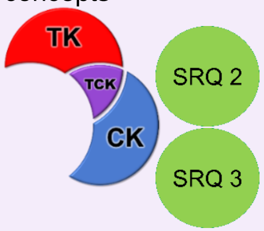
The supporting evidence in this study indicates that play-based learning is recommended for Grade R as it benefits both teachers and learners, and implicitly integrates subject areas, topics, and abilities. Furthermore, when teachers plan activities, they should consider kinaesthetic, concrete, representational, and abstract experiences. Although technology can be used to enrich these activities, teachers must ensure that it has a clear objective and is developmentally appropriate. Coding and robotics can be integrated with mathematical concepts, but the teachers still require training. Lastly, the use of coding and robotics also supports necessary 21st-century skills, such as cooperation, creativity, lateral and critical thinking, algorithm understanding, language skills, and physical development. Table 7.1 addresses the supporting evidence from the body of existing knowledge in comparison to the study's findings.

Table 7.1: Findings compared to existing knowledge: supporting evidence

THEMES	EXISTING LITERATURE	STUDY'S FINDINGS	INTERPRETATION AND DISCUSSION
MAIN THEME: Integrating coding and robotics with Grade R mathematical concepts			
THEME 1: *How teaching occurs in Grade R* • Play-based teaching and learning • Integration of subject areas • Pedagogical theories and/or international practices PK SRQ 1	**Play-based teaching and learning**		
	Play-based teaching and learning activities should be enjoyable and adaptable in their implementation (Smith & Vollstedt, 1985; The LEGO Foundation, 2017; Stach & Veldsman, 2021). Learners should be actively involved in play-based activities to increase meaning as they make sense of their surroundings and relate new knowledge to existing knowledge (The LEGO Foundation, 2017; Stach & Veldsman, 2021). These learning opportunities should also allow learners to solve problems, try out new ideas, be creative, and work collaboratively (Whitebread & Basilio, 2013; Golinkoff & Hirsh-Pasek, 2017; The LEGO Foundation, 2017; Stach & Veldsman, 2021).	All ten teachers agreed that learners learn best when they play. The participants remarked that play helps learners to have fun while learning without worrying about the outcome. T2, T6, and T10 all agreed that learning through play is easy for learners and improves their collaboration skills. One participants remarked that play should avoid utilising worksheets in order to focus on interactive, learner-centred learning experiences. As a result, it is clear that teachers see play as effortless, while still encouraging engagement and comprehension in Grade R. Photograps captured during the guided observations also supports the data received from teachers as it was evident that the learners had a lot of fun; were immersed in creative problem-solving experiences; and they worked collaboratively.	Play-based learning and teaching should be used in Grade R since they have many benefits when put into practice. For this reason, the integration of coding and robotics activities with mathematics must be enjoyable; engaging for learners; meaningful; iterative to guarantee that problem-solving occurs; and, socially interactive.
	Integration of subject areas		
	Grade R learners learn through "integration and play-based learning" (DBE, 2011a:9). The notion of integrated learning is crucial to outcomes-based education, according to the DE (2003), since it supports and enhances learners' potential to gain skills, knowledge, and attitudes and values across the curriculum. An integrated and play-based approach, according to Excell and Linington (2015), is most effective for Grade R learners' development since it encourages problem-solving, logical thinking, and reasoning.	Throughout the data generation process, it was obvious that the integration of all three subject areas occurred without any special emphasis. The teachers unknowingly combined the topic areas throughout the activities, and when they thought about it, they were able to identify the areas that were integrated. Each activity and participant reflection contained language integration, with speaking and listening skills being the two most notably integrated language-related skills. Each activity and reflection included the incorporation of life skills, with an emphasis on beginning	Subject areas, as well as many topics and abilities, were implicitly incorporated into Grade R teaching and learning when integrating coding and robotics with mathematical concepts. This practice benefits both teachers and learners since it can connect knowledge, values and skills needed by learners.

THEMES	EXISTING LITERATURE	STUDY’S FINDINGS	INTERPRETATION AND DISCUSSION
MAIN THEME: Integrating coding and robotics with Grade R mathematical concepts			
		knowledge, creative arts, and physical development. Although the study's focus is on numbers, operations, and relationships, the participants inadvertently included additional mathematical topic areas. The most notable of these mathematical abilities include the use of ordinal numbers to express order, location, or position; learners' understanding of direction; the application of patterns, functions, and algebra; and a mastery of spatial awareness, symmetry, shapes, and measurement. Furthermore, participants stated that subject integration is effective in reinforcing concepts and abilities, particularly with younger learners, since they are more likely to recall material if they encounter and apply it frequently.	
	Pedagogical theories and/or international practices		
	The teacher in a Vygotskian ELE must create learning opportunities that include not just what learners can accomplish on their own, but also what they cannot do alone. This may be successfully implemented by the teacher by creating play-based activities within the learners' ZPD. Teachers in a Piagetian ELE should provide learners with activities that allow them to interact directly with the physical environment and should be dependent on the learner's developmental stage. Montessori practices urge teachers to create learner-centred learning experiences that should expand learners' developmental potential to new heights through planning as well as directing learning opportunities and integrate a variety of	The participants reported that they used Vygotsky's ZPD as well as scaffolding since it allowed learners to progress autonomously while yet receiving direction when needed. Additionally, the participants emphasised the importance of learners’ social connection with peers in their activities. Some teachers’ learning chances were also based on the developmental stage of the learners by building on the learners’ past knowledge. Five teachers stated that they used Piaget’s theory by offering a range of learner-centred activities and reinforcing the learners' gross and fine motor abilities as well as language skills. However, journal entry 7(2) states that the teachers only offered the learners different opportunities to discover and explore during the first guided observations. Three participants also	Although the extent to which the teachers implemented the theories and practices were not measured; the inclusion of these supported the rationale behind the implementation of their methods and how it fosters the development of their learners.

THEMES	EXISTING LITERATURE	STUDY'S FINDINGS	INTERPRETATION AND DISCUSSION
MAIN THEME: Integrating coding and robotics with Grade R mathematical concepts			
	materials. Last but not least, the Reggio Emilio method asserts that it is the teacher's duty to set up the foundations for learning opportunities and give learners open-ended materials so they can explore and construct their own thinking and learning experiences in the natural environment (Thornton & Brunton, 2010:13). According to this method, teachers should monitor their learners' progress and promote peer learning.	highlighted using Montessori techniques, such as designing learning experiences that were appropriate for the learners' developmental stages and focused on the learners' interests. In journal entry 7(3), I mentioned two more components of Montessori techniques that were employed: first, most teachers encouraged most learners to participate in kinaesthetic activities, and second, the Bee-Bot was used to supplement their teaching in most cases. The participants opined that they had incorporated Reggio Emilia techniques after observing the learners' learning to expand individual experiences and encouraging the learners to learn from one another.	
THEME 2: *Mathematics in Grade R teaching* KCRA approach 	**KCRA approach**		
	The DBE (2011b) and Naudé (2021:181) highlight that mathematical activities in Grade R should be centred on integration and play. The DBE (2011b) recommends that the teacher should be a proactive mediator during child-centred and teacher-guided activities in order to integrate mathematics playfully. Literature states that using the KCRA method enhances learner performance (Wolf, 2017), allows learners to understand topics in their own unique ways (Tranquillo, 2008), helps them remember practical alternatives (Witzel, 2005), and aids in conceptualising basic procedures (Mancl *et al.*, 2012). Learners can use mathematical concepts through teacher-guided activities (guided play), routines, and child-initiated activities	All of the data-gathering instruments used revealed that teachers employ the KCRA approach or the constructs thereof. It is also clear that teachers value the KCRA approach's concepts in the context of Grade R learning and instruction. The teachers guided the activities that they presented by scaffolding the learning process and setting up play opportunities. However, the teachers did not provide the learners with a lot of choices of play. The activities were structured and focused.	Mathematical activities should be informed by guided play, routines, and free play. When planning activities, teachers should consider kinaesthetic experiences first, then concrete experiences, subsequently representational experiences, and finally abstract thinking.

THEMES	EXISTING LITERATURE	STUDY'S FINDINGS	INTERPRETATION AND DISCUSSION
MAIN THEME: Integrating coding and robotics with Grade R mathematical concepts			
	(free play) (DBE, 2011b; Fisher *et al.*, 2013; Weisberg & Zosh, 2018). During guided play, the teacher monitors and supports the learner to scaffold their learning (Stach, 2017:72; Stach & Veldsman, 2021:54). The role of the teacher is to guide learners in problem-solving and provide them with new problems, while also observing their innate interests and valuing their desire to learn more about the world (Stach, 2017:72; Stach & Veldsman, 2021:54).		
THEME 3: *Integrating coding and robotics with mathematics*	**Integrating coding and robotics with mathematical concepts**		
Integrating coding and robotics with mathematical concepts 	Literature (Lydon, 2007; Highfield, 2010; Bers, 2021; Shumway *et al.*, 2021; Emen-Parlatan *et al.*, 2023) indicates that coding and robotics can be integrated with counting skills; addition and subtraction; number recognition; mental mathematics; describing, comparing, and arranging numbers'; as well as recognising, identifying, and reading number symbols and names.	All of the data collection methods employed demonstrated that the activities planned by teachers to integrate coding and robotics with counting abilities; identifying and recognising number names and symbols; describing, sorting, and comparing numbers; as well as simple addition.	Coding and robotics can be integrated with numbers, operations, and relationships. These are: counting, identifying and recognising number names and symbols; describing, sorting, and comparing numbers; as well as simple operations.
THEME 4: *The effect and use of coding and robotics in Grade R*	**Benefits of using coding and robotics**		
	It is crucial for teachers to keep current with educational innovations, such as coding and robotics since it prepares learners for life beyond school (Kazakoff *et al.*, 2013; DBE, 2023; Sapounidis & Alimisis, 2021).	T6 stated that coding and robotics technologically prepare learners for formal school. The participants felt that coding and robotics will also help Grade R learners prepare for life after school. T7 furthermore	Teachers should seize the opportunity to integrate coding and robotics with teaching in general, as well as to incorporate them into

THEMES	EXISTING LITERATURE	STUDY'S FINDINGS	INTERPRETATION AND DISCUSSION
MAIN THEME: Integrating coding and robotics with Grade R mathematical concepts			
• Benefits of using coding and robotics • Difficulties that arise in the integration of coding and robotics • Assessment of coding and robotics • Teachers' attitudes and dispositions regarding the integration of coding and robotics  		stated that it will educate learners' ethics and discipline in the use of technology in our rapidly evolving environment. The participants believe that coding and robotics has the power to assist learners to grasp and comprehend skills necessary in Grade R. To enhance their teaching skills, all ten teachers felt that they need to stay current on emerging advances, such as coding and robotics.	other subject areas, because it benefits both the teacher and the learners.
	Difficulties that arise in the integration of coding and robotics		
	Teachers who lack an appropriate understanding of integrating coding and robotics will focus on how to use it rather than integrating it into mathematics education, which may be addressed through professional development opportunities (Bers *et al.*, 2013; Savard and Highfield, 2015). Furthermore, overcrowded LEs may pose a challenge to successfully integrate coding and robotics with mathematics (Cortes, 2012; Marais, 2016; Kanadlı, 2019; Sisman *et al.*, 2020; West & Meier, 2020; Zulu, 2020; Callaghan *et al.*, 2023). Further to that, Khanlari (2014) discovered that the most significant barrier to incorporating robotics in ELEs is teachers' lack of educational robots.	All ten teachers agreed that certain issues must be solved before coding and robotics can be properly integrated into their ELEs.T3-T10 showed the need for a handbook or textbook with defined goals and objectives that can be used to prepare lessons. Furthermore, T1 and T2 showed a desire for a robot. T2 and T7 voiced apprehension about combining coding and robotics into a full curriculum. T3 and T10 expressed worry on how coding and robotics would be applied successfully in overcrowded LEs, as well as how a shortage of funds may possibly hinder its implementation.	Teachers must be trained in the integration of coding and robotics before they can incorporate them into other subject areas. Furthermore, overcrowding in LEs and a comprehensive curriculum may provide hurdles to the successful application of coding and robotics. Finally, in order to include robotics in their ELEs, teachers require a robot.
	Assessment of coding and robotics		
	According to CAPS (DBE 2011a; 2011b; 2011c), assessment in Grade R is informal, and teacher observations should be the primary assessment method.	To assess multiple objectives and conduct necessary interventions, all ten teachers agreed that coding and robotics activities should be performed through informal observation as part of general assessments throughout the school year.	When integrating coding and robotics with Grade R mathematical concepts, the assessment must be informal, documented through teacher observations.

THEMES	EXISTING LITERATURE	STUDY'S FINDINGS	INTERPRETATION AND DISCUSSION
MAIN THEME: Integrating coding and robotics with Grade R mathematical concepts			
	Teachers' attitudes and dispositions regarding the integration of coding and robotics		
	Using coding and robotics promotes critical 21st-century skills, such as cooperation, creativity, lateral and critical thinking, and algorithm knowledge (Clements *et al.*, 2001; Hoyles & Noss, 2003; Fernandes *et al.*, 2006; Highfield *et al.*, 2008; Adams *et al.*, 2010; Highfield, 2010; Chalmers *et al.*, 2012; Allen, 2013; Ardito *et al.*, 2014; Chambers, 2015; Sullivan & Bers, 2018; Alves-Oliveira, 2020; Angeli & Valanides, 2020; Govind *et al.*, 2020; DBE, 2023; Diago *et al.*, 2022). Alhumaid (2019) and Strom (2021), on the other hand, agree that technology, in general, has a detrimental influence on learners' verbal and physical skills. Nonetheless, several studies (Fernandes *et al.*, 2006; Nugent *et al.*, 2016; Di Lieto *et al.*, 2017; Vázquez *et al.*, 2019:578; Urlings, Coppens & Borghans, 2019) show that utilising coding and robotics integrates learners' language skills through cooperation with peers and the teacher, as well as that kinaesthetic coding opportunities exist (Campbell & Walsh, 2017; Lee & Junho, 2019). Finally, Nel *et al.*, (2021) say that coding and robotics should be utilised as a reinforcement to attain a specific learning goal.	Participants stated that coding and robotics have the potential for educational innovation; that it is an enjoyable activity; that it includes learners' collaboration skills; that it includes learners' creativity skills; that it includes learners' lateral and critical thinking; that it exposes learners to technology and that it supports their algorithm understanding. T1, T7, and T10, on the other hand, expressed concerns that when learners are introduced to technology at a young age, they become passive rather than active learners, which is damaging to their listening skills, gross motor abilities, and problem-solving skills without technology. T8 and T10 also emphasised the need of avoiding replacing traditional teaching methods and learning, otherwise, optimal learning will not occur.	Despite the ability of integrating coding and robotics with mathematical concepts, it also includes other necessary skills needed in the 21st century, such as cooperation, creativity, lateral and critical thinking, understanding of algorithms, as well as learners' language skills and physical development.

The existing literature (only a few included) substantially supports the study's findings, which show how teachers can integrate coding and robots with numbers, operations, and/or relationships as well as influences that may affect the successful implementation thereof (Witzel, 2005; Lydon, 2007; Tranquillo, 2008; DBE, 2011; Cortes, 2012; Mancl *et al.*, 2012; Bers *et al.*, 2013; Excell & Linington, 2015; Savard & Highfield, 2015; Marais, 2016; Wolf, 2017; Kanadlı, 2019; Sisman *et al.*, 2020; Zulu, 2020; Shumway *et al*., 2021; Emen-Parlatan *et al*., 2023). According to the participants, integrating coding and robotics with specific mathematical concepts is affected by their needs as teachers; external factors; a unique learning process that must be followed; and some positive outcomes can be anticipated when integrating coding and robotics with Grade R mathematical concepts. The participants in this study showed how they integrate coding and robotics with Grade R learners' mathematics abilities in various ways. The following table examines the discrepancies between data and reviewed literature.

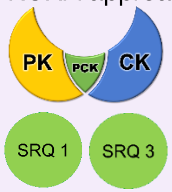
7.2.2 Contradicting evidence

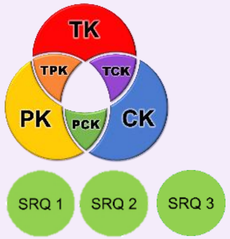
Table 7.1, in the previous section, examines the results' supporting evidence against the literature, however, Table 7.2 provides the contradicting evidence of integrating coding and robotics with specific mathematical skills. The contradicting evidence is a summary of the literature review compared to the study's findings as embodied in the main theme and themes (see Table 6.2 for an example). The interpretation of the contradicting evidence suggests that the effective teaching of Grade R learners involves subject integration, but this should be left to the discretion of the teacher. It is also essential for teachers to be aware of the theories and practices that impact their teaching and their learners' learning since most teachers had a limited understanding of how these theories can be used to plan their activities. Furthermore, when planning activities, teachers should consider a range of experiences, including kinaesthetic, concrete, representational, and abstract thinking by not focusing only on one type of activity to ensure learners' holistic development. Lastly, there is a need for teachers to receive training opportunities to understand how coding and robotics can complement their teaching.

Table 7.2: Findings compared to existing knowledge: contradicting evidence

THEMES	EXISTING LITERATURE	STUDY'S FINDINGS	INTERPRETATION AND DISCUSSION
MAIN THEME: Using coding and robotics to teach Grade R mathematical concepts			
THEME 1: *How teaching occurs in Grade R* • Integration of subject areas • Pedagogical theories and/or international practices PK SRQ 1	**In[21]tegration of subject areas**		
	Although literature (UNESCO, 2005; DiCarlo, 2009) suggests that subject-area integration is difficult and complex and necessitates a lot of planning, other research (Straessle, 2014; Niemelä & Tirri, 2018; Olovsson, 2021) refutes this and asserts that integration can occur in a variety of ways and differ between schools, allowing teachers to help learners understand the connections and interdependencies between the phenomena being studied. Learners are assisted in structuring and broadening their worldviews as well as in connecting their knowledge and abilities across a variety of subjects and in interacting with others (Niemelä & Tirri, 2018).	The participants opined that integrating too many aspects of subject areas can complicate a lesson unnecessarily.	When integrating coding and robotics with mathematical concepts, it is proposed that subject integration take place; however, this should be done at the teacher's professional discretion.
	Pedagogical theories and/or international practices		
	Teachers, as knowledge facilitators, must have extensive knowledge and awareness of how to enhance learning in their educational environments by being informed of the major learning theories and how they may be adopted (Pritchard, 2009:103). In 1904, John Dewey explained the notion of teachers' implementation of theory. Dewey (1904:15) states that theory presents aspects of psychology, logic, and the history of education, however, that practice is influenced by factors, such as "*blind experimentation; through examples which are not rationalized; through precepts which are more or less arbitrary and mechanical; through advice based upon the experience of others*". When teachers' practices become ingrained in their minds, they become well-versed in both the subject matter and the psychological and ethical philosophy of	Although the teachers were able to identify constructs and aspects of which theories and/or practices they used in their activities, this was not an active awareness and this was not measured. I provided the teachers with the TCB consisting of information related to both the theories and the practices for them to inform their teaching holistically – they, however, chose specific aspects from the TCB and were not entirely sure how to adopt and integrate them. This is also evident in the statements provided by T1 and T2 who said that they had incorporated Reggio Emilia techniques after observing the learners' learning to	It is advised that teachers be aware of the theories and practices that impact their teaching and the learning of their learners.

[21] Only a few sub-themes have been discussed as not all sub-themes were applicable.

THEMES	EXISTING LITERATURE	STUDY'S FINDINGS	INTERPRETATION AND DISCUSSION
MAIN THEME: Using coding and robotics to teach Grade R mathematical concepts			
	education (ibid.). Their practices will then be implemented "automatically, unconsciously, and hence promptly and effectively" (Dewey, 1904:15).	expand individual experiences and encouraging the learners to learn from one another. Nonetheless, I did not see any of the teachers using specific Reggio Emilia practices in my journal entry, with the exception of embracing learners' interests and using coding and robotics as a tool to supplement their teaching.	
THEME 2: *Mathematics in Grade R teaching* KCRA approach 	**KCRA approach**		
	As previously stated, teaching should proceed through three phases of learning (KCR) (DBE, 2011b). Furthermore, while the DBE (2011a) does not directly mention abstract learning occurring in the Grade R learning environment, it was included in the analysis since numerous studies support both the application and execution of kinaesthetic learning and the CRA method (Witzel, 2005; Butler *et al.*, 2003; Mancl *et al.*, 2012; Wolf; 2017). CAPS (DBE, 2011b) also provides thorough guidance on how to progress from kinaesthetic to representational learning experiences.	Even though the teachers used the KCRA approach, they did not always implement it in the correct sequence as required by the DBE (2011b). Few teachers used kinaesthetic learning to start with activities and some even started on an abstract level (TO1-TO10).	Teachers should explore kinaesthetic experiences first, then concrete experiences, subsequently representational experiences, and ultimately abstract thinking when preparing activities.
	Difficulties that arise in the integration of coding and robotics		

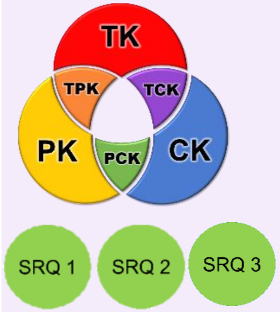
THEMES	EXISTING LITERATURE	STUDY'S FINDINGS	INTERPRETATION AND DISCUSSION
MAIN THEME: Using coding and robotics to teach Grade R mathematical concepts			
THEME 4: *The effect and use of coding and robotics in Grade R* Difficulties that arise in the implementation of using coding and robotics 	Nel *et al*. (2021); Shumway *et al*. (2021) and Emen-Parlatan *et al*. (2023) are of the opinion that coding and robotics can be integrated with mathematical concepts. Furthermore, when teachers receive professional development opportunities, it will enable them to know how to integrate coding and robotics with mathematics education (Bers *et al.*, 2013; Savard & Highfield, 2015).	This study indicates that teachers are still unsure of how to integrate coding and robotics with mathematical concepts.	Teachers should receive training opportunities in the integration of coding and robotics prior to integrating them with mathematics.

Contradictions are common in situations because people rarely perceive events in the same way (Etokabeka, 2021). Teachers lacked an active understanding of how educational theories and international practices may promote learners' development. According to the literature, teachers must have comprehensive knowledge and awareness of how to increase learning in their educational environments by being knowledgeable of the key learning theories and how they may be implemented (Pritchard, 2009:103). However, Dewey (1904) contends that once teachers have actual teaching experience, the execution of these theories and/or practices may become an unconscious practice. The teachers who took part in this study had been teaching between six to 22 years, which may indicate that their experience led to the unconscious implementation of theories and/or practices. Second, the discrepancies were caused by teachers not following the KCRA approach, particularly KCR, in a chronological manner. Teachers would commence from a higher to a lower level or leave out other levels. According to the DBE (2011b), it is critical to transition from kinaesthetic learning to concrete learning, and only then to representational learning; therefore, abstract learning should be the final stage to enhance learners' comprehension. However, I did not observe the teachers' prior teaching and it could be that they made use of the 'lower' levels, such as kinaesthetic and concrete levels to introduce these concepts to the learners. Furthermore, the contradictions highlight the value of teacher training in order for teachers to consider coding and robotics as a possibility for integration in all other subject areas rather than as a separate topic. The next section describes the study's gaps and silences.

7.2.3 Silences and gaps

Table 7.3 summarises the literature's silences and gaps and the study's findings which were performed in accordance with the study's main theme and themes. These silences and gaps reveal information that has not been addressed, necessitating deeper investigation. Again, the need for teachers to receive training in using coding and robotics is highlighted. The interpretative discussion in Table 7.3 integrates learning experiences from both the literature and actual data to integrate coding and robotics with mathematical concepts.

Table 7.3: Findings compared to existing knowledge: silences and gaps

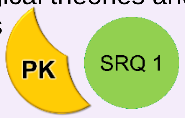
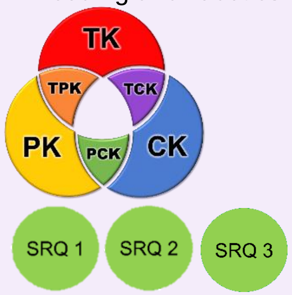
THEMES	EXISTING LITERATURE	STUDY'S FINDINGS	INTERPRETATION AND DISCUSSION
MAIN THEME: Using coding and robotics to teach Grade R mathematical concepts			
THEME 3: *Integrating coding and robotics with mathematics* **THEME 4:** *The effect and use of coding and robotics in Grade R* 	Although there is ample literature on how to use coding and robotics; how to use coding and/or robotics to reinforce mathematics; and how to introduce coding and robotics to young learners (see Chapter 2), there is a shortfall in how to integrate coding and robotics with specific mathematical concepts to Grade R learners in a South African context. South Africa is a developing country with numerous imbalances in technological resources; the acquisition of 21st-century skills; and, training possibilities (Makgato, 2014; Adukaite *et al.*, 2016; Nokwali *et al.*, 2017; Torres & Giddie, 2020).	The study sought to develop a framework to support teachers to integrate coding and robotics with numbers, operations, and relationships to South African Grade R learners. The participants (TO1-TO10, except the second observation of TO3) battled to include mathematics through the integration of coding and robotics since their focus was mostly on how to use the robot or what coding entails. Mathematics was still addressed but did not always form part of instruction. Furthermore, the participants experienced coding and robotics as something new, albeit sometimes challenging, to use in their ELEs.	For teachers to successfully integrate coding and robotics with Grade R mathematical concepts, especially in a South African context, they should have training opportunities in these areas.

The silences and gaps in existing information and findings emphasise the need for more investigation. Despite a wealth of literature on using coding and robotics, reinforcing mathematics with coding and/or robotics, and engaging young learners in coding and robots, there is a gap in how to integrate coding and robotics with specific mathematical concepts to Grade R learners in a South African context. This is critical since South African schools differ from those in developed nations and have unique requirements and characteristics that must be addressed such as overcrowded LEs and lack of resources. Furthermore, in order to integrate coding and robotics with mathematics and other subject areas, teachers must be supported and trained in their use. The next section describes the insights and information gained from this study.

7.2.4 New insights and knowledge

Table 7.4 demonstrates the new insights and information generated by the study, as well as topics that may justify further investigation. The findings of the study are described in the middle column of Table 7.4. (combining the results of the literature review with those of the research). The right column in Table 7.4 outlines learning experiences that may be used to integrate coding and robotics with certain mathematical concepts.

Table 7.4: Findings compared to existing knowledge: new insights and knowledge

MAIN THEME AND THEMES	EXPLANATION	INTERPRETATION AND DISCUSSION
MAIN THEME: Integrating coding and robotics with Grade R mathematical concepts **THEME 1:** *How teaching occurs in Grade R* Pedagogical theories and/or international practices  	Teachers in the study were unaware of how educational theories and international practices might improve the development of learners as well as their practices. According to the literature, teachers must have extensive knowledge and awareness of how to improve learning in their educational settings by understanding major learning theories and how they may be implemented (Pritchard, 2009).	Teachers are advised to be aware of the theories and practices that have an influence on their teaching and the development of their learners.
THEME 4: *The effect and use of coding and robotics in Grade R* • Difficulties that arise in the integration of using coding and robotics • Teachers' attitudes and dispositions regarding the implementation of coding and robotics  	Teacher training opportunities (including initial teacher education courses and continuous professional development) should focus on: • The importance and necessity of integrating coding and robotics • How to use and integrate the implementation of coding and robotics • Integrating coding and robotics with mathematics Teachers should also be provided with guidelines on how to plan lessons to integrate coding and robotics with specific mathematical concepts as well as information on how to set up the ELE for free play with coding and robotics. Finally, as stipulated in Table 6.3, teachers in South Africa require support in integrating coding and robotics with specific mathematical concepts to Grade R learners. The foundation of good technology integration is determining what you want to accomplish with your activity (UNESCO, 2005; Lydon, 2007). Prior to selecting a technological solution to help you achieve your goals, you must consider the learning objectives and criteria (UNESCO, 2005; Lydon, 2007). Once you have set specific learning objectives and goals, as well as the technologies most suited for each segment of the activity, you may start thinking about inventive methods to teach a diverse population of learners with varying learning preferences (UNESCO, 2005; Lydon, 2007).	To successfully integrate coding and robotics with Grade R mathematical concepts, teachers should have access to training in these areas, specifically the importance of using coding and robotics, as well as how to use and integrate the implementation of coding and robotics into all subject areas that will allow learners to engage in free play while also allowing the teacher to guide their play.

New insights from this study indicate that teachers should be knowledgeable about the theories and practices that affect their teaching and their learners' learning. Moreover, teachers must have access to training in the use and integration of coding and robotics across all subject areas.

The framework's goal is to support Grade R teachers' understanding of:

- The requirements and external factors that need to be addressed before integrating coding and robotics with specific Grade R mathematical concepts (Tables 7.2, 7.3, 7.4). Summarised as 'needs' and 'external factors', NE.
- The process of integrating coding and robotics with specific Grade R mathematical concepts (Table 7.2). Summarised as 'learning process', L.
- Potential benefits of integrating coding and robotics with certain Grade R mathematical concepts (Table 7.1). Summarised as 'outcomes', O.

Based on the supporting evidence, contradictions, silences, and new insights, as well as the findings, literature, and external review, I developed a framework for teachers to integrate coding and robotics with numbers, operations, and/or relationships in Grade R.

7.3 NELO: FRAMEWORK TO INTEGRATE CODING AND ROBOTICS WITH GRADE R MATHEMATICAL CONCEPTS

To create the framework, I incorporated knowledge gained from the literature, findings, and information gathered from the external review as well as the interpretation of the findings from the teacher participants. Through this, I intend to assist teachers of this study in understanding what needs and circumstances must be addressed, how the learning process must be facilitated, and the possible beneficial outcomes of integrating coding and robotics with specific Grade R mathematical concepts. According to Jimoyiannis (2012), a framework should include more than simply a set of activities and their outcomes, but should also include reflections and collaboration from role players. This is why I listed teachers' needs as well as external factors that must be addressed as the EP advocated the importance of including these before the integration of coding and robotics with specific Grade R mathematical concepts. As previously indicated and also emphasised by the EP, this study was carried out in a particularly unique environment, and in order to determine whether the framework's principles will apply in other contexts, it must be used and reviewed in future studies or by teachers.

As indicated in Figure 6.5, the preliminary framework comprises four guidelines, two of which must be addressed prior to the integration of coding and robotics with specific mathematical concepts (teachers' needs and external factors) and the other two is applied during integration (learning process and outcomes). These four guidelines remained after the systematising expert interview. Figure 7.1 visually represents how the preliminary guidelines were adapted to inform Figure 7.2. This process and the rationale for this were thoroughly discussed in 6.6.3 Guidelines of preliminary framework.

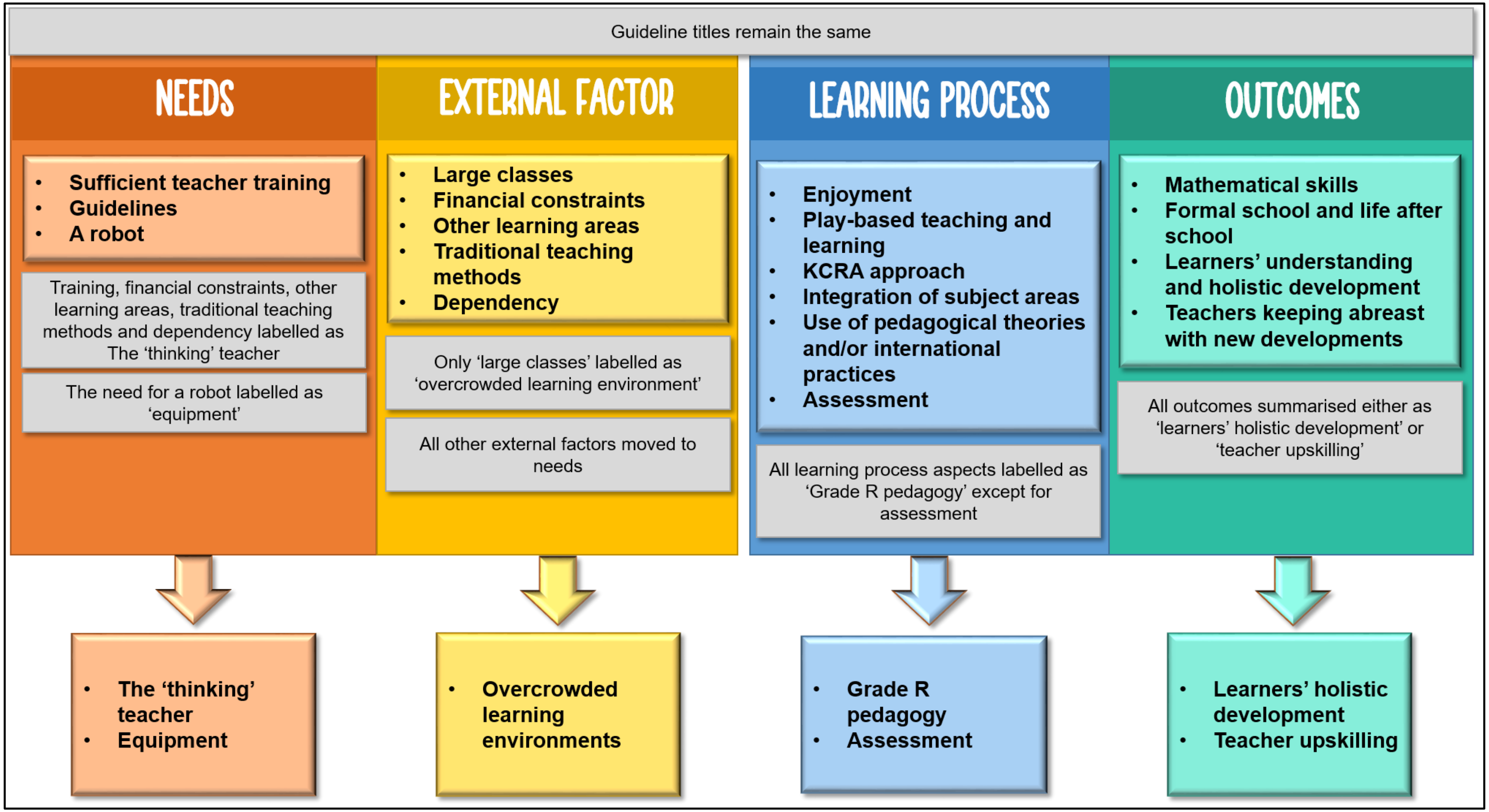


Figure 7.1: The development of the final framework from the preliminary framework

As mentioned previously in 6.6.3 Guidelines of preliminary framework and indicated in Figure 7.1, teacher training which include financial constraints; the neglect of other learning areas; the replacement of traditional teaching methods; and, learners' dependency were collectively labelled 'the thinking teacher'. The need for a robot was labelled as 'equipment'. For external factors, only large classes were labelled as 'overcrowded learning environments'. All learning process aspects were labelled as 'Grade R pedagogy' except for assessment. Lastly, all outcomes were either labelled 'learners' holistic development' (inclusion of mathematical skills; preparation for formal school and life after school; and, learners' understanding and holistic development) or 'teacher upskilling' (teachers keeping abreast with new developments).

Teachers' **needs** are informed by two factors, namely 'the thinking teacher' and 'equipment'. The thinking teacher component consists of two parts: teacher training, which comprises basic teacher education as well as professional development opportunities; as well as the accompanying material. The aspects that teachers require training on, such as gaining an understanding as to why coding and robotics should be introduced; where to begin to integrate coding and robotics; how to integrate coding and robotics with mathematics; and knowing why the implementation of pedagogical theories and/or international practices is beneficial in a South African context, inform teacher training.

Additionally, framing coding and robotics within learning areas addresses using coding and robotics as a joyful teaching and learning resource or tool, not as a primary teaching method or approach. This component was recognised through the findings as a component that teachers need guidance with. It is also crucial in order to assist teachers in dealing with the issue of overburdened curricula, as indicated by T2 and T7, in order to understand how they may integrate coding and robotics with mathematics without taking up extra time. Lastly, the accompanying material should explain how to integrate coding and robotics, as well as how to set it up for free play. Although the activities offered by the teacher participants (TO1-TO10) did not include free play, this was requested by the teachers. The teachers may also employ the framework to develop activities integrating coding and robotics with mathematical concepts.

The need for a robot and the financial implications of this were placed separately in the preliminary framework under ‘needs’ and ‘external factors’, but the conclusions from the systematising expert interview prompted me to merge these two into a need required by teachers, namely ‘equipment’. Teachers indicated that financial constraints may pose a challenge if specific equipment, such as a robot, needs to be purchased; however, the findings from the expert interview provided insight into using recyclable materials, and literature substantiated that coding can be discovered through kinaesthetic, concrete, and representational experiences, indicating that equipment may not need to be purchased.

Initially, there were five external factors that needed to be addressed prior to integration as seen in Figure 7.1; however, after the systematising expert review, some of these aspects were regrouped and renamed (see Figure 7.2). This was done in order to ensure that all aspects related to a specific guideline were summarised according to an appropriate heading within each guideline.

As a result, only one **external factor** was addressed, namely, overcrowded LEs. Overcrowding in schools is a problem in South Africa, and while this study does not offer solutions to this issue, it must be mentioned as it was found to be a concern during the findings.

The **learning process** is informed by Grade R pedagogy as well as assessment when integrating coding and robotics with particular mathematical concepts. A play-based approach to teaching and learning; enjoyment; the KCRA approach; and cross-curricular integration all play a role in Grade R pedagogy in the context of this study. Furthermore, the assessment should be part of general assessments conducted through informal observations, and the purpose of the assessment should be emphasised.

The framework is completed by the final guideline, which is **outcomes**. As previously stated, these outcomes explicitly correspond to the potential benefits by integrating coding and robotics with mathematical concepts, and are influenced by the context of this study. Two components are emphasised in this guideline, namely ‘learners' holistic development’ and ‘teacher upskilling’. The mathematical knowledge and skills that learners can use when integrating coding and robotics, as well as other parts of their holistic development that will facilitate their transition to formal education and life after school, are referred to as learners' holistic development. In the context of this study, ‘teacher upskilling’ refers to teachers adopting coding and robotics as a new tool to improve their teaching practices and staying current on educational innovations. I also made an effort to link each guideline to the TPACK framework by referring back to Tables 5.3 and 6.2 to create Table 7.5 as seen below.

Table 7.5: How TPACK supports the guidelines

TPACK CONSTRUCT(S)	SUB-THEME	THEME	GUIDELINE
PK	Play-based teaching and learning	How teaching occurs in Grade R	Learning process
PCK	Integration of subject areas		
PK	Pedagogical theories and/or international practices		
PCK	KCRA approach	Mathematics in Grade R teaching	Learning process
TCK, CK, TPK	Integrating coding and robotics with mathematical concepts	Integrating coding and robotics with mathematics	Outcomes
TPK, TK	Benefits of using coding and robotics	The effect and use of coding and robotics in Grade R	
	Difficulties that arise in the integration of using coding and robotics		Needs External factor
	Assessment of coding and robotics		Learning process
	Teachers’ attitudes and dispositions regarding the integration of coding and robotics		Outcomes Needs External factor

As seen in Table 7.5, all the guidelines were supported by one or more constructs of TPACK. I provide the finalised framework, NELO, below in Figures 7.2 – 7.6, however, the full framework can be viewed in Appendix M. All of the visuals in the framework were made by myself using either PowerPoint or Icograms Designer[22].

[22] A tool that enables the creation of isometric drawings.

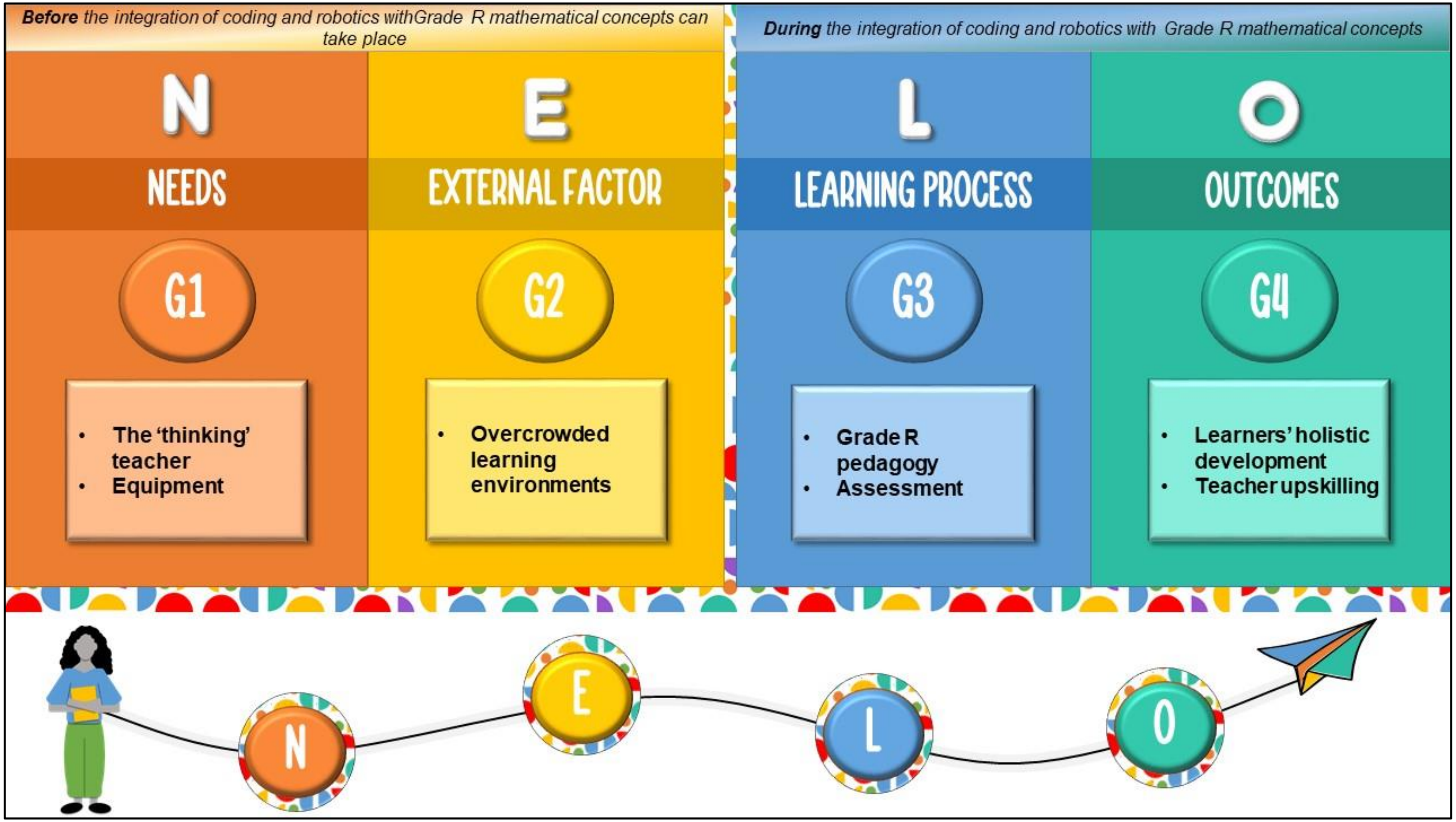


Figure 7.2: Layout of the NELO framework

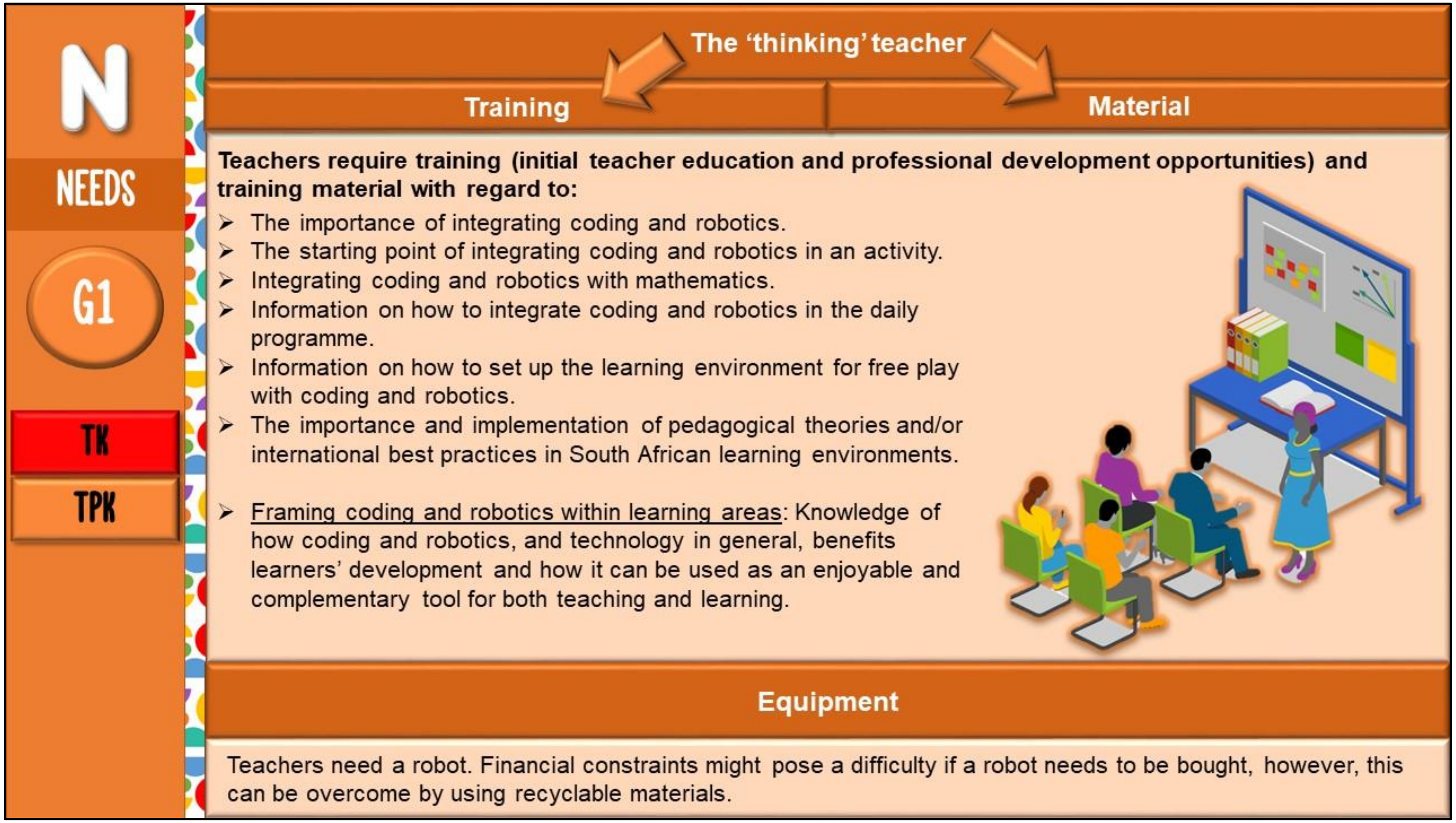


Figure 7.3: Guideline 1, needs

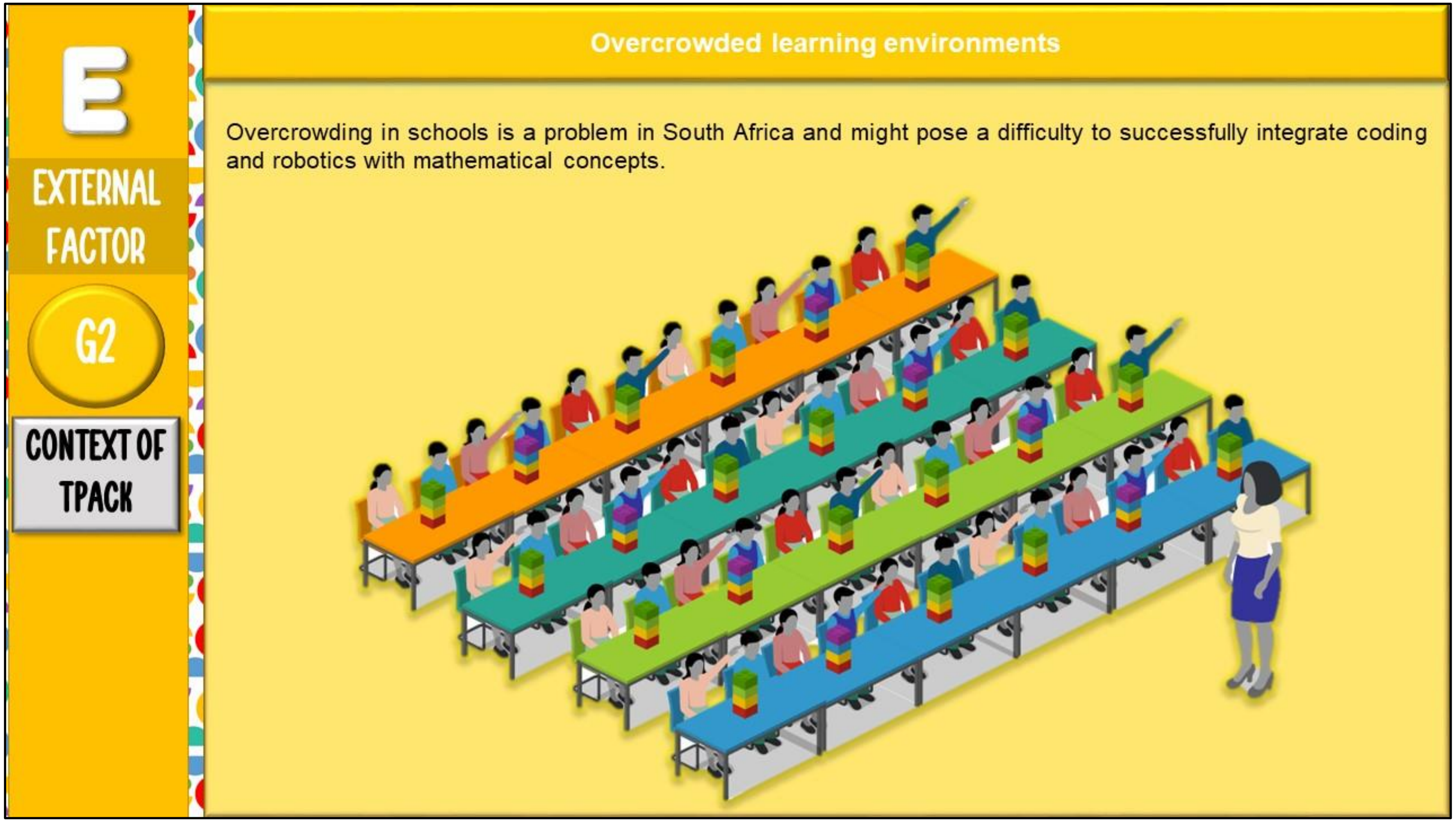


Figure 7.4: Guideline 2, external factor

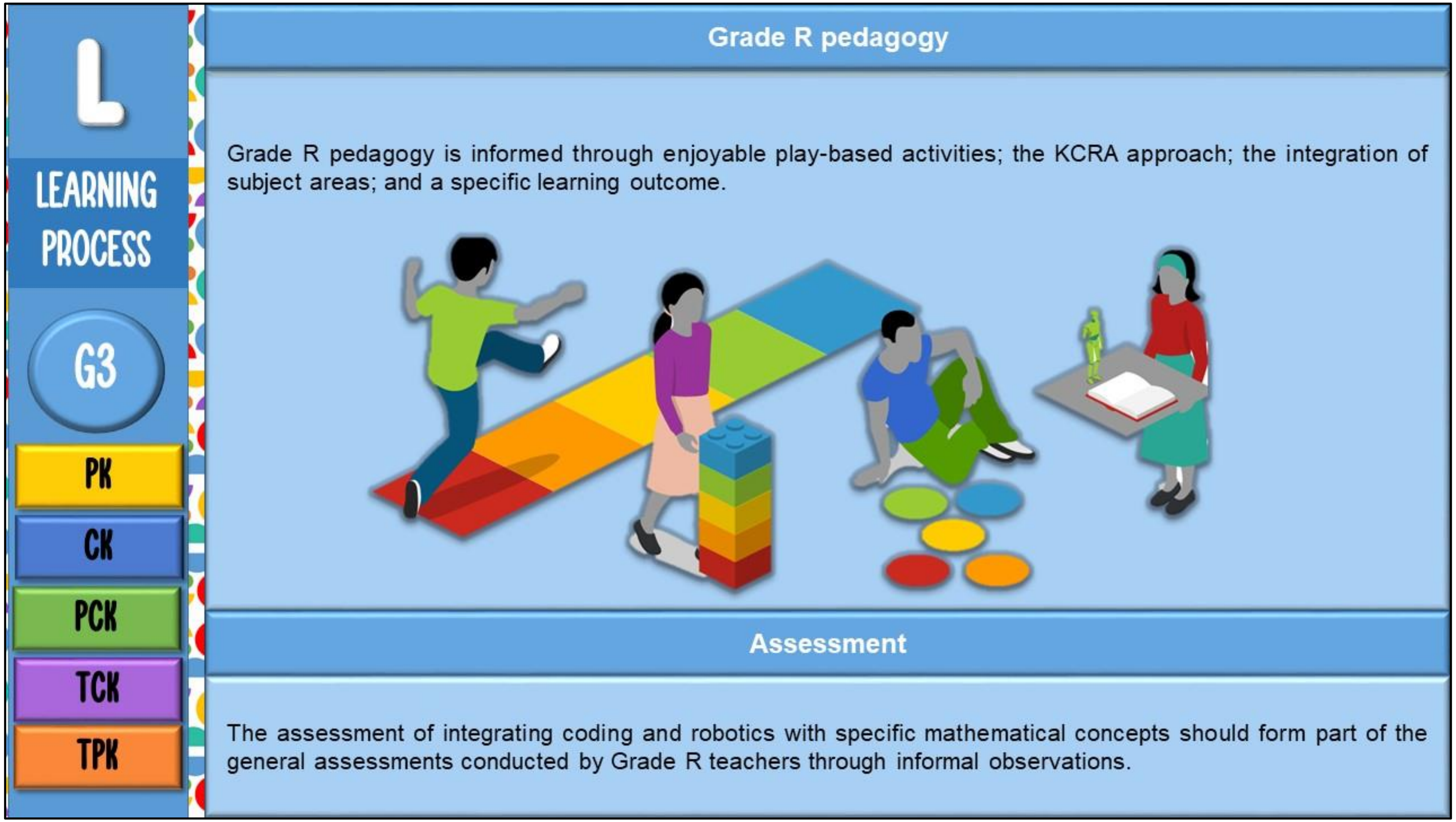


Figure 7.5: Guideline 3, learning process

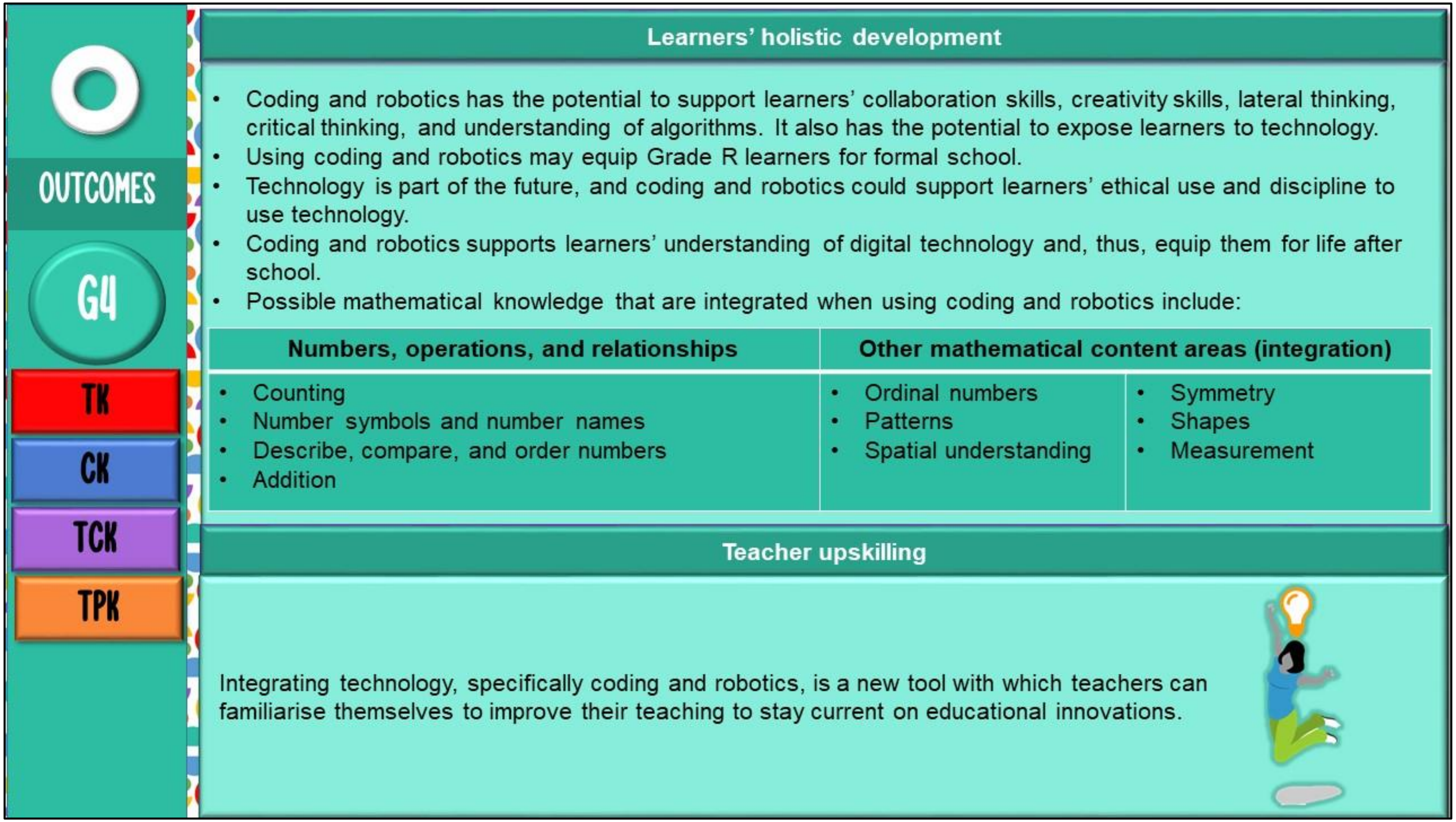


Figure 7.6: Guideline 4, outcomes

Owing to the fact that each guideline is supported by TPACK, I contend that teachers might be supported to integrate coding and robotics with specific mathematical concepts in this context by utilising the TPACK framework and paying close attention to the guidelines above. In Chapter 8 (see Figure 8.1), I visually represent this by indicating how teachers can use TPACK in their immediate environment to integrate coding and robotics with numbers, operations, and relationships in Grade R.

7.4 SUMMARY OF CHAPTER 7

In this chapter, I organised the study's findings into tables that support and contradict the current literature. Furthermore, the research identifies gaps in the literature, such as a lack of knowledge on how to integrate coding and robotics with specific mathematical concepts in Grade R within a South African setting. As new insights emerge, the need for teacher training opportunities and guidelines is highlighted as well as the need for teachers to maintain an awareness of educational theories and practices. In conclusion, the developed framework encourages teachers to integrate coding and robotics with certain mathematical concepts. Chapter 8 discusses the chapters' reflections, answers the research questions, elucidates the study's limits, and provides suggestions.

CHAPTER 8: CONCLUDING REMARKS

8.1 INTRODUCTION

"*The principal goal of education in the schools should be creating men and women who are capable of doing new things, not simply repeating what other generations have done.*" – Jean William Fritz Piaget

In light of the quotation above, I want to offer thoughts on how the novel topic of integrating coding and robotics with certain mathematical topics in Grade R, or at the very least to reflect on the information gathered by this study's participants. Chapter 7 provided an overview of the supporting evidence, contradictions, silences, and growing understanding in relation to the evaluated literature. Furthermore, the NELO framework was presented to integrate coding and robotics with specific mathematical concepts. In this last chapter, the preceding chapters' reflections on the study are reviewed, followed by a discussion on how the findings answer the research questions. The chapter then discusses the study's shortcomings and makes recommendations for future research. A summary of the research study concludes the chapter.

8.2 RESPONDING TO THE RESEARCH QUESTIONS

This section addresses the research in terms of how it answered the research questions of the study, beginning with a review of the SRQs and then proceeding to the PRQ. A summary of answering each research question is presented in a green block.

8.2.1 SRQ1: How does pedagogical knowledge support Grade R teaching?

PK

According to the literature, having pedagogical expertise improves teachers' classroom teaching quality and helps teachers establish successful teaching and LEs. It helps teachers with classroom management; teaching methods; assessment; establishing learning objectives and learning processes; and addressing learners' particular needs (Koehler & Mishra, 2009; Mishra *et al.*, 2011; Hannaway, 2016). The literature review's PK was motivated by play-based learning, theories, and best practices. Teachers need to develop play-based activities that are: (1) not centred on a result but are rather joyful and flexible; (2) actively engage all learners to focus when learning through play; (3) meaningful and driven by learners' interests since learners will attempt to make sense of their surroundings to relate new knowledge to prior knowledge; (4) creative by using a variety of familiar and unfamiliar objects to allow learners to solve problems and test their ideas; and (5) social in nature to allow learners to communicate, share ideas, and build relationships (Smith & Vollstedt, 1985; Whitebread & Basilio, 2013; Golinkoff & Hirsh-Pasek, 2017; Irvin, 2017; The LEGO Foundation, 2017; Stach & Veldsman, 2021).

According to Fleer (2013), theories not only influence our perceptions but also provide structure and direction to our actions. When evaluating theories and concepts, we assess their influence on the quality and care provided to young learners in the early years (Conkbayir & Pascal, 2016). This study examined two foundational theorists and two international practices, notably Lev Vyotsky, Jean Piaget, Montessori, and Reggio Emilia. I chose these because of their valuable contributions to ECE. When following the Reggio Emilia practice, teachers actively implement the theories and practices, they create LEs that encourage social interaction; challenge learners' thinking; allow independent problem solving; allow independent exploration and experimentation; provide a safe and child-centred environment; encourage lifelong learning; base activities on learners' interests and learning styles; as well as provide open-ended materials (Wood *et al.*, 1976; May & Kundert, 1997; Rogoff, 2003; Morrison, 2010; Daniels, 2014; McNally & Slutsky, 2017; Berk, 2018; Isaacs, 2018; Van Heerden & Du Preez, 2021). Consequently, literature helped answer this question by providing guidelines to base general Grade R teaching on as well as how it benefits teachers and learners. However, the participants of this study need training based on these theories and practices regarding the importance and the implementation thereof.

The data also indicated the importance of play-based teaching and learning. All the teachers indicated that learners learn best through play without worrying about a specific outcome. Furthermore, the findings noted that playing supports learners' collaboration skills and focuses on interactive, learner-centred learning experiences. In addition, the implementation of foundational theories and international best practices allowed them to provide support to the learners when they required it but also to support their independent problem-solving skills. Furthermore, it supported social interaction between peers and with the teacher; built learner-centred and developmentally-appropriate learning experiences based on learners' prior knowledge; as well as developed learners' motor abilities and language skills. Consequently, the data shows that PK is crucial for successful learning and teaching in Grade R.

How does pedagogical knowledge support Grade R teaching?

From the findings of the study and the reviewed literature, it is evident that PK is essential for successful Grade R teaching. The study highlights the importance of PK for classroom management, teaching methods, assessment, establishing learning objectives and processes, and addressing learners' needs. Moreover, PK based on play-based learning theories and best practices is beneficial for creating effective LEs. The study reveals that the implementation of foundational theories and international best practices supports social interaction, challenges thinking, allows independent problem-solving, and provides a safe environment for learners. Additionally, play-based teaching and learning support collaboration, learner-centeredness, and interactive learning experiences. Therefore, PK based on play-based learning theories and practices is crucial for successful Grade R teaching.

8.2.2 SRQ2: How does coding and robotics support Grade R teaching?

Based on the findings from the literature, coding and robotics support Grade R teaching by developing various skills and competencies in ECE. According to the DBE (2023), learners are exposed to a variety of knowledge, skills, and values through coding and robotics that improve their aesthetic, creative, and cognitive development. These include knowledge gained from participating in dance, music, drama, and visual art activities; knowledge of digital and ICT skills supported by the technological process; and basic social and environmental understanding. Using coding and robotics also promotes the development of critical 21st-century skills, such as cooperation, creativity, lateral and critical thinking, as well as algorithm knowledge (Clements *et al.*, 2001; Hoyles & Noss, 2003; Fernandes *et al.*, 2006; Highfield *et al.*, 2008; Adams *et al.*, 2010; Highfield, 2010; Chalmers *et al.*, 2012; Allen, 2013; Ardito *et al.*, 2014; Chambers, 2015; Sullivan & Bers, 2018; Alves-Oliveira, 2020; Angeli & Valanides, 2020; Govind *et al.*, 2020; DBE, 2023; Diago *et al.*, 2022). Furthermore, robotics is a fascinating way to build transdisciplinary discoveries. Robotics also allows young learners to participate in creative experiments, improve their fine motor skills and hand-eye coordination, and communicate and work as a team (Bers, 2008; Lee, Sullivan, & Bers, 2013). The Bee-Bot, specifically, encourages learners with their problem-solving abilities and cognitive flexibility (Diago *et al.*, 2022). Coding and robotics also develop learners' language skills and physical development (Fernandes *et al.*, 2006; Nugent *et al.*, 2016; Campbell & Walsh, 2017; Di Lieto *et al.*, 2017; Vázquez *et al.*, 2019:578; Lee & Junho, 2019; Urlings *et al.*, 2019). As a result, the literature provides an explanation for how coding and robotics complement Grade R teaching by enabling teachers to develop a wide range of abilities of learners through a playful, interactive, and complementary method, such as using coding and robotics. Constructing learning experiences that integrate coding and robotics as a tool to complement teaching practices will also develop fundamental characteristics of DL (Conlon & Simpson, 2003; Belshaw, 2012; Hannaway, 2016).

The data gathered show that coding and robotics technologically prepare learners for formal school; prepare learners for life beyond school; teach learners about ethical use and discipline when it comes to using technology in our rapidly evolving world; aid learners in grasping and comprehending abilities required in Grade R, such as collaboration, creativity and problem-solving skills; enable teachers to keep current on upcoming developments; and have the potential for educational innovation. As a consequence, the findings suggest that coding and robotics can enhance Grade R education.

How does coding and robotics support Grade R teaching?

The data indicates that coding and robotics has a positive effect on learners' aesthetic, creative, and cognitive development, including critical 21st-century skills, such as cooperation, creativity, lateral and critical thinking, as well as algorithm knowledge. Additionally, coding and robotics support collaboration, problem-solving skills, cognitive flexibility, language skills, and physical development. The research also shows that coding and robotics complements Grade R teaching by enabling teachers to develop a wide range of skills required by learners through a playful, interactive, and complementary method. As a result, this study suggests that coding and robotics, as a complementary tool, has the potential to enhance Grade R education.

8.2.3 SRQ3: How can Grade R mathematical concepts be used in play-based teaching?

Literature states that Grade R mathematical concepts should be used in an integrated, playful and informal manner (DBE, 2011b; Naudé, 2021). Furthermore, as mentioned previously, the use of mathematical concepts should move through four stages of learning to enhance learner performance (Butler *et al.*, 2003; Witzel, 2005; Tranquillo, 2008; DBE, 2011b; Mancl *et al.*, 2012; Wolf, 2017). These stages are the kinaesthetic stage, the concrete stage, the representational stage, and finally, the abstract stage. These four stages situated within a playful and informal environment can also be used in the integration of coding and robotics with mathematical concepts of numbers, operations, and relationships, which are counting forwards and backwards from one to ten; recognising, identifying, and reading number symbols and names from one to ten; describing, comparing, and ordering numbers from one to ten; as well as addition and subtraction (Lydon, 2007; Highfield, 2010; Gura, 2012; Samuels & Haapasalo, 2012; Kazakoff *et al.*, 2013; Ardito *et al.*, 2014; Khanlari, 2014; Sullivan & Bers, 2016). The literature offers an explanation of developing activities that are playful, informal, and integrated activities based on the KCRA approach.

Grade R teachers value and employ the KCRA method to develop learning activities. Furthermore, the activities designed by teachers to integrate coding and robotics included counting; as well as learners' ability to identify and recognise number names and symbols, describe, sort, and compare numbers, and do simple addition. The results imply that the KCRA approach should be used to integrate coding and robotics with mathematics playfully. Additionally, the research and literature support the connection between mathematics curriculum in South Africa and other countries like Japan, New Zealand, and Singapore.

How can Grade R mathematical concepts be used in play-based teaching?

The literature suggests that Grade R mathematical concepts should be integrated in a playful, and informal manner, moving through four stages of learning: kinaesthetic, concrete, representational, and abstract. The integration of coding and robotics can also enhance and complement the use of mathematical concepts, such as numbers, operations, and relationships. The study suggests that the integration of coding and robotics with mathematical concepts should be deployed using the KCRA approach.

8.2.4 PRQ: How can Grade R teachers be supported to integrate coding and robotics with mathematical concepts?

The idea that someone is born to teach is simply untrue; effective teaching is a skill that can be acquired (DeMonte, 2013). Teaching for a long period of time does not always result in improved practice (ibid.). Aspects of teaching that may be learnt and improved upon include: (1) skill development; (2) familiarising oneself with teaching strategies and approaches; (3) CK; and (4) PCK to simplify content so that learners can grasp elements of instruction (ibid.). Given the need to improve teaching and a lack of information on how teachers can integrate coding and robotics with Grade R mathematical concepts especially, in a South African context, this research question pursues what is known already, what can be done, and what still needs to be addressed in order for teachers to be supported to integrate coding and robotics with Grade R mathematical concepts.

According to several research studies, teachers feel more at ease when training supports them in a step-by-step manner and allows unstructured time with alternatives to work on (Kay & Moss, 2012; Liu *et al.*, 2012). In order to support teachers right now in a methodical manner, this study proposes that teachers integrate what is known already and what they are capable of doing. By implementing the NELO framework, teachers may be supported to integrate coding and robotics with Grade R mathematical concepts. Teachers can plan informal, integrated, play-based learning experiences by implementing fundamentals of various educational theories and practices using the KCRA approach to ensure the holistic development of Grade R learners. Teachers should also be expected to create integrated activities which focus on the integration of coding and robotics with specific mathematical concepts (Wolz, Stone, Pearson, Pulimood & Switzer, 2011).

The PRQ of this study is how teachers can be supported to effectively integrate coding and robotics with Grade R mathematical concepts. To address this research question, the study proposes following the four guidelines of NELO. Firstly, it is essential to ensure that teachers' needs are met, which includes providing adequate training and support for them to effectively integrate coding and robotics with mathematics into their LEs. Secondly, external factors that may impact the integration process must be addressed. Both of these factors must be addressed before commencing with the integration of coding and robotics with mathematical concepts. Thirdly, teachers need to plan the learning process carefully according to the points mentioned to ensure that it is effective and engaging for Grade R learners. Finally, by meeting these conditions, it is possible to achieve the anticipated positive outcomes.

How can teachers be supported to integrate coding and robotics with Grade R mathematical concepts?

The study argues that effective teaching is a skill that can be learned, and there is a need to support teachers to integrate coding and robotics with Grade R mathematical concepts. The NELO framework is suggested as a way to support teachers in a methodical manner, with an emphasis on meeting their needs and addressing external factors that may impact implementation. Teachers should integrate what they already know and use the KCRA approach to plan informal, play-based learning experiences. The study proposes four guidelines to support effective integration of coding and robotics with mathematical concepts: meeting teachers' needs, addressing external factors, careful planning of the learning process, and achieving positive outcomes.

8.3 CONTRIBUTIONS

The current study seeks to understand the integration of coding and robots with Grade R mathematical concepts, making theoretical, practical, and methodological contributions in the process. Based on the findings of this study, these contributions aim to assist teachers who engage in the integration of coding and robotics activities with mathematics in a Grade R context. In the next section, these contributions are discussed.

8.3.1 Theoretical contribution

The study's theoretical contribution highlights the importance of supporting teachers in their ongoing learning and development. Teachers' professional development has generally taken the form of short courses organised by schools or other institutions that provide professional training (Mury, Negrini, Assaf & Skweres, 2022). However, the literature indicates that these brief training opportunities are largely focused on theoretical knowledge and may lack relevance and applicability in schools (Guskey, 2002; Mury *et al.*, 2022). Thus, teachers are urged to seek support from role players in their immediate educational setting and to exchange experiences and ideas with these role players in order to better their understanding (Mury *et al.*, 2022). PAR can assist with this.

PAR in this study elicited participation from all parties involved to empower and actively engage participants; promote collaboration; obtain rich contextual data; and provide a practical solution (Conner & Duncan, 2013; Johnson, 2013; Mubuuke & Leibowitz, 2013; Lawson, 2015; Ebersöhn *et al*., 2016). For this reason, PAR will support teachers to participate in learning over a longer period of time and address their needs, self-efficacy, and pedagogical beliefs to use coding and robotics to teach mathematical concepts (Duncan-Howell, 2010; Nørgård and Paaskesen, 2016; Papadakis *et al*., 2021; Boz & Allexsaht-Snider, 2022; Mury *et al*., 2022). The teachers can discuss, reflect, and exchange ideas on how they implement TPACK (as discussed in this study).

As seen in Figure 8.1, the theoretical contribution of this study firstly underscores the critical role that teachers play in the education system and highlights the need to support their ongoing learning and development. Secondly, it proposes PAR as a more effective and sustainable approach to teacher professional development compared to other development opportunities. This contribution provides a solution to address the limitations of current professional development approaches and offers a way to immediately support teachers in their ongoing learning and growth. Thirdly, it demonstrates how the TPACK framework can be used to examine the complex interactions between technology, pedagogy, and content in a specific teaching context. Lastly, it shows how PAR can facilitate the development and application of TPACK among teachers, by providing a collaborative and supportive environment for sharing knowledge, expertise, and experiences. For this reason, the theoretical contribution offers evidence for the potential benefits of PAR to support teachers to integrate coding and robotics with Grade R mathematical concepts.

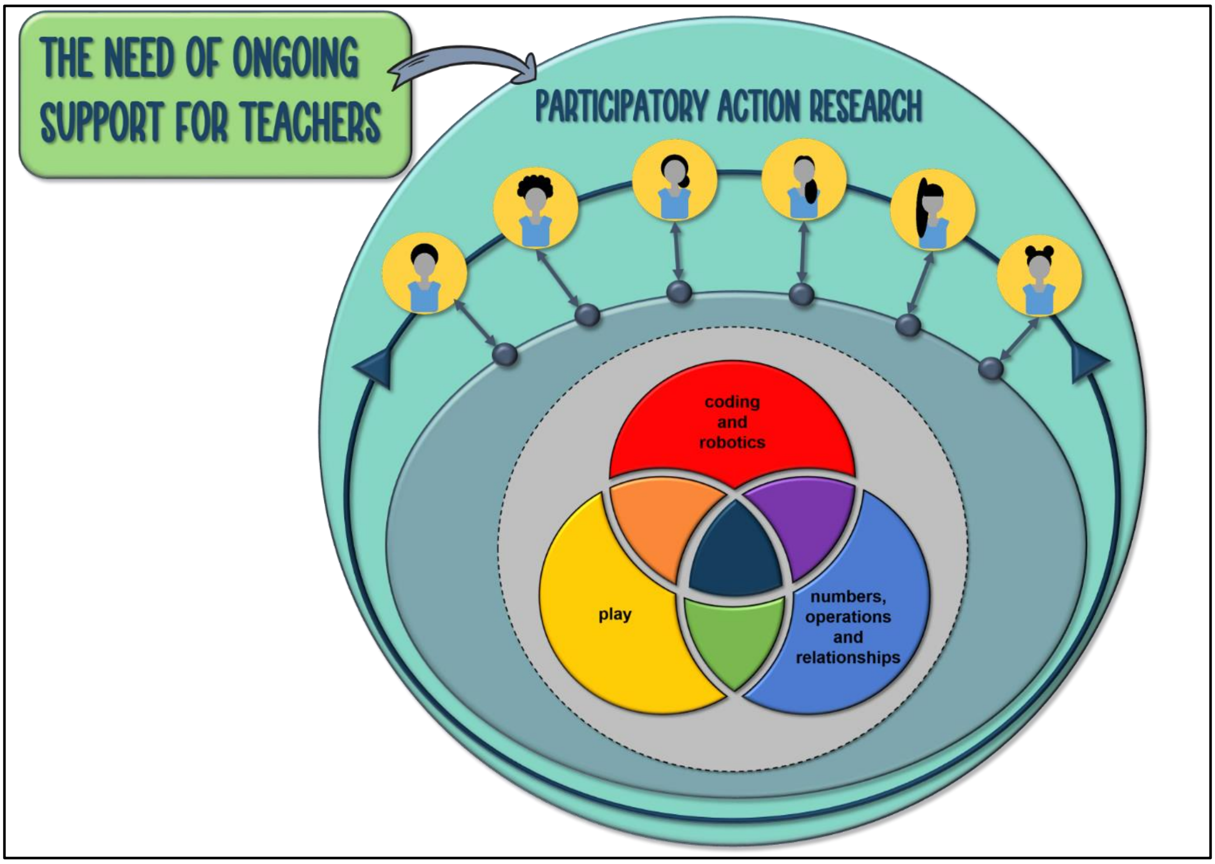


Figure 8.1: Theoretical contribution of this study

In order to support teachers in integrating coding and robotics with Grade R mathematical concepts, PAR can be used based on the interrelated nature of the TPACK framework regarding play, coding and robotics, and mathematical concepts. This is illustrated in Figure 8.1, which presents a visual representation of PAR as proposed in this study. Owing to PAR, teachers can collaborate with one another to share knowledge, expertise, and experiences, and gain support in their ongoing learning and growth. This can help to address the limitations of current professional development approaches, and provide a more effective and sustainable means of supporting teachers.

8.3.2 Practical contribution

The NELO framework constitutes the practical contribution of this study (see 7.3 NELO: Framework to integrate coding and robotics with Grade R mathematical concepts). The framework expands on the limited research on the integration of coding and robotics with Grade R mathematical concepts in a South African context. The framework is fundamentally based on the TPACK framework, which, in my opinion, may be used to help teachers become better practitioners in relation to the topic at hand. TPACK as a framework has drawn attention, and this study suggests that its application and comprehension will connect the unfamiliar to the familiar. When systemic barriers have been addressed, the deployment of the framework may assist teachers in integrating coding and robotics with mathematical concepts and establish a community that is reflective and encouraging in demeanour.

Teachers may also be supported when creating and planning their own activities, which may liberate the teacher to simply act as a facilitator while the learners collaborate and apply their own learning to the various activities. This may also enable teachers to understand how to integrate coding, robotics, or technology in general, as a complementary teaching tool rather than viewing it as complex and unfamiliar.

The study also emphasises that coding and robotic activities can be created without needing financial resources or an internet connection. Except for the activities that used the Bee-Bot and the Cubroid Coding Blocks, which would incur a cost, the materials used in this study were easily accessible to both teachers and learners. This is demonstrated through the use of recyclable materials, plastic toys, and grids drawn in chalk – its practical implication is that, provided that teachers receive appropriate training and access to guidelines, such as NELO, teachers from different socioeconomic backgrounds might be able to employ the topic of enquiry without needing funding or internet access.

Lastly, the study also addresses the crucial need for knowledge expertise in PK, specifically using general play-based theories and international practices, and why it should be employed when integrating coding and robotics with Grade R mathematical concepts. These may support teachers to understand why their practices are employed in a certain manner and how these practices develop learners holistically. It may also provide a foundation for understanding how various components of these theories and international practices can be incorporated and fulfilled to offer learners learning opportunities that are tailored to their developmental levels and to assist learners in developing new knowledge and skills.

8.3.3 Methodological contribution

This study offers one methodological contribution. I argue that if used in future research to dramatically change practice, employing PAR as described in the section below to create a teaching framework might make a significant methodological contribution (Bergh, Boyd, Byron, Gove & Ketchen, 2022). Before this methodological contribution is elucidated; a need to revisit what constitutes PAR is needed. PAR is defined as a strategy for empowering and engaging individuals through cycles of planning, acting, observing, and reflecting in order to inspire social change that promotes capacity building and strengthening (McTaggart, 1997; Cohen *et al.*, 2007; Goto, 2010; Denzin & Lincoln, 2011; Macdonald, 2012; Schneider, 2012; Conner & Duncan, 2013; Lawson, 2015; Le Cordeur, 2016).

PAR was used in this study to better understand how teachers may be supported and to create a teaching framework based on the topic of enquiry. Although the OECD's (2009) definition of a teaching framework was used, two other features were also highlighted, namely teachers' needs and external factors. The findings were examined using both deductive and inductive thematic data analysis, both of which are types of qualitative data analysis. The methodological contribution, then, relates to the possibility that using PAR and carrying out these types of data analysis will result in the development of a framework for teaching that will empower and encourage participation in order to promote transformation that fosters capacity development. This contribution is visually represented in Figure 8.2.

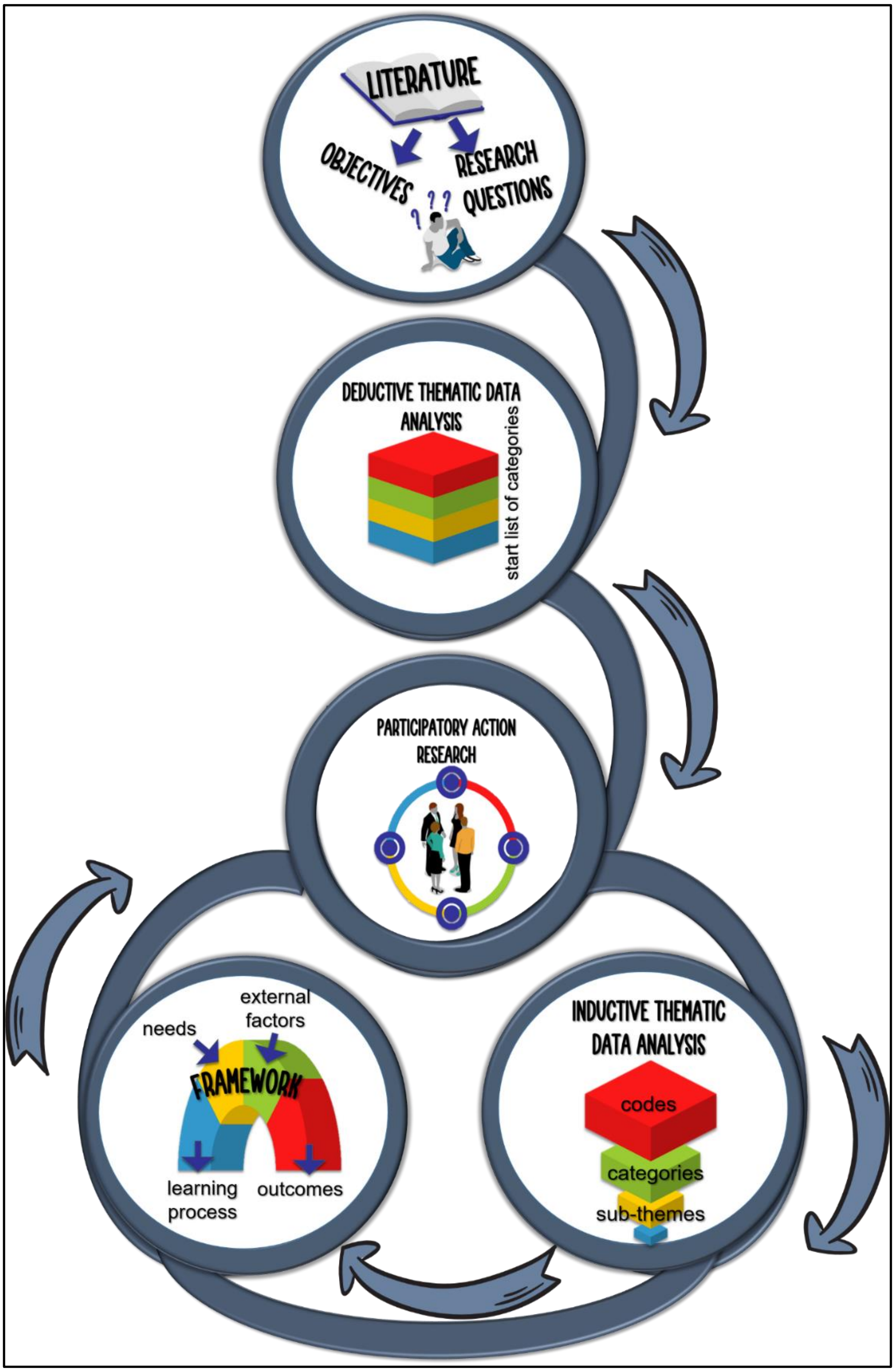


Figure 8.2: Employing participatory action research to design a teaching framework

As seen in Figure 8.2, after a presentation of the importance of the research through literature, research objectives, and research questions, I recommend that deductive thematic data analysis be used by generating a list of categories to organise data, which will serve as the foundation for deductive reasoning. The data generation instruments should then be created based on these categories, but they should also be flexible so that they can be updated in accordance with participant responses. Consequently, the PAR cycles should commence with inviting the participants who should be regarded as competent agents. Between the PAR cycles, deductive analysis should be conducted to inform the next cycle by organising, reading, digesting, making sense of, and coding the data. Following these cycles, which should explicitly include the role players required for 'action change', inductive analysis should be used to construct a preliminary framework. When the researcher is absorbed in the data; codes, categories, sub-themes, and themes will immerse. The preliminary framework should then be externally reviewed, and the data should be analysed again using inductive analysis to generate the final teaching framework. Another PAR cycle is then recommended to implement this framework and assess its effectiveness and shortcomings.

8.4 PERSONAL REFLECTION ON STUDY

In this section, I reflect on my experience in conducting this study.

I was intrigued by and drawn towards the research topic because of the DBE's impending implementation of coding and robotics as a subject and the subsequent rising interest in technology-enhanced teaching and learning. I could see how relevant it is in today's world, and as I ventured further into researching the literature, I acquired a desire to prepare young learners for a more technology-driven world. As a member of the ECE discipline, I recognised the importance of understanding how coding and robotics may be used in an integrative, informal, and playful manner. I opted to investigate its integration with mathematics primarily because there is a need to improve mathematics teaching and learning in the South African environment.

According to the literature that was reviewed for this study, it is critical to ensure that DT is effectively initiated in learning experiences for young learners. Furthermore, this provides learners with the knowledge they will require to be more competitive in the modern environment. It was fascinating to discover how both teachers and learners were involved in the topic, and how teachers' activities integrated coding and robotics with various mathematical concepts.

Using PAR also assisted me in delving deeply into the participants' lived experiences in order to develop a framework based on their dispositions and reflections. It was a fascinating experience, one I had never undertaken before, that assisted me in comprehending the topic of enquiry. Through the use of PAR, I was able to cultivate the valuable attributes of collaboration, understanding, and curiosity as a researcher.

To acquire new knowledge, this study endeavour necessitated perseverance and reiterative cycles of revisiting known concepts. It demonstrated the significance of involving teachers in data generation cycles, since I would not have been able to obtain the insights that I now have without their involvement.

8.5 LIMITATIONS

Although this research study succeeded in its aim as stated in Chapter 1 (see 1.5 Research questions) by developing evidence-based recommendations and guidelines, there were still some limitations. According to Queirós, Faria and Almeida (2017), qualitative research offers both advantages and disadvantages, which made it possible to identify some of the limitations that this study faced. The first point to notice is that the study was only done in five schools in one district in the Gauteng province. This is an insignificant quantity when compared to the number of schools in South Africa. I wish I could have visited more schools to learn more about how teachers may be supported in integrating coding and robots with mathematical concepts but obvious constraint on time precluded my doing so. Furthermore, despite the fact that ten different participants were recruited to participate in the study, all of the participants taught in an affluent district. The study may have generated more and other data if I had been able to examine and compare schools in less affluent areas to those in more affluent areas. Such observations would have allowed me to identify disparities in implementation in rural schools, such as the problems encountered and their experiences within their context.

The second constraint was that I could only observe the participants and learners twice. More PAR cycles would have benefited the study, especially if the framework had been deployed to evaluate how it worked in practice. It would also have allowed me to see if the teachers used the same approaches over and over again, and if their understanding of integrating coding and robots with mathematics developed over time.

An additional constraint of this study pertains to the omission of an exploration into the pedagogical methods employed for teaching mathematical concepts and the complex progression involved in this process. A promising avenue for future investigation would involve comprehending the potential utilisation of coding and robotics in the teaching of mathematical concepts, or conversely, how mathematical concepts could be employed to facilitate the teaching of coding and robotics. The current study centered on an integrative approach in relation to these aspects, as dictated by the inherent nature of TPACK.

Finally, it is noteworthy that this study solely relied on the input of a single external reviewer to evaluate the guidelines. To augment the credibility and generalisability of this study, it would be advantageous to involve additional stakeholders to form a panel. The inclusion of diverse perspectives would further fortify the robustness of the research findings. It is important to mention that although this study engaged only one external reviewer, their feedback primarily focused on the potential application of the framework, rather than providing commentary on the data analysis process.

These considerations indicate that the findings cannot be generalised to a larger population but must be interpreted within this specific context (Smith, 2018). More research from a larger and more diverse population group would thus be necessary. However, I acknowledged and sought to control the bias in school and participant selection by using the quality criteria listed in 3.7 Ensuring the quality and rigour of the study.

8.6 RECOMMENDATIONS

Based on the study's findings, I would like to propose the following recommendations for teacher training, addressing systemic barriers, Grade R teachers, and future research.

8.6.1 Recommendations for teacher training

The key to providing developmentally-appropriate experiences for young learners, particularly in relation to the use of technology, is the presence of a knowledgeable and responsive adult (Jones & Dexter, 2018; Callaghan *et al.*, 2023). Given the rapid pace of technological change, many teachers lack access to professional development opportunities and training, which can create a knowledge gap between what is developmentally appropriate and what can be effectively implemented in the classroom (Paulus, Villegas & Howze-Owens, 2020). Rather than taking an all-encompassing approach to solving this problem, professional development and technological training should be tailored to suit the particular demands of individual teachers (Jones & Dexter, 2018). It is unrealistic to expect teachers to successfully integrate technology in their instruction without the necessary training and implementation resources (Ho & Dimmock, 2023).

The findings particularly emphasise that teachers need training in the use of coding and robotics, as well as understanding the importance of its application and integrating coding and robotics with specific content, such as mathematics. As a result, teachers must receive training in the development of their TK and TCK. Furthermore, this study suggests that teachers should not perceive coding and robotics as complex or unfamiliar, but rather understand their use in everyday activities, such as providing instructions to obtain a desired outcome (coding). Coding and robotics should be viewed as creative and innovative tools to supplement learning environment instruction. Finally, teachers should understand how critical it is for learning activities to develop from kinaesthetic to concrete to representational to abstract learning (KCRA). This will allow learners to absorb concepts more quickly and effectively.

According to research (DeMonte, 2013; Adler & Kim, 2018; Mury, Negrini, Assaf & Skweres, 2022), even one-day workshops had a positive impact on participants' views about coding and robotics in terms of teachers' attitudes toward robotics. Moreover, most studies have shown that teacher self-esteem increased as their knowledge of coding and robotics increased (Kay & Moss, 2012), and it improved even more once teachers implemented what they had learned in training and used coding and robotics in their actual LEs (Chalmers, 2018; Cooper, Dann, Lewis, Lawhead, Rodger, Schep & Stalvey, 2011; Holmes, Hickmott, Prieto-Rodrigues & Berger, 2018; Marcelino, Pessoa, Vieira, Salvador & Mendes, 2018; Boz & Allexsaht-Snider, 2022). Additionally, it is advised that training planners use a variety of tools and materials, including training materials and lesson plan examples (Cooper *et al.*, 2011; Boz & Allexsaht-Snider, 2022). Nevertheless, a thorough investigation of how teachers learn to integrate coding and robotics and what supports or inhibits their learning during the process, is lacking.

8.6.2 Recommendations for addressing systemic barriers

The systemic barrier this study explicated was overcrowded LEs; although there are many other systemic barriers that have not been addressed. According to West and Meier (2020), teachers may be able to overcome the difficulties brought on by overcrowding with the support of a collaborative effort from all role players, including the SMTs and the teachers. A mentorship programme that is well-implemented and in-service training provided by the SMTs are additional solutions that will help, equip, support, and empower teachers who are having difficulty instructing in overcrowded LEs (ibid.).

Despite the fact that there are currently support structures in place and further ideas to address systemic barriers, research consistently indicates that teachers still seek support with this barrier. Thus, this study suggests that relevant parties, such as the DBE and SMTs, perform a thorough investigation and evaluation in order to develop solutions for these issues that adversely affect teaching and learning.

8.6.3 Recommendations for Grade R teachers

The study suggests that through training, teachers should learn more about the integration of coding and robotics and how to use them to complement their teaching. During teacher training opportunities, teachers should learn skills and competencies in coding and robotics, as well as guidelines of how it can be used to optimise integration. However, for the time being, this study suggests that teachers use the framework to integrate coding and robotics with numbers, operations, and relationships (or other subject/content areas).

Furthermore, as seen in the framework, teachers should be actively aware of how both pedagogical theories and international best practices can support their teaching practices in Grade R. This study was limited to two theorists and two practices, however, there are many more to choose from.

8.6.4 Recommendations for future research

The available literature makes it abundantly evident that further research is necessary before it will be possible to teach existing Grade R teachers how to integrate coding and robotics in their teaching activities. In terms of attitudes toward coding and robotics among Grade R teachers; development of skills and knowledge; efficient coding and robotics training needs; and systemic barriers to integrate coding and robotics with mathematics, the existing literature and findings of this study also indicate some rising commonalities (see Table 7.1). More research studies are needed to develop an agreement on delivering useful practices for South African Grade R teachers' robotics and coding learning as well as their integrating approaches (Boz & Allexsaht-Snider, 2022).

This study was likewise primarily concerned with the inclusion of mathematical skills and knowledge, as well as operations and number relationships. However, both the literature and the data suggested that other subjects, notably language and life skills, should be seamlessly interwoven. Future studies might focus on these other subjects or other content areas of mathematics to create a comprehensive picture of how coding and robotics can be integrated within Grade R teaching in general. This study's framework and conceptual representation of how teachers might be helped to integrate coding and robotics with Grade R mathematical concepts (see Figure 8.1) are similarly mainly focused on the identified content area of mathematics. This framework and representation may be used by researchers in LEs to examine its applicability and success in all other subjects and mathematical content areas.

Finally, this research was carried out in affluent learning contexts. Further research might look at how the study's topic affects and is comprehended in impoverished and rural communities. Research on the challenges experienced by these teachers may also provide useful insight into how these difficulties might be addressed. Furthermore, all of the teachers recruited had between six and 22 years of teaching experience; consequently, it would be useful to investigate how fewer years of teaching experience impact teachers' attitudes, dispositions, and implementation.

I want to emphasise that these conclusions and recommendations are specific to this context and that it is not possible to make a general evaluation of Grade R teachers in South Africa.

8.7 CONCLUSION

The chapter outlined the conclusion of the study by exploring the research questions and how they had been answered by this research (see Section 7.3). By exploring how teachers can be supported to integrate coding and robotics with specific mathematical concepts by implementing TPACK, I was able to design learning experiences that develop learners holistically and prepare them for the world of tomorrow; identify opportunities for teachers to work together on this fascinating subject; and culminate ideas for teachers to make learning interesting, enjoyable, interactive, and hands-on.

I was intrigued by the creative ways in which teachers approached uncharted territory; by how they seized the chance to engage in active learning and advance their practices, not just for themselves but also for the generations to come. It takes careful preparation and comprehension of the TPACK constructs as described in this study to assist teachers in integrating coding and robotics with mathematical concepts. It should be emphasised to teachers that staying current with these new advancements is important.

On the other hand, the study revealed the need of teacher training opportunities, particularly when a new concept is introduced. The study created a framework and conceptual representation to address the need of training, which may help these teachers and, perhaps, other teachers if further investigation is conducted. Training needs as as well as external issues, such as overcrowded LEs, must be explored in future research and addressed by the necessary educational role players.

The main message of my study is that coding and robotics can be integrated as effective complementary tools with Grade R mathematical concepts in a playful and informal manner. To support teachers in using these tools, the study proposes the NELO framework, which emphasises meeting teachers' needs, addressing external factors, careful planning of the learning process, and achieving positive outcomes. The study also suggests that teaching, in general, is a skill that can be learned and improved upon, and that teachers should integrate what they already know and use the KCRA approach to plan informal, play-based learning experiences. Overall, the study highlights the potential of integrating coding and robotics with mathematics in Grade R LEs, and provides practical guidance for supporting teachers in this endeavour.

I will let the reader draw their own interpretations of the following quote as I end my research study:

> *"A man's mind, stretched by new ideas, may never return to its original dimensions"* – Oliver Wendell Holmes Jr.

REFERENCE LIST

Abumiya, M.I. 2015. *Preschool education and care in Japan*. [Online] Available from: https://www.nier.go.jp/English/educationjapan/pdf/201109ECEC.pdf [Accessed: 2022-01-05].

Adams, J., Kaczmarczyk, S., Picton, P. & Demian, P. 2010. Problem solving and creativity in engineering: Conclusions of a three year project involving reusable learning objects and robots. *Engineering Education*, 5(2):4–17.

Adesola, A.P. & Olla, G.O. 2019. Bridging the digital divide in Nigerian information landscape: The role of the library. *International Journal of Digital Literacy and Digital Competence,* 10(3):1–22.

Adukaite, A., Zyl, I. & Cantoni, L. 2016. The role of digital technology in tourism education: A case study of South African secondary schools. *Journal of Hospitality, Leisure, Sport & Tourism Education*, 19:54–65.

Agbagbla, F. 2018. *A professional development programme for Ghanaian kindergarten to implement an indigenous play-based pedagogy*. Unpublished doctoral thesis. Pretoria: University of Pretoria.

Alhumaid, K. 2019. Four ways technology has negatively changed education. *Journal of Educational and Social Research*, 9(4):10-20.

Aliyu, A.A., Singhry, I.M., Adamu, H. & Abubakr, M.M. 2015. *Ontology, epistemology and axiology in quantitative and qualitative research: elucidation of the research philosophical misconception*. Paper presented at the Academic Conference: Mediterranean Publications & Research International on New Direction and Uncommon, University of Agric, Abeokuta, Nigeria, 22nd December 2015: 24-29. [Online] Available from: http://www.mprcenter.org/ [Accessed: 2022-01-05].

Aljabreen, H. 2020. Montessori, Waldorf, and Reggio Emilia: A comparative analysis of alternative models of early childhood education. *International Journal of Early Childhood*, 52(1):337–353.

Allen, K.S. 2013. Robots bring math-powered ideas to life. *Mathematics Teaching in the Middle School*, 18(6):340–347.

Alvarez, C., Alarcon, R. & Nussbaum, M. 2011. Implementing collaborative learning activities in the classroom supported by one-to-one mobile computing: A design-based process. *The Journal of Systems and Software*, 84(11):1961–1976.

Alves-Oliveira, P. 2020. *Boosting children's creativity through creative interactions with social robots*. Unpublished master's dissertation. Lisbon, Portugal: University Institute of Lisbon.

Ananiadou, K. & Claro, M. 2009. *21st century skills and competences for new millennium learners in OECD countries*. [Online]. Available from: https://files.eric.ed.gov/fulltext/ED529649.pdf [Accessed: 2022-01-04].

Ajani, O.A. 2021. Curriculum and Assessment Policy Statement (caps) Document: The challenges and limitations to its effectiveness in South African schools. *African Journal of Development Studies*, 11(3):77–100.

Andrade, C. 2021. The inconvenient truth about convenience and purposive samples. *Indian Journal of Psychological Medicine*, 43(1):86-88.

Angeli, C. & Valanides, N. 2009. Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education*, 52(1):154–168.

Angeli, C. & Valanides, N. 2020. Developing young children's computational thinking with educational robotics: An interaction effect between gender and scaffolding strategy. *Computers in Human Behavior*, 105:1–13.

Anney, V.N. 2014. Ensuring the quality of the findings of qualitative research: Looking at trustworthiness criteria. *Journal of Emerging Trends in Educational Research and Policy Studies*, 5(2):272–281.

Archambault, L. & Barnett, J.H. 2010. Revisiting technological pedagogical content knowledge: Exploring the TPACK framework. *Computers & Education*, 55(1):1656–1662.

Ardiny, H., Witwicki, S. & Mondada, F. 2015. *Construction automation with autonomous mobile robots: A review*. 2015 3rd RSI International Conference on Robotics and Mechatronics, pp. 418-424. [Online]. Available from: https://ieeexplore.ieee.org/abstract/document/7367821 [Accessed: 2023-01-06].

Ardito, G., Mosley, G. & Scollins, L. 2014. WE, ROBOT. Using robotics to promote collaborative and mathematics learning in a middle school classroom. *Middle Grades Research Journal*, 9(3):73–88.

Arifin, S.R. 2018. Ethical considerations in qualitative study. *International Islamic University Malaysia*, 1(2):30–33.

Astolfo, D., Ferrari, M. & Ferrari, G. 2007. *Building robots with LEGO Mindstorms NXT*. Burlington, MA: Syngress Publishing Inc.

Atli, S., Korkmaz, A.M., Tastepe, T. & Koksal Akyol, A. 2016. Views on Montessori approach by teachers serving at schools applying the Montessori Approach. *Eurasian Journal of Educational Research*, 66:123–138.

Attard, C. 2012. Teaching with technology: exploring the use of robotics to teach mathematics. *Annals of Punjab Medical College*, 17(2):31–32.

Australian Curriculum, Assessment and Reporting Authority (ACARA). 2011. *General Capabilities in the Australian Curriculum: Technologies.* [Online] Available from: https://docs.acara.edu.au/ [Accessed: 2022-08-08].

Australian Government Department of Education and Training for the Council of Australian Government. 2009. *Belonging, being & becoming: The early years learning framework for Australia*. [Online]. Available from: https://www.acecqa.gov.au/ [Accessed: 2022-08-08].

Awofala, A.O., Akinoso, S.O., Oladiran, S.O. & Ojo O.T. 2022. Chapter Three: Learning in the context of Piaget's intellectual advancement: Implications for science, technology and mathematics education. In: *Learning: The All Inclusive Concept.* Faculty of Education, University of Lagos Akoka-Yaba: Lagos, Nigeria. pp.51-63. [Online]. Available from: https://www.researchgate.net/ [Accessed: 2023-02-15].

Awopegba, P.O., Oduolowu, E.A. & Nsamenang, A.B. 2013. *Indigenous early childhood care and education (IECCE) curriculum framework for Africa: a focus on context and contents*. [Online]. Available from: https://unesdoc.unesco.org/ [Accessed: 2022-01-07].

Azungah, T. 2018. Qualitative research: deductive and inductive approaches to data analysis. *Qualitative Research Journal*, 18(4):383-400.

Badmus, O. & Omosewo, E.O. 2020. Evolution of STEM, STEAM and STREAM education in Africa: The implication of the knowledge gap. *International Journal of Research in STEM Education*, 2(2):99–106.

Ball, D.L., Thames, M.H. & Phelps, G. 2008. Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59(5):389–407. [Online]. Available from: https://www.researchgate.net/ [Accessed: 2022-01-07].

Barnard, E. & Braund, M. 2016. Strategies for the implementation of mathematics in Grade R: Teachers' beliefs and practices. *South African Journal of Childhood Education*, 6(1):1–8.

Baroody, A.J. 2017. The Use of Concrete Experiences in Early Childhood Mathematics Instruction. *Advances in Child Development and Behavior*, 53:43-94.

Barr, A., Gillard, J., Firth, V., Scrymgour, M., Welford, R., Lomax-Smith, J., Bartlett, D., Pike, B. & Constable, E. 2008. *Melbourne declaration on educational goals for young Australians*. [Online] Available from: https://files.eric.ed.gov/ [Accessed: 2022-08-08]

Barron, B., Cayton-Hodges, G., Bofferding, L., Copple, C., Darling-Hammond, L. & Levine, M. 2011. *Take a giant step: A blueprint for teaching children in a digital age*. [Online]. Available from: https://joanganzcooneycenter.org/ [Accessed: 2022-01-04].

Barrow, J.M., Brannon, G.D. & Khandhar, P.B. 2021. *Research ethics*. Treasure Island, FL: StatPearls Publishing.

Bayram-Jacobs, D., Henze, I., Evagorou, M., Shwartz, Y., Aschim, E.L., Alcaraz-Dominguez, S., Barajas, M. & Dagan, E. 2019. Science teachers' pedagogical content knowledge development during enactment of socioscientific curriculum materials. *Journal of Research in Science Teaching*, 56(9):1207–1233.

Belshaw, D.A.J. 2012. *What is 'digital literacy'? A pragmatic investigation*. Unpublished doctoral thesis. Durham: Durham University.

Bengtsson, M. 2016. How to plan and perform a qualitative study using content analysis. *NursingPlus Open*, 2(1):8–14.

Bennett, M. 2019. A review of the literature on the benefits and drawbacks of participatory action research. *First Peoples Child & Family Review*, 14(1):109–122.

Bergh, D.D., Boyd, B.K., Byron, K., Gove, S. & Ketchen, D.J. What constitutes a methodological contribution? *Journal of Management*, 48(7):1835-1848.

Berk, L.E. 2018. *Development through the lifespan*. 7th ed. Hoboken, NJ: Pearson.

Bers, M.U. 2008. *Blocks to robots: Learning with technology in the early childhood classroom*. New York, NY: Teachers College Press.

Bers, M.U. 2018. *Coding, playgrounds and literacy in early childhood education: The development of KIBO robotics and ScratchJr.* Paper presented at the 2018 IEEE Global Engineering Education Conference (EDUCON), Santa Cruz de Tenerife, Canary Islands, Spain, 17-20 April 2018: 2100-2108. [Online] Available from: https://ieeexplore.ieee.org/document/8363373 [Accessed: 2023-01-06].

Bers, M.U. 2021. *Coding as a playground: Programming and computational thinking in the early childhood classroom*. 2nd ed. New York, NY: Routledge.

Bers, M.U. & Ettinger, A.B. 2012. Programming robots in kindergarten to express identity: An ethnographic analysis. In: Barker, B.S., Nugent, G., Grandgenett, N. & Adamchuk, V.I. (eds.). *Robots in K-12 education: A new technology for learning*. Hershey, PA: IGI Global.

Bers, M.U. & Horn, M.S. 2010. Tangible programming in early childhood: Revisiting developmental assumptions through new technologies. In: Berson, I.R. & Berson, M.J. (eds.). *High-tech tots: Childhood in a digital world*. Greenwich, CT: Information Age Publishing.

Bers, M.U. & Portsmore, M. 2005. Teaching partnerships: Early childhood and engineering students teaching math and science through robotics. *Journal of Science Education and Technology*, 14(1):59–73.

Bers, M.U., González-González, C. & Armas-Torres, M.B. 2019. Coding as a playground: Promoting positive learning experiences in childhood classrooms. *Computers & Education*, 138:130–145. [Online]. Available from: https://doi.org/10.1016/j.compedu.2019.04.013 [Accessed: 2023-05-26].

Bers, M.U., Ponte, I., Juelich, K., Viera, A. & Schenker, J. 2002. Teachers as designers: Integrating robotics into early childhood education. *Information Technology in Childhood Education*, pp.123–145.

Bers, M.U., Seddighin, S. & Sullivan, A. 2013. Ready for robotics: Bringing together the T and E of STEM in early childhood teacher education. *Journal of Technology and Teacher Education*, 21(3):355–377.

Blin, F. & Munro, M. 2008. Why hasn't technology disrupted academics' teaching practices? Understanding resistance to change through the lens of activity theory. *Computers & Education*, 50(2):475-490.

Bier, H., Cheng, A.L., Mostafavi, S., Anton, A. & Bodea, S. 2018. Robotic building as integration of design-to-robotic-production and -operation. In: Bier, H. (ed.). *Robotic Building*. Dordrecht: Springer.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M. & Rumble, M. 2012. Defining twenty-first century skills. In: P. Griffin, B. McGaw & E. Care (eds.). *Assessment and Teaching of 21st Century Skills*. Dordrecht: Springer.

Birt, L., Scott, S., Cavers, D., Campbell, C. & Walter, F. 2016. Member checking: A tool to enhance trustworthiness or merely a nod to validation? *Qualitative Health Research*, 26(13):1802–1811.

Björklund, C. 2008. Toddlers' opportunities to learn mathematics. *International Journal of Early Childhood*, 40(1):81–95.

Bjuland, R. & Helgevold, N. 2017. Dialogic processes that enable student teachers' learning about pupil learning in mentoring conversations in a Lesson Study field practice. *Teaching and Teacher Education*, 70(2018):246–254.

Boaduo FRC, N.A.P., Milondzo, K.S. & Gumbi, D. 2011. Teacher education and training for Africa in the 21st century: What form should it take? *Educational Research and Review*, 6(1):1–16.

Bocconi, S., Chioccariello, A., Dettori, G., Ferrari, A. & Engelhardt, K. 2016. *Developing computational thinking in compulsory education - Implications for policy and practice*. European Union: Joint Research Centre.

Bodrova, E. & Leong, D.J. 2007. *Tools of the Mind: The Vygotskian Approach to Early Childhood Education*. 2nd ed. Pearson. [Online]. Available from: https://www.researchgate.net/profile/Elena-Bodrova/publication/31663781_Tools_of_the_Mind_Vygotskian_approach_to_early_childhood_education_E_Bodrova_DJ_Leong/links/596bcaafa6fdcc18ea7

9267a/Tools-of-the-Mind-Vygotskian-approach-to-early-childhood-education-E-Bodrova-DJ-Leong.pdf [Accessed: 2023-05-26].

Bogdan, R.C. 2003. Data analysis and interpretation. *Qualitative research for education*. 4th ed. New York, NY: Syracuse University.

Boggan, M., Harper, S. & Whitmire, A. 2010. Using manipulatives to teach elementary mathematics. *Journal of Instructional Pedagogies*, 3, 1–6. [Online]. Available from: https://files.eric.ed.gov/fulltext/EJ1096945.pdf [Accessed: 2023-05-26].

Bolstad, R. 2004. *The role and potential of ICT in early childhood education: A review of New Zealand and international literature*. [Online]. Available from: https://www.nzcer.org.nz/system/files/ictinecefinal.pdf [Accessed: 2020-07-19].

Bonache, J. & Festing, M. 2020. Research paradigms in international human resource management: An epistemological systematisation of the field. *German Journal of Human Resource Management: Zeitschrift für Personalforschung*, 32(2):99-123.

Bonawitz, E., Shafto, P., Gweon, H., Goodman, N.D., Spelke, E. & Schulz, L. 2011. The double-edged sword of pedagogy: Instruction limits spontaneous exploration and discovery. *Cognition*, 120(3):322–330.

Boz, T. & Allexzaht-Snider, M. 2022. How do elementary school teachers learn coding and robotics? A case study of mediations and conflicts. *Education and Information Technologies*, 27(3):3935-3963.

Bradley, E.H., Curry, L.A. & Devers, K.J. 2007. Qualitative data analysis for health services research: developing taxonomy, themes, and theory. *Health Services Research*, 42(4):1758-1772. [

Brandao, N. & Theodotou, E. 2020. The Reggio Emilia and the Mosaic approach: Opponents or allies in multimodal teaching and learning? A discussion of their contribution to multimodal learning in early years education. *Journal of Global Education and Research*, 4(1):1-13.

Braun, V. & Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2):77–101.

Braun, V. & Clarke, V. 2018. Thematic analysis. In: Cooper, H., Camic, P.M., Long, D.L., Panter, A.T., Rindskopf, D. & Sher, K.J. (eds.). *APA handbook of research methods in psychology, Vol. 2: Research designs: Quantitative, qualitative, neuropsychological, and biological*. Washington, DC: American Psychological Association.

Brennan, K. & Resnick, M. 2012. *Using artifact-based interviews to study the development of computational thinking in interactive media design*. Paper presented at annual American Educational Research Association meeting, Vancouver. [Online]. Available from: https://web.media.mit.edu/ [Accessed: 2023-05-28].

Brinkmann, S. & Kvale, S. 2008. Ethics in qualitative psychological research. In: Willig, C. & Stainton-Rogers, W. (eds.). *The SAGE handbook of qualitative research in psychology*. Thousand Oaks, CA: SAGE.

Brock, A. 2009. Playing in the early years: At liberty to play – not only legal but also statutory! In: Brock, A., Dodds, S., Jarvis, P. & Olusoga, Y. (eds.). *Perspectives on play: Learning for fife*. Harlow: Pearson Longman.

Brooks, K.W. 1979. Delphi technique: Expanding applications. *North Central Association Quarterly*, 53(3):377–385. [Online]. Available from: https://eric.ed.gov/?id=EJ206895 [Accessed: 2023-05-26].

Brown, R.H., Roehrig, P. & Malhotra, V. 2015. *The Robot and I: How new digital technologies are making smart people and businesses smarter by automating rote work*. [Online]. Available from: https://www.cognizant.com/ [Accessed: 2021-01-28].

Bruce, T. 1997. Adults and children developing play together. *European Early Childhood Education Research Journal*, 5(1):89–99.

Bruce, T. 2004. *Developing learning in early childhood*. London: Paul Chapman Publishing Ltd.

Bruner, J.S. & Kenney, H.J. 1965. Representation and mathematics learning. *Monographs of the Society for Research in Child Development*, 30(1):50–59.

Bryman, A. 2016. *Social Research Methods*. Oxford: Oxford University Press.

Burnett, C. 2011. Pre-Service teachers' digital literacy practices: Exploring contingency in identity and digital literacy in and out of educational contexts. *Language and Education*, 25(5):33–49.

Burton, M. 2010. Five strategies for creating meaningful mathematics experiences in the primary years. *Young Children*, 65(6):92–96.

Butler, F.M., Miller, S.P., Crehan, K., Babbitt, B. & Pierce, T. 2003. Fraction instruction for students with mathematics disabilities: Comparing two teaching sequences. *Learning Disabilities Research & Practice*, 18(2):99–111.

Butz, W.P., Kelly, T.K., Adamson, D.M., Bloom, G.A., Fossum, D. & Gross, M.E. 2004. *Will the scientific and technology workforce meet the requirements of the federal government*? Pittsburgh, PA: RAND.

Callaghan, R., Joubert, J. & Engelbrecht, J. 2022. Using enaction to evolve from pre-covid to post-covid pedagogy: A case study with South African mathematics teachers. *ZDM: The International Journal on Mathematics Education,* 55(193-206).

Campbell, C. & Walsh, C. 2017. Introducing the 'new' digital literacy of coding in the early years. *Practical Literacy*, 22(3):10-12.

Campbell, E. & Kapp, R. 2020. Developing an integrated, situated model for digital literacy in pre-service teacher education. *Journal of Education*, 79:18–30.

Cataldi, S. & Sena, B. 2021. *Mixed-methods data collection in a study on interprofessional care: interviews, a survey, and the delphi technique*. London: SAGE Publications. [Online]. Available from: https://methods.sagepub.com/case/data-collection-interprofessional-care-interviews-survey-delphi-technique [Accessed: 2023-05-26].

Cejka, E., Rogers, C. & Portsmore, M. 2006. Kindergarten robotics: Using robotics to motivate math, science, and engineering literacy in elementary school. The *International Journal of Engineering Education*, 22(4):711–722.

Chalmers, C., Chandra, V. & Hudson, P. 2012. *Preservice teachers teaching technology with robotics.* Paper presented at Australian Teacher Education Association (ATEA) 2012 Conference, Samford Grand Adelaide (Glenelg), Adelaide, Australia, 1-8 July 2012: 1-8. [Online] Available from: https://eprints.qut.edu.au/52669/ [Accessed: 2023-01-10].

Chalmers, C. 2018. Robotics and computational thinking in primary school. *International Journal of Child Computer Interaction*, 17:93–100. [Online]

Chambers, J. 2015. *Inside Singapore's plans for robots in pre-schools*. [Online]. Available from: https://govinsider.asia/intl-en/article/exclusive-singapore-puts-robots-in-pre-schools [Accessed: 2022-01-06].

Charmaz, K. 2014. *Constructing grounded theory*. London: SAGE.

Cherniak, S., Lee, K., Cho, E. & Jung, S.E. 2019. Child-identified problems and their robotic solutions. *Journal of Early Childhood Research*, 17(4):347–360.

Chevalier, M., Giang, C., Piatti, A. & Mondada, F. 2020. Fostering computational thinking through educational robotics: A model for creative computational problem solving. *International Journal of STEM Education*, 7:39. [Online]. Available from: https://doi.org/10.1186/s40594-020-00238-z [Accessed: 2023-05-26].

Ching, Y.H. & Hsu, Y.C. 2023. Educational Robotics for Developing Computational Thinking in Young Learners: A Systematic Review. *TechTrends*, 1-12. [Online]. Available from: https://link.springer.com/article/10.1007/s11528-023-00841-1#citeas [Accessed: 2023-05-26].

Ching, Y.H., Hsu, Y.-C. & Baldwin, S. 2018. Developing computational thinking with educational technologies for young learners. *TechTrends: Linking Research and Practice to Improve Learning*, 62(6):563–573.

Chiong, W., Leonard, M.K. & Chang, E.F. 2018. Neurosurgical patients as human research subjects: Ethical considerations in intracranial electrophysiology research. *Neurosurgery*, 83(1):29–37.

Chowdhry, S., Sieler, K. & Alwis, L. 2014. A Study of the impact of technology-enhanced learning on student academic performance. *Journal of Perspectives in Applied Academic Practice*, 2(3):3-15.

Churchman, S.L. 2006. *Bringing math home: A parent's guide to elementary school math*. Chicago, IL: Zephyr Press.

Clements, D.H. & Sarama, J. 2012. Learning and teaching early and elementary mathematics. In: J. Carlson & J. Levin (eds.). *Psychological perspectives on contemporary educational issues: Vol. 3. Instructional strategies for improving students' learning*. North Carolina: Information Age. [Online]. Available from: https://www.researchgate.net/profile/Douglas-Clements-2/publication/258932996_Learning_and_teaching_early_and_elementary_mathematics/links/5467ae510cf2f5eb18036d5f/Learning-and-teaching-early-and-elementary-mathematics.pdf [Accessed: 2023-05-26].

Clements, D.H. & Sarama, J. 2014. *Learning and teaching early math: The learning trajectories approach*. 2nd ed. New York, NY: Routledge.

Clements, D.H., Battista, M.T. & Sarama, J. 2001. Logo and geometry. *Journal for Research in Mathematics Education*, 10:1–177.

Clements, L.J. 2022. Cooperation between preschool peers in relation to their math learning. *The Journal of Education Research*, 115(3):199-208. [Online] Available from: https://www-tandfonline-com.uplib.idm.oclc.org/ [Accessed: 2023-05-24].

Cohen, E., Manion, L. & Morrison, K. 2007. *Research Methods in Education*. 6th ed. New York, NY: Routledge.

Vygotsky, L.S. 1978. *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.

Collins, C.S. & Stockton, C.M. 2018. The central role of theory in qualitative research. *International Journal of Qualitative Methods*, 17(1):1-10.

Conner, A., Crawford, B.A., Foutz, T., Hill, R.B., Jackson, D.F., Kim, C.M. and Thompson, S.A. 2020. Argumentation in primary grades STEM Instruction: Examining teachers' beliefs and practices in the USA. In: Anderson, J. & Li, Y. (eds.). *Integrated Approaches to STEM Education: An International Perspective.* Dordrecht: Springer.

Conner, L. & Duncan, J. 2013. Introduction. In: Duncan, J. & Conner, L. (eds.). *Research partnerships in early childhood education*. New York, NY: Palgrave Macmillan.

Conkbayir, C.M. & Pascal, C. 2016. *Early childhood theories and contemporary issues: an introduction*. 3rd ed. London: Bloomsbury.

Conlon, T. & Simpson, M. 2003. Silicon Valley versus silicon glen: The impact of computers upon teaching and learning: A comparative study. *British Journal of Educational Technology*, 34(2):137–150.

Cooper, K. & White, R. 2012. *Qualitative research in the post-modern era: Contexts of qualitative research*. Dordrecht: Springer.

Cooper, S., Dann, W., Lewis, D., Lawhead, P., Rodger, S., Schep, M. & Stalvey, R. 2011. *A pre-college professional development program*. Paper presented at the 16th Annual Joint Conference on Innovation and Technology in Computer Science Education, Association for Computing Machinery Digital Library, pp. 188–192. [Online] Available from: https://doi.org/10.1145/1999747.1999801 [Accessed: 2023-01-10].

Cortes, K.E., Moussa, W.S. & Weinstein, J.M. 2012. *Making the grade: The impact of classroom behaviour on academic achievement*. Paper presented at APPAM Fall Research Conference, Baltimore, MD, 8-10 November: 1-28.

Couse, L.J. & Chen, D.W. 2010. A tablet computer for young children? Exploring its viability for early childhood education. *Journal of Research on Technology in Education*, 43(1):75-96.

Creswell, J. 2014. *Research design: qualitative, quantitative and mixed methods approaches*. 4th ed. Thousand Oaks, CA: SAGE.

Creswell, J.W. 2009. *Research design: Qualitative, quantitative, and mixed methods approaches*. 3rd ed. Thousand Oaks, CA: SAGE.

Creswell, J.W. & Creswell, J.D. 2018. *Research design: Qualitative, quantitative, and mixed methods approaches*. 5th ed. Thousand Oaks, CA: SAGE.

Creswell, J.W. & Plano Clark, V.L. 2018. *Designing and conducting mixed methods research*. 3rd ed. Thousand Oaks, CA: SAGE.

Czerniewicz, L. & Brown, C. 2013. The Habitus of Digital ‘Strangers’ in Higher Education. *British Journal of Educational Technology,* 44(1):44–53.

Da Silva, D.C., Júnior, F.R.F.M., Silva, T.M.R. & Nunes, J.B.C. 2022. The characteristics of qualitative research: A study with theses from a postgraduate program in education. *Educação em Revista*, 38:1-16.

Daniel, J. 2012. *Sampling essentials: practical guidelines for making sampling choices*. Thousand Oaks, CA: SAGE.

Daniels, H. 2014. Vygotsky and Dialogic Pedagogy. *Cultural Historical Psychology*, 10(3):19–29.

Danielson, C. 2007. *Enhancing professional practice: A framework for teaching*. 2nd ed. Alexandria, VA: Association for Supervision and Curriculum Development.

Darling-Hammond, L. 2006. Constructing 21st-century teacher education. *Journal of Teacher Education*, 57(3):300-314.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B. & Osher, D. 2020. Implications for educational practice of the science of learning and development. *Applied Developmental Science*, 24(2):97-140.

Das, K. 2019. The role and impact of ICT in improving the quality of education: An overview. *International Journal of Innovative Studies in Sociology and Humanities*, 4(6):28-34.

De Holton, D., Ahmed, A., Williams, H. & Hill, C. 2001. On the importance of mathematical play. *International Journal of Mathematical Education in Science and Technology*, 32(3):401–415.

DeMonte, J. 2013. *High-quality professional development for teachers: Supporting teacher training to improve student learning*. Centre for American Progress. [Online]. Available from: https://files.eric.ed.gov/fulltext/ED561095.pdf [Accessed: 2023-08-01].

Denzin, N.K. & Lincoln, Y.S. 2018. *The SAGE Handbook of Qualitative Research*. 5th ed. Thousand Oaks, CA: SAGE.

Department of Basic Education (DBE). 2009. *Numeracy Handbook for Foundation Phase Teachers: Grades R-3*. [Online]. Available from: https://www.gov.za/ [Accessed: 2023-05-26].

Department of Basic Education (DBE). 2011. *National Curriculum Statement: Curriculum and Assessment Policy Statement Grade R (English) Home Language*. [Online]. Available from: https://www.education.gov.za/ [Accessed: 2023-01-07].

Department of Basic Education (DBE). 2011a. *National Curriculum Statement: Curriculum and Assessment Policy Statement Grade R (English) Life Skills*. [Online]. Available from: https://www.education.gov.za/ [Accessed: 2023-01-05].

Department of Basic Education (DBE). 2011b. *National Curriculum Statement: Curriculum and Assessment Policy Statement Grade R (English) Mathematics*. [Online]. Available from: https://www.education.gov.za/ [Accessed: 2021-02-01].

Department of Basic Education (DBE). 2011c. *National protocol for assessment: Grades R-12.* [Online]. Available from: https://www.education.gov.za/ [Accessed: 2021-02-01].

Department of Basic Education (DBE). 2015. *The South African National Curriculum Framework for children from Birth to Four*. [Online]. Available from: https://www.education.gov.za/ [Accessed: 2021-02-01].

Department of Basic Education (DBE). 2017. *Learning Through Playing: Online training for Early Development and Foundation Phase launched*. [Online]. Available from: https://www.education.gov.za/ [Accessed: 2021-02-01].

Department of Basic Education (DBE). 2019. *Africa play conference*. [Online]. Available from: https://www.education.gov.za/AfricaPlayConference.aspx [Accessed: 2021-02-01].

Department of Basic Education (DBE). 2021a. *Coding and Robotics Pilot Project Awareness and Advocacy Roadshows underway*. [Online]. Available from: https://www.education.gov.za/CodingandRoboticsPilotProject.aspx [Accessed: 2023-05-21].

Department of Basic Education (DBE). 2021b. *DBE and partners workshop Coding and Robotics Curriculum for the GET Band*. [Online]. Available from: https://www.education.gov.za/ [Accessed: 2021-01-27].

Department of Basic Education (DBE). 2021c. *DBE to pilot draft Curriculum on Coding and Robotics in schools*. [Online]. Available from: https://www.education.gov.za [Accessed: 2023-05-21].

Department of Basic Education (DBE). 2023. *Proposed amendments to the Curriculum and Assessment Policy Statement (CAPS) to make provision for coding and robotics Grades R-9*. [Online]. Available from: https://www.education.gov.za/ [Accessed: 2021-01-27].

Department of Education (DE). 2003. Revised National Curriculum Statement Grades R-9 (Schools): Teacher's Guide for the Development of Learning Programmes (Foundation Phase). [Online]. Available from: https://www.education.gov.za/ [Accessed: 2021-07-06].

Department of Education, Employment and Workplace Relations (DEEWR). 2010. *Educators' belonging, being and becoming: Educators' guide to the early years learning framework for Australia*. [Online]. Available from: https://www.acecqa.gov.au/ [Accessed: 2022-01-07].

Department of eLearning. 2015. *Digital literacy. 21st century competences for our age. The building blocks of digital literacy from enhancement to transformation*. [Online]. Available from: https://education.gov.mt/ [Accessed: 2022-01-07].

Derman, M.T., Zeteroğlu, E.S. & Birgül, A.E. 2020. The effect of play-based math activities on different areas of development in children 48 to 60 months of age. *SAGE Open*, 10(2):1–12.

Desoete, A. & Grégoire, J. 2006. Numerical competence in young children and in children with mathematics learning disabilities. *Learning and Individual Differences*, 16(4):351–367.

Dewey, J. 1904. The relation of theory to practice in education. *Teachers College Record: The Voice of Scholarship in Education*, 5(6):9-30.

Dewey, J. 1938. *Experience and Education*. New York, NY: Kappa Delta Pi.

Di Lieto, M., Inguaggiato, E., Castro, E., Cecchi, F., Cioni, G., Dell'Omo, M., Laschi, C., Pecini, C., Santerini, G., Sgandurra, G. & Dario, P. 2017. Educational Robotics intervention on Executive Functions in preschool children: A pilot study. *Computers in Human Behavior*, 71(1):16–23.

Diago, P.D., González-Calero, J.A. & Yáñez, D.F. 2022. Exploring the development of mental rotation and computational skills in elementary students through educational robotics. *International Journal of Child-Computer Interaction*, 32(1):1–10.

DiCarlo, S.E. 2009. Too much content, not enough thinking, and too little FUN! *American Journal of Physiology - Advances in Physiology Education*, 33(4):257-264.

Dicker, A.-M. & Naudé, M. 2014. Teaching mathematics in Grade R: a play-based approach. In: Naudé, M. & Meier, C. (eds.). *Teaching foundation phase mathematics: A guide for South African students and teachers*. Hatfield, Pretoria: Van Schaik Publishers.

Dingli, A. & Seychell, D. 2015. Who are the digital natives? In: Dingli, A. & Seychell, D. (eds.). *The new digital natives*. Dordrecht: Springer.

Doherty, J. & Hughes, M. 2014. *Child development: theory and practice 0-11*. 2nd ed. London: Pearson.

Duncan-Howell, J. 2010. Teachers making connections: On-line communities as a source of professional learning. *British Journal of Educational Technology*, 41(2):324–340.

Ebersöhn, L., Eloff, I. & Ferreira, R., 2016. First steps in action research. In: Maree, K. (ed.). *First Steps in Research*. Hatfield, Pretoria: Van Schaik Publishers.

Economic Commission for Latin America and the Caribbean (eCLAC). 2021. *Digital Technologies for a New Future* (LC/TS.2021/43). [Online]. Available from: https://www.cepal.org/. [Accessed: 2022-08-08]

Edwards, C.P., Gandini, L. & Nimmo, J. 2015. *Loris Malaguzzi and the teachers*. Lincoln, NE: Zea Books.

Elkin, M., Sullivan, A. & Bers, M.U. 2014. Implementing a robotics curriculum in an early childhood Montessori classroom. *Journal of Information Technology Education: Innovations in Practice*, 13(1):153–169.

Ellis, S. 2017. *Play in Early Childhood Education*. [Online]. Available from: https://digitalcommons.murraystate.edu/ [Accessed: 2021-01-12].

Elo, S., Kääriäinen, M., Kanste, O., Pölkki, T., Utriainen, K. & Kyngäs, H. 2014. Qualitative content analysis: A focus on trustworthiness. *SAGE Open*, 4(1):1–10.

Emen-Parlatan, M., Ördek-İnceoğlu, S., Gürgah-Oğu, İ. Aslan, D. 2023. Technology and Early Mathematics Skills: Effectiveness of I Love Math with Robots. *The Journal of Educational Research*, 1–10. [Online]. Available from: https://www-tandfonline-com.uplib.idm.oclc.org/ [Accessed: 2023-05-26].

Engelbrecht, A. 2016. Supporting learners in acquiring the skill of mathematisation. In: Nel, M., Nel, N., & Hugo, A. (eds.). *Learner support in a diverse classroom: A guide for foundation, intermediate and senior phase teachers of language and mathematics*. Pretoria: Van Schaik Publishers.

Etikan, I., Musa, S.A. & Alkassim, R.S. 2016. Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, 5(4):1-4.

Etokabeka, E.M.C. 2021. *The role of structured play in facilitating preschool learners' executive functions*. Unpublished doctoral thesis. Pretoria: University of Pretoria.

Excell, L. & Linington, V. (eds.) 2015. *Teaching Grade R*. Cape Town: Juta.

Faisal, A., Kapila, V. & Iskander, M.G. 2012. *Using robotics to promote learning in elementary grades.* Paper presented at K-12 and Pre-college Engineering Poster Session, 2012 ASEE Annual Conference & Exposition, San Antonio, Texas, 10-13 June 2012. American Society for Engineering Education. pp.1-6. [Online] Available from: https://peer.asee.org/using-robotics-to-promote-learning-in-elementary-grades [Accessed: 2022-08-08].

Falikman, M. 2021. There and back again: A (reversed) Vygotskian perspective on digital socialization. *Frontiers in Psychology*, 12:1-4.

Fazlul Hoque, A.K.M. 2019. *4th Industrial Revolution – impact and challenges*. Paper presented at the National Conference on Electronics and Informatics jointly organized by Bangladesh Electronics Informatics Society and Bangladesh Atomic Energy Commission, Atomic Energy Centre, Dhaka, 4-5 December 2019. [Online] Available from: https://www.researchgate.net/publication/337830441_4th_Industrial_Revolution-_Impact_and_Challenges [Accessed: 2022-08-08].

Fereday, J. & Muir-Cochrane, E. 2006. Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods*, 5(1):80–92.

Fernandes, E., Fermé, E. & Oliveira, R. 2006. *Using robots to learn functions in math class*. Paper presented at the Seventeenth Study Conference, Technology Revisited in Hanoi, Vietnam, 2006:pp.1-10. [Online]. Available from: http://cee.uma.pt/people/faculty/elsa.fernandes/artigos/ICMI17.pdf [Accessed: 2022-01-06].

Fernandes, E., Fermé, E. & Oliveira, R. 2010. The robot race: Understanding proportionality as a function with robots in mathematics class. In: Proceedings of the Sixth Congress of European Research in Mathematics Education (pp.1211–1220). [Online]. Available from: https://hal.archives-ouvertes.fr/hal-00642755/document [Accessed: 2023-01-10].

Fisher, K.R., Hirsh-Pasek, K., Newcombe, N. & Golinkoff, R.M. 2013. Taking shape: Supporting preschoolers' acquisition of geometric knowledge through guided play. *Child Development*, 84(6):1872–1878.

Fitzgerald, M., Kruschwitz, N., Bonnet, D. & Welch, M. 2013. *Embracing digital technology: A new strategic imperative*. [Online]. Available from: https://emergenceweb.com/ [Accessed: 2021-06-13].

Fleer, M. 2010. Part 2: Cultural-historical theories of play and learning. In: Fleer, M. (ed.). *Early learning and development: Cultural-historical concepts in play*. Cambridge, MA: Cambridge University Press.

Fleer, M. 2013. *Play in the early years*. Cambridge, MA: Cambridge University Press.

Fleer, M. & Veresov, N. 2018. Cultural-historical and activity theories informing early childhood education. In: Fleer, M. & Van Oers, B. (eds.). *International handbook of early childhood education.* Dordrecht: Springer.

Francis, K. & Davis, B. 2018. Coding Robots as a Source of Instantiations for Arithmetic. *Digital Experiences in Mathematics Education*, 4:71–86 (2018). [Online]. Available from: https://doi.org/10.1007/s40751-018-0042-7 [Accessed: 2023-05-26].

Franklin, P., Rowland, E., Fox, R. & Nicolson, P. 2012. Research ethics in accessing hospital staff and securing informed consent. *Qualitative Health Research*, 22(12):1727–1738.

Fritz, A., Long, C., Herzog, M., Balzer, L., Ehlert, A. & Henning, E. 2020. Mismatch of the South African foundation phase curriculum demands and learners' current knowledge. *African Journal of Research in Mathematics, Science and Technology Education*, 24(1):10-20.

Fulton, K. & Britton, T. 2011. STEM teachers in professional learning communities: From good teachers to great teaching. *Journal of Science Teacher Education*, 22(1):19-34.

Gadzikowski, A. 2018. *Robotics for young children: STEM activities and simple coding*. St. Paul, MN: Redleaf Press.

Gale, N.K., Heath, G., Cameron, E., Rashid, S. & Redwood, S. 2013. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Medical Research Methodology*, 13(1):117-124.

Gandini, L. 2015. Chapter two: From the beginning of the Atelier to materials as 100 languages: Loris Malaguzzi’s thoughts and strategies. In: L. Gandini, L. Hill, L. Cadwell & C. Schwall, (eds.). *In the spirit of the studio: Learning from the Atelier of Reggio Emilia*. 2nd ed. New York, NY: Teachers College Press.

Gantt, B.H. 2021. *Perceptions of the Reggio Emilia approach to early childhood education*. Unpublished doctoral thesis. Minneapolis, MN: Walden University.

Gentry, R., Sallie, A.P. & Sanders, C.A. 2013. *Differentiated instructional strategies to accommodate students with varying needs and learning styles*. Paper presented at The Urban Education Conference, Jackson, Mississippi, United States, 10-12 July 2013. [Online]. Available from: https://eric.ed.gov/?id=ED545458 [Accessed: 2023-02-18].

Gess-Newsome, J. 2002. Pedagogical content knowledge: an introduction and orientation. In: Lederman, N.G. & Gess-Newsome, J. (eds.). *Examining pedagogical content knowledge: The construct and its implications for science education*. Amsterdam: Kluwer Academic Publishers.

Ghisho, M.P. 2012. Supporting teacher voices through inquiry and collaboration in professional development courses. *Voices of Practitioners*, 7(1), 1–6.

Gilster, P. 1997. *Digital literacy*. New York, NY: Wiley.

Gioia, D.A., Corley, K.G. & Hamilton, A.L. 2013. Seeking qualitative rigor in inductive research notes on the Gioia methodology. *Organizational Research Methods*, 16(1):15-31. [Online].

Given, L.M. 2008. Secondary participants. In: Given, L.M. (ed.). *The SAGE encyclopedia of qualitative research methods*. Thousand Oaks, CA: Sage.

Göker, S.D. 2016. Use of reflective journals in development of teachers’ leadership and teaching skills. *Universal Journal of Educational Research*, 4(12A):63–70. [Online].

Goldin, T., Rauch, E., Pacher, C. & Woschank, M. 2022. Reference architecture for an integrated and synergetic use of digital tools in education 4.0. *Procedia Computer Science*, 200:407-417.

Goldkuhl, G. 2019. The generation of qualitative data in information systems research: The diversity of empirical research methods. *Communications of the Association for Information Systems*, 44:572-599.

Golinkoff, R.M. & Hirsh-Pasek, K. 2017. *Becoming brilliant: What science tells us about raising successful children*. Washington, DC: American Psychological Association.

Gömleksiz, M.N. 2004. Use of education technology in English classes. *The Turkish Online Journal of Educational Technology*, 3(2):71–77.

Goto, K. 2010. Academic researchers' role in participatory action research, theory development and the improvement of community-based health projects. *Global Journal of Psychology Practice*, 1(2):1-12.

Govind, M., Relkin, E. & Bers, M.U. 2020. Engaging children and parents to code together using the ScratchJr App. *Visitor Studies*, 23(1):46–65.

Graham, C.R. 2011. Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education*, 57(3):1953–1969.

Green, W., Parker, D., Deacon, R. & Hall, G. 2011. Foundation phase teacher provision by public higher education institutions in South Africa. *South African Journal of Childhood Education,*1(1):109-122.

Groos, K. 1898. *The Play of Animals*. New York: D. Appleton & Company.

Gura, M. 2012. Lego robotics: STEM sport of the mind. *Learning and Leading with Technology*, 40(1):12–16.

Gushta, M.M. & Rupp, A.A. 2012. Reliability. In: Salkind, N.J. (ed.). *Encyclopedia of research design*. Thousand Oaks, CA: SAGE.

Guskey, T.R. 2002. Professional development and teacher change. *Teachers and Teaching*, 8(3):381–391.

Haarhoff, K. 2020. *Strengthening teacher support to learners experiencing dyscalculia in Grade 3*. Unpublished master's dissertation. Pretoria: University of Pretoria.

Haleem, A., Javaid, M., Qadri, M.A. & Suman, R. 2022. Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, 3:275-285.

Hamilton, M., Clarke-Midura, J., Shumway, J.F. & Lee, V.R. 2020. An emerging technology report on computational toys in early childhood. *Technology, Knowledge and Learning*, 25(1):213–224.

Hannaway, D.-A.M. 2016. *Teachers' and learners' experiences of technology-based teaching and learning in the foundation phase*. Unpublished doctoral thesis. Pretoria: University of Pretoria.

Hannon, P. 2000. History and Future of Literacy. In: Hannon, P. (ed.). *Reflecting on literacy in education*. London: Routledge Falmer.

Hapompwe, C.C., Karim, A.M.K. & Kambikambi, T.-T. 2020. An empirical evaluation of public secondary schools' education financing and its impact on service quality in Lusaka, Zambia. *African Journal of Education and Practice*, 6(2):13–32. [Online].

Hardell, L. 2017. Effects of mobile phones on children's and adolescents' health: A commentary. *Child Development*, 89(1):137–140.

Harding, J. 2013. *Qualitative data analysis from start to finish*. 2nd ed. London: SAGE.

Harris, B. & Petersen, D. 2017. *Developing math skills in early childhood*. [Online]. Available from: https://files.eric.ed.gov/ [Accessed: 2020-07-15].

Hart, S. & Laher, S. 2015. Perceived usefulness and culture as predictors of teachers' attitudes towards educational technology in South Africa. *South African Journal of Education*, 34(4):1–13.

Harvey, T., Drolet, B.M. & DeVore, D.P. 2014. *Leading for excellence: A twelve step program to student achievement*. Lanham, MA: Rowman & Littlefield.

Hays, D.G. & Singh, A.A. 2012. *Qualitative inquiry in clinical and educational settings*. New York, NY: Guilford Press.

Henning, E. 2004. *Finding your way in qualitative research*. Pretoria: Van Schaik Publishers.

Henricks, T.S. 2015. Overview: Play as self-realization – Toward a general theory of play. In: Johnson, J.E., Eberle, S.G., Henricks, T.S. & Kuschner, D. (eds.). *The handbook of the study of play*. London: Rowman & Littlefield.

Highfield, K. 2010. Robotic toys as a catalyst for mathematical problem solving. *Australian Primary Mathematics Classroom*, 15(2):22–27.

Highfield, K., Mulligan, J. & Hedberg, J. 2008. *Early mathematics learning through exploration with programmable toys*. Paper presented at the Joint Meeting of PME 32 and PME-NA XXX, Morelia, Mexico, July 17-21, pp.169–176. [Online]. Available from: https://researchers.mq.edu.au/en/publications/early-mathematics-learning-through-exploration-with-programmable- [Accessed: 2021-11-20].

Hill, H.C., Ball, D.L. & Schilling, S.G. 2008. Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for Research in Mathematics Education*, 39(4):372–400.

Ho, L., & Dimmock, C. 2023. Changing teachers' beliefs and practices towards learner-centred education: experiences and lessons from Vietnam's education system reforms. *PRACTICE: Contemporary Issues in Practitioner Education*. [Online]. Available from: https://www.tandfonline.com/doi/full/10.1080/25783858.2023.2177191. [Accessed: 2021-11-20].

Holmes, K., Hickmott, D., Prieto-Rodrigues, E. & Berger, N. 2018. *Using coding to teach mathematics: Results of a pilot project*. Paper presented at the 5th International STEM in Education Conference: Integrated Education for Real

World, Queensland University of Technology, Australia:152-158. [Online]. Available from: https://researchdirect.westernsydney.edu.au/islandora/object/uws:49792 [Accessed: 2023-01-10].

Horn, M.S., Crouser, R.J. & Bers, M.U. 2012. Tangible interaction and learning: The case for a hybrid approach. *Personal and Ubiquitous Computing*, 16(4):379–389. [Online]. Available from: 10.1007/s00779-011-0404-2 [Accessed: 2023-01-10].

Howell. 2012. *Teaching with ICT: Digital pedagogies for collaboration and creativity.* Victoria, Australia: Oxford University Press.

Hoyles, C. & Noss, R. 2003. What can digital technologies take from and bring to research in mathematics education? In: Bishop, A., Clements, M., Keital, C., Kilpatrick, C. & Leung, F. (eds.). *Second international handbook of research in mathematics education*. Dordrecht: Kluwer Academic Publishers.

Hsu, T.C., Chang, S.C. & Hung, Y.T. 2018. How to learn and how to teach computational thinking: Suggestions based on a review of the literature. *Computers and Education*, 126(June):296–310. [Online]. Available from: https://doi.org/10.1016/j.compedu.2018.07.004 [Accessed: 2023-05-26].

Hubert, C. 2021. *Interdisciplinary Learning and the Effects on Students*. Unpublished literature review. Orange City, IA: Northwestern College.

Hughes, J. & Robertson, L. 2013. The power of digital literacy to transform and shape teacher identities. In: Yang, H.H. & Wang, S. (eds.). *Cases on online learning communities and beyond*. Hershey, PA: Information Science Reference.

Hunsaker, E. 2018. Computational thinking. In: Ottenbreit-Leftwich, A. & Kimmons, R. (eds.). *The K-12 educational technology handbook*. [Online]. Available from: https://edtechbooks.org/k12handbook/computational_thinking [Accessed: 2023-02-11].

Ingram, N., Holmes, M., Linsell, C., Livy, S., McCormick, M. & Sullivan, P. 2020. Exploring an innovative approach to teaching mathematics through the use of challenging tasks: A New Zealand perspective. *Mathematics Education Research Journal*, 32(4):497-522.

International Society for Technology in Education and the Computer Science Teachers Association. 2011. *Operational definition of computational thinking for K-12 education*. Available from: https://cdn.iste.org/ [Accessed: 2023-05-26].

Irvin, M. 2017. *The importance of play in early childhood education*. [Online]. Available from: https://nwcommons.nwciowa.edu/cgi/viewcontent.cgi?article=1067&context=education_masters [Accessed 2022-03-09].

Isaacs, B. 2018. *Understanding the Montessori Approach: Early Years Education in Practice*. 2nd ed. New York, NY: Routledge.

Jackl, A., Baenen, N. & Regan, R. 2017. *Effective Teaching Framework (ETF): Final Report 2015-16*. [Online]. Available from: https://files.eric.ed.gov/fulltext/ED606976.pdf [Accessed: 2023-01-10].

Jacobs, H.H. & Alcock, M. 2017. Transitioning from 'old school' to a contemporary learning environment. In: Harvey, J., Fisher, D. & Frey, N. (eds.). *Bold moves for schools: How we create remarkable learning environments*. Alexandria, VA: ASCD.

Jaiswal, A., Arun, C.J. & Varma, A. 2022. Rebooting employees: Upskilling for artificial intelligence in multinational corporations. *The International Journal of Human Resource Management*, 33(6):1179–1208.

Jalongo, M.R. & Isenberg, J.P. 2012. *Exploring your role in early childhood education*. 4th ed. Upper Saddle River, NJ: Pearson Education.

Janka, P. 2008. *Using a programmable toy at preschool age: Why and how?* Paper presented at SIMPAR 2008: Conference on simulation, modeling and programming for autonomous robots, Venice, Italy: 112-121. [Online]. Available from: https://www.terecop.eu/downloads/simbar2008/pekarova.pdf [Accessed: 2022-01-06].

Janse van Rensburg, O. 2015. The school readiness performance of a group of Grade R learners in primary schools in the Gauteng province of South Africa. *South African Journal of Childhood Education*, 5(1):106–124. [Online].

Jansen van Vuuren, E., Herzog, M. & Fritz, A. 2018. Meerkat Maths – A comprehensive maths learning programme for Grade-R. *South African Journal of Childhood Education*, 8(2):a565. [Online]. Available from: https://journals-co-za.uplib.idm.oclc.org/doi/10.4102/sajce.v8i2.565 [Accessed: 2023-04-02].

Jensen, H., Pyle, A., Zosh, J.M., Ebrahim, H.B., Zaragoza Scherman, A., Reunamo, J. & Hamre, B.K. 2019. *Play facilitation: the science behind the art of engaging young childre*n. [Online]. Available from: https://cms.learningthroughplay.com/ [Accessed: 2022-03-25].

Jimoyiannis, A. 2012. Developing a pedagogical framework for the design and the implementation of e-portfolios in educational practice. *Themes in Science & Technology Education*, 5(1/2):107–132.

Johansen, M.V., Aagaard-Hansen, J. & Riis, P. 2008. Benefit – A neglected aspect of health research ethics. *Danish medical bulletin*, 55(4):216–218.

Johnson, G.M. 2008. Functional internet literacy: Required cognitive skills with implications for instruction. In: C. Lankshear and M. Knobel, (eds.). *Digital literacies: Concepts, policies and practices*. New York, NY: Peter Lang.

Johnson, R. 2013. Foreword by Richard Johnson. In: Duncan, J. & Conner, L. (eds.). *Research Partnerships in Early Childhood Education.* New York, NY: Palgrave Macmillan.

Johnson, J.E. 2015. Introduction. In: Johnson, J.E., Eberle, S.G., Henricks, T.S. & Kuschner, D. (eds.). *The handbook of the study of play*. London: Rowman & Littlefield.

Jones, S.J. 2017. Technology in the Montessori classroom: Teachers' beliefs and technology use. *Journal of Montessori Research*, 3(1):16–29.

Jones, M. & Dexter, S. 2018. Teacher perspectives on technology integration professional development: Formal, informal, and independent learning activities. *Journal of Educational Multimedia and Hypermedia*, 27(1):83–102.

Jordaan, M. & Pieterse, V. 2020. Photovoice as a critical reflection methodology for a service learning module. *South African Journal of Higher Education*, 34(3):128-145.

Jordan, B. 2009. Scaffolding learning and co-construction of understanding. In: A. Anning, J. Cullen and M. Fleer, (eds.). *Early childhood education society and culture*. 2nd ed. London: SAGE publications.

Joubert, I. 2015. *Literacy in the foundation phase*. Pretoria: Van Schaik Publishers.

Jung, H.-W. 2020. A study on the current state of artificial intelligence based coding technologies and the direction of future coding education. *International Journal of Advanced Culture Technology*, 8(3):186-191.

Kanadlı, S. 2019. A meta-summary of qualitative findings about STEM education. *International Journal of Instruction*, 12(1):959-976.

Kanemune, S., Shirai, S. & Tani, S. 2017. Informatics and programming education at primary and secondary schools in Japan. *Olympiads in Informatics*, 11:143–150.

Katovich, B. 2019. *Awesome robotics projects for kids*. Emeryville, CA: Rockridge Press.

Kay, J. S. & Moss, J. G. 2012. *Using robots to teach programming to K-12 teachers*. Paper presented at Frontiers in Education Conference, Seattle, USA: 1-6. [Online]. Available from: https://doi.org/10.1109/FIE.2012.6462375 [Accessed: 2023-01-10].

Kazakoff, E.R. & Bers, M.U. 2012. Programming in a robotics context in the kindergarten classroom: The impact on sequencing skills. *Journal of Educational Multimedia and Hypermedia*, 21(4):371–391.

Kazakoff, E.R., Sullivan, A. & Bers, M.U. 2013. The effect of a classroom-based intensive robotics and programming workshop on sequencing ability in early childhood. *Early Childhood Education Journal*, 41:245–255.

Keating, A., Gardiner, C. & Rudd, P. 2009. *E-Access, e-Maturity, e-Safety: A Learner Survey*. [Online] Available from: https://www.researchgate.net/publication/242570324_E-access_E-maturity_E-safetyA_Learner_Survey [Accessed: 2022-08-08].

Khanlari, A. 2014. *Teachers' perceptions of using robotics in primary/elementary schools in Newfoundland and Labrador*. Unpublished master's dissertation. Newfoundland: Memorial University of Newfoundland.

Kilag, O.K.T., Ignacio, R., Lumando, E.B., Alvez, G.U., Abendan, C.F.K., Quiñanola, N.M.P. & Sasan, J.M. 2022. ICT integration in primary school classrooms in the time of pandemic in the light of Jean Piaget's Cognitive Development Theory. *International Journal of Emerging Issues in Early Childhood Education*, 4(2):42–54.

Kilbane, C.R. & Milman, N.B. 2014. *Teaching models: Designing instruction for 21st century learners*. Hoboken, NJ: Pearson.

Kingsley-Hughes, A. & Kingsley-Hughes, K. 2005. *Beginning programming*. New York, NY: Wiley Publishing.

Kirschner, P.A. & Lai, K.W. 2007. Online communities of practice in education. *Technology, Pedagogy and Education*, 16(2):127–131.

Kirova, A. & Jamison, N.M. 2018. Peer scaffolding techniques and approaches in preschool children's multiliteracy practices with iPads. *Journal of Early Childhood Research*, 16(3): 245-257.

Kivunja, C. & Kuyini, A.B. 2017. Understanding and applying research paradigms in educational contexts. *International Journal of Higher Education*, 6(5):26-45.

Koehler, M.J. & Mishra, P. 2005. What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research*, 32(2):131–152.

Koehler, M.J. & Mishra, P. 2009. What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education*, 9(1):60–70.

Korstjens, I. & Moser, A. 2018. Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing. *European Journal of General Practice*, 24(1):120–124.

Krasnor, L.R. & Pepler, D.J. 1980. The study of children's play: Some suggested future directions. In: Rubin, K.H. (ed.). *New directions for child development: Children's play*. San Francisco, CA: Jossey-Bass.

Lawrence, T.B. & Dover, G. 2015. Place and institutional work creating housing for the hard-to-house. *Administrative Science Quarterly*, 60(3):371-410.

Lawson, H.A. 2015. Introducing participatory action research. In: Lawson, H.A., Caringi, J., Pyles, L., Jurkowski, J. & Bozlak, C. (eds.). *Participatory action research*. New York, NY: Oxford University Press.

Lee, J. & Junho, J. 2019. Implementing unplugged coding activities in early childhood classrooms. *Early Childhood Education Journal*, 47(1):709–716.

Lee, K.T.H., Sullivan, A. & Bers, M.U. 2013. Collaboration by design: Using robotics to foster social interaction in kindergarten. *Computers in the Schools*, 30(3):271–281.

Leedy, P. & Omrod, J. 2014. *Practical research: planning and design*. 10th ed. Harlow, Essex: Pearson Education.

Le Cordeur, M. 2016. Aksienavorsing. In: Joubert, I., Hartell, C. & Lombaard, K. (eds.). *Navorsing: 'n gids vir die beginnernavorser*. Pretoria: Van Schaik Publishers.

LEGO Foundation. 2018. *Learning through play: Strengthening learning through play in early childhood education programmes*. Billund: LEGO Fonden. [Online]. Available from: https://cms.learningthroughplay.com/ [Accessed 2022-05-05].

Leoste, J., Pastor, L., López, J.S.M., Garre, C., Seitlinger, P., Martino, P. & Peribáñez, E. 2021. Using robots for digital storytelling. A game design framework for teaching human rights to primary school students. In: Lepuschitz, W., Merdan, M., Koppensteiner, G., Balogh, R. & Obdržálek, D. (eds.). *Robotics in Education*. Dordrecht: Springer

Li, Y., Schoenfeld, A.H., Disessa, A.A., Graesser, A. Benson, L., English, L. & Duschl, R. 2020. On Computational Thinking and STEM Education. *Journal for STEM Education Research*. 3:147-166.

Liamputtong, L. 2010. Cross-cultural research and qualitative inquiry. *Turkish Online Journal of Qualitative Inquiry*, 1(1):16-29.

Lodico, M., Spaulding, D. & Voegtle, K. 2010. *Methods in educational research: From theory to practice*. 2nd ed. San Francisco, CA: John Wiley & Sons.

Lopez-Caudana, E., Ramirez-Montoya, M.S., Martínez-Pérez, S. & Rodríguez-Abitia, G. 2020. Using robotics to enhance active learning in mathematics: A multi-scenario study. *Mathematics*, 8(2163):1–21.

Lydon, A. 2007. *Let's Go with Bee-Bot*. [Online]. Available from: https://blocs.xtec.cat/impulsrobotica/files/2018/10/Lets-Go-with-Bee-Bot-ilovepdf-compressed.pdf [Accessed: 2021-07-05].

Mabena, N., Mokgosi, P.N. & Ramapela, S.S. 2021. Factors contributing to poor learner performance in mathematics: A case of selected schools in Mpumalanga province, South Africa. *Problems of Education in the 21st Century*, 79(3):451–66.

Macdonald, C.D. 2012. Understanding participatory action research: A qualitative research methodology. *Canadian Journal of Action Research*, 13(2):34-50.

MacDonald, A., Huser, C., Sikder, S. & Danaia, L. 2020. Effective early childhood STEM education: Findings from the Little Scientists Evaluation. *Early Childhood Education Journal*, 48(3):353–363.

Madill, H., Campbell, R.G., Cullen, D.M., Armour, M.A., Einsiedel, A.A., Ciccocioppo, A.L. and Coffin, W.L. 2007. Developing career commitment in STEM-related fields: Myth versus reality. In: Burke, R.J., Mattis, M.C. & Elgar, E. (eds.). *Women and minorities in science, technology, engineering and mathematics: Upping the numbers*. Northampton, MA: Edward Elgar Publishing

Madjitey, P. 2014. *The socio-educational development of children of street vendors in Ghana*. Unpublished master's dissertation. Pretoria: University of Pretoria.

Makgato, M. 2014. Challenges contributing to poor integration of educational technology at some schools in South Africa. *Mediterranean Journal of Social Sciences*, 5(2):1285–1292.

Malaguzzi, L. 1998. History, ideas, and basic philosophy: An interview with Lella Gandini. In: Edwards, C., Gandini, L. & Forman, G. (eds.). *The hundred languages of children: The Reggio Emilia approach – advanced reflections*. 2nd ed. Westport, CT: Ablex Publishing Corporation.

Mancl, D.B., Miller, S.P. & Kennedy, M. 2012. Using the Concrete-Representational-Abstract Sequence with integrated strategy instruction to teach subtraction with regrouping to students with learning disabilities. *Learning Disabilities Research & Practice*, 27(4):152–166.

Mapaire, L. 2016. Learners' performance in mathematics: A case study of public high schools, South Africa. *European Journal of STEM Education,* 1(3):1–10.

Mapungubwe Institute for Strategic Reflection (MISTRA). 2015. *Nation formation and social cohesion: An enquiry into the hopes and aspirations of South Africa*. In: J. Netshitenzhe, Y.A. Omar, L. Dikeni and R. Browne, (eds). Mapungubwe Institute for Strategic Reflection.

Marais, P. 2016, '"We can't believe what we see": Overcrowded classrooms through the eyes of student teachers', *South African Journal of Education*, 36(2), 1–10.

Marcelino, M.J., Pessoa, T., Vieira, C., Salvador, T. & Mendes, A.J. 2018. Learning computational thinking and Scratch at distance. *Computers in Human Behavior*, 80:470–477.

Mardell, B., Wilson, D., Ryan, J., Ertel, K., Krechevsky, M. & Baker, M. 2016. *Towards a pedagogy of play: A project zero working paper*. [Online]. Available from: http://www.pz.harvard.edu/ [Accessed: 2022-01-26].

Maree, K. 2016. Planning a research proposal. In: Maree, K. (ed.). *First steps in research*. Pretoria: Van Schaik Publishers.

Maree, K. & Pietersen, J. 2016. Sampling. In: Maree, K. (ed.). *First steps to research.* Pretoria: Van Schaik Publishers.

Marienko, M., Nosenko, Y., Sukhikh, A., Tataurov, V. & Shyshkina, M. 2021. Personalization of learning through adaptive technologies in the context of sustainable development of teachers education. *International Journal of Emerging Technologies in Learning*, 16(18):240-255.

Marsh, J. 2020. Researching the digital literacy and multimodal practices of young children: A European agenda for change. In: Erstad, O., Flewitt, R., Kümmerling-Meibauer, B. & Pereira, I.S.P. (eds.). *The Routledge handbook of digital literacies in early childhood*. New York, NY: Routledge.

Matos, J.F.L., Pedro, A. & Piedade, J. 2019. Integrating digital technology in the school curriculum. *International Journal of Emerging Technologies in Learning*, 14(21):4-15.

May, D.C. & Kundert, D.K. 1997. School readiness practices and children at-risk: examining the issues. *Psychology in the Schools*, 34(2):73–84.

Mayes, R. & Myers, J. 2014. *Quantitative reasoning in the context of energy and environment: modeling problems in the real world*. Rotterdam: SensePublishers.

McClure, E.R., Guernsey, L., Clements, D.H., Bales, S.N., Nichols, J., Kendall-Taylor, N. & Levine, M.H. 2017. *STEM starts early: Grounding science, technology, engineering, and math.* New York, NY: Joan Ganz Cooney Center at Sesame Workshop.

McDougall, A. & Jones, A. 2006. Theory and history, questions and methodology: current and future issues in research into ICT in education. *Technology, Pedagogy and Education*, 15(3):353–360.

McGrath, C. 2010. General principles for teaching mathematics to young children. In: C. McGrath, (ed.). *Supporting Early Mathematical Development Practical approaches to play-based learning*. New York, NY: Routledge.

McLennan, D.P. 2017. Creating coding stories and games. *Teaching Young Children*, 10(3):1–7.

McMillan, J. & Schumacher, S. 2014. *Research in education: Evidence-based inquiry*. 7th ed. London: Pearson.

McNally, S.A. & Slutsky, R. 2017. Key elements of the Reggio Emilia approach and how they are interconnected to create the highly regarded system of early childhood education. *Early Child Development and Care*, 187(12):1925–1937.

McPake, J., Plowman, L. & Stephen, C. 2013. Pre-school children creating and communicating with digital technologies in the home. *British Journal of Educational Technology*, 44(3):421–431.

McTaggart, R. 1997. *Participatory Action Research: International Contexts and Consequences*. New York, NY: State University of New York Press.

Merino-Armero, J.M., González-Calero, J.A. & Cózar-Gutiérrez, R. 2022. Computational thinking in K-12 education. An insight through meta-analysis. *Journal of Research on Technology in Education*, 54(3):410–437. [Online]. Available from: https://doi.org/10.1080/15391523.2020.1870250 [Accessed: 2023-05-26].

Metz, S.S. 2007. Attracting the engineering of 2020 today. In: Burke, R. & Mattis, M. (eds.). *Women and minorities in science, technology, engineering and mathematics: Upping the numbers*. Northampton, MA: Edward Elgar Publishing.

Miller, E. & Almon, J. 2009. *Crisis in kindergarten: why children need to play in school*. [Online]. Available from: https://files.eric.ed.gov/fulltext/ED504839.pdf [Accessed: 2022-01-26].

Milner, H.V. 2006. The digital divide: The role of political institutions in technology diffusion. *Comparative Political Studies*, 39(2):176–199.

Ministry of Education. 2012. *Nurturing early learners: A curriculum framework for kindergartens in Singapore*. Republic of Singapore: Ministry of Education.

Ministry of Education. 2017a. *Te Whāriki: He whāriki mātauranga mō ngā mokopuna o Aotearoa: Early childhood curriculum*. [Online]. Available from: https://education.govt.nz/assets/Documents/Early-Childhood/ELS-Te-Whariki-Early-Childhood-Curriculum-ENG-Web.pdf [Accessed: 2021-01-12].

Ministry of Education. 2017b. *Teaching and learning guidelines on the use of information and communication technology in pre-school centres*. [Online]. Available from: https://www.nel.moe.edu.sg/qql/slot/u143/Resources/Downloadable/pdf/(MOE)ICT%20Guidelines_Final.pdf [Accessed: 2021-01-15].

Ministry of Education. 2018. *Technology in the New Zealand curriculum*. Auckland: New Zealand Government.

Miracle, V.A. 2016. The Belmont Report: The triple crown of research ethics. *Dimensions of Critical Care Nursing*, 35(4):223–228.

Mishra, P. & Koehler, M.J. 2006. Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6):1017–1054.

Mishra, P., Koehler, M.J. & Henriksen, D. 2011. The 7 trans-disciplinary habits of mind: Extending the TPACK framework towards 21st century learning. *Educational Technology*, 11(2):22–28.

Mntunjani, L. 2015. *The use of mathematical resources to teach number concepts in the foundation phase*. Unpublished master's dissertation. Cape Town: Cape Peninsula University of Technology.

Montessori, M. 2012. *The absorbent mind*. Hoboken, NJ: Start Publishing LLC.

Mooney, C.G. 2013. *Theories of Childhood: An Introduction to Dewey, Montessori, Erikson, Piaget, and Vygotsky*. 2nd ed. St Paul, MN: Redleaf Press.

Morgan, D.L. & Ravitch, S.M. 2018. Trustworthiness. In: Frey, B.B. (ed.). The *SAGE enclyclopedia of educational research, measurement, and evaluation*. Thousand Oaks, CA: SAGE.

Mori, M., Nezu, A., Samizo, C., Naito, T. & Ishizuka, M. 2009. The meaning of play and learning for 0-3-year-old children in Japan. In. Pramling-Samuelsson, I. & Fleer, M. (eds.). *Play and learning in early childhood settings: International perspectives.* Dordrecht: Springer.

Morrison, G.S. 2010. *Principles of the Montessori method*. [Online]. Available from: http://www.broughtonpreschool.co.uk/ [Accessed: 2022-04-08].

Morse, J.M. 1999. Qualitative methods: the state of the art. *Qualitative Health Research*, 9(3):393-406.

Moyles, J.R. 2012. *A-Z of Play in Early Childhood*. New York, NY: McGraw Hill Open University Press.

Mubuuke, A.G. & Leibowitz, B. 2013. Participatory action research: The key to successful implementation of innovations in health professions education. *African Journal of Health Professions Education*, 5(1):30-33.

Mukherji, P. & Albon, D. 2010. *Research methods in early childhood: An introductory guide*. Thousand Oaks, CA: SAGE.

Mullis, I.V.S., Martin, M.O., Foy, P., Kelly, D.L. & Fishbein, B. 2020. *TIMSS 2019: International results in mathematics, Boston: Boston College.* [Online] Available from: https://www.iea.nl/. [Accessed: 2022-04-07].

Murris, K., Reynolds, R.-A. & Peers, J. 2018. Reggio Emilia inspired philosophical teacher education in the Anthropocene: Posthuman child and the family (tree). *Journal of Childhood Studies*, 43(1):15–29.

Mury, S.R., Negrini, L., Dorit, A. & Skweres, M. 2022. How to support teachers to carry out educational robotics activities in school? The case of Roteco, the Swiss robotic teacher community. *Frontiers in Education*, 7:1-12.

Muzari, T., Shava, G.N. & Shonhiwa, S. 2022. Qualitative research paradigm, a key research design for educational researchers, processes and procedures: A theoretical overview. *Indiana Journal of Humanities and Social Sciences*, 3(1):14-20.

National Association for the Education of Young Children [NAEYC]. 2019. *NAEYC early learning program accreditation standards and assessment items.* [Online]. Available from: https://www.naeyc.org/ [Accessed: 2023-02-26].

National Association for the Education of Young Children (NAEYC) and Fred Rogers Center for Early Learning and Children's Media. 2012. *Technology and interactive media as tools in early childhood programs serving children from birth through age 8*. [Online]. Available from: www.naeyc.org/files/naeyc/file/positions/PS_technology_WEB2.pdf [Accessed: 2022-01-04].

National Research Council. 2010. *Report of a workshop on the scope and nature of computational thinking*. National Academies Press. [Online]. Available from: https://nap.nationalacademies.org/read/12840/chapter/1 [Accessed: 2023-05-26].

Naudé, M. 2014. How foundation phase learners learn mathematics. In: Naudé, M. & Meier, C. (eds.). *Teaching foundation phase mathematics: A guide for South African students and teachers*. Pretoria: Van Schaik Publishers.

Naudé, M. 2021. Learning mathematics through play. In: Van Heerden, J.C. & Veldsman, A. (eds.). *Rethinking learning through play*. Pretoria: Van Schaik Publishers.

Naudé, M. & Meier, C. 2019. Elements of the physical learning environment that impact on the teaching and learning in South African Grade 1 classrooms. *South African Journal of Education*, 39(1):1-11.

Neeley, T.B. & Dumas, T.L. 2016. Unearned status gain: evidence from a global language mandate. *Academy of Management Journal*, 59(1):14-43.

Negrini, L. 2020. Teachers' attitudes towards educational robotics in compulsory school. *Italian Journal of Educational Technology*, 28(1):77–90.

Nel, C., Marais, E. & Bird, J. 2021. Learning about technology through play. In: Van Heerden, J.C. & Veldsman, A. (eds.). *Rethinking learning through play*. Pretoria: Van Schaik Publishers.

Ng, D.T.K., Leung, J.K.L., Su, J., Ng, R.C.W. & Chu, S.K.W. 2023. Teachers' AI digital competencies and twenty-first century skills in the post-pandemic world. *Educational Technology Research and Development*, 71. [Online]. Available from: https://doi.org/10.1007/s11423-023-09933-4. [Accessed: 2021-07-09].

Nguyen, C.D. 2021. The construction of age-appropriate pedagogies for young learners of English in primary schools. *The Language Learning Journal*, 49 (1):13–26.

Niemelä, M.A. & Tirri, K. 2018. Teachers' knowledge of curriculum integration: A current challenge for Finnish subject teachers. In: Weinberger, Y. & Libman, Z. (eds.). *Contemporary pedagogies in teacher education and development.* London: IntechOpen.

Nieuwenhuis, J. 2016a. Analysing qualitative data. In: Maree, K. (ed.). *First steps to research*. Pretoria: Van Schaik Publishers.

Nieuwenhuis, J. 2016b. Introducing Qualitative Research. In: Maree, K. (ed.). *First steps to research*. Pretoria: Van Schaik Publishers.

Nieuwenhuis, J. 2016c. Qualitative research designs and data-gathering techniques. In: Maree, K. (ed.). *First steps to research*. Pretoria: Van Schaik Publishers.

Nokwali, M., Mammen, K. & Maphosa, C. 2017. How is technology education implemented in South African schools? View from technology education learners. *International Journal of Educational Sciences*, 8(3):563–571.

Nørgård, R. T. & Paaskesen, R. B. 2016. Open-ended education: How openendedness might foster and promote technological imagination, enterprising and participation in education. *Conjunctions Transdisciplinary Journal of Cultural Participation*, 3(1):1-25.

Nugent, G., Barker, B.S., Grandgenett, N. & Welch, G. 2016. Robotics camps, clubs, and competitions: Results from a US robotics project. *Robotics and Autonomous Systems*, 75(1):686–691.

Nunes, T., Bryant, P., Barros, R. & Sylva, K. 2012. The Relative Importance of Two Different Mathematical Abilities to Mathematical Achievement. *The British Journal of Educational Psychology*, 82(1):136–56. [Online]. Available from: https://bpspsychub.onlinelibrary.wiley.com/ [Accessed: 2023-05-26].

Nyumba, T.O., Wilson, K., Derrick, C.J. & Mukherjee, N. 2017. The use of focus group discussion methodology: Insights from two decades of application in conservation. *Methods in Ecology and Evolution*, 9:20–32.

Ohnishi, Y., Honda, K., Nishioka, R., Mori, S. & Kawada, K. 2017. Robotics programming learning for elementary and junior high school students. *Journal of Robotics and Mechatronics*, 29(6):992–998.

Oldridge, M. 2019. *The playful approach to math: Math doesn't have to be serious. One teacher believes play is the key to math comprehension for all ages.* [Online]. Available from: https://www.edutopia.org/article/playful-approach-math [Accessed: 2021-09-09].

Olovsson, T.G. 2021. Teaching and learning in integrated social studies: What knowledge is most important for students to acquire? *Journal of Social Science Education*, 20(4):121-146.

Organization for Economic Co-operation and Development (OECD). 2009. *Creating effective teaching and learning environments: First results from TALIS*. [Online]. Available from: https://www.oecd.org/newsroom/43125523.pdf/ [Accessed: 2021-07-07].

Organization for Economic Co-operation and Development. 2012. *Starting strong III: A quality toolbox for early childhood education and care*. OECD.

Owens, R.L. 2010. Informed consent. In: Salkind, N.J. (ed.). *Encyclopedia of research design*. Thousand Oaks, CA: SAGE.

Özdoğan, E. 2011. Play, mathematic and mathematical play in early childhood education. *Procedia Social and Behavioral Sciences*, 15:3118–3120.

Padayachee, K., Gouws, P. M. & Lemmer, M. 2015. *Evaluating the effectiveness of LEGO robots in engaged scholarship*. Paper presented at Annual Global Online Conference on Information and Computer Technology (GOCICT), Online: 16-20. [Online]. Available from: http://dx.doi.org/10.1109/GOCICT.2015.12 [Accessed: 2023-01-10].

Papadakis, S. 2020. Robots and robotics kits for early childhood and first school age. *International Journal of Interactive Mobile Technologies*, 14(18): 34–56.

Papadakis, S., Vaiopoulou, J., Sifaki, E., Stamovlasis, D. & Kalogiannakis, M. 2021. Attitudes towards the use of educational robotics: Exploring pre-service and in-service early childhood teacher profiles. *Education Sciences*, 11(204):1–14.

Papert, S. 1980. *Mindstorms: Children, computers and powerful ideas*. New York, NY: Basic Books, Inc.

Paulus, M. T., Villegas, S. G. & Howze-Owens, J. 2020. Professional learning communities: Bridging the technology integration gap through effective professional development. *Peabody Journal of Education*, 95(2):193–202.

Parette, H.P., Hourcade, J.J., Blum, C., Watts, E.H., Stoner, J.B., Wojcik, B.W. & Chrismore, S.B. 2013. Technology user groups and early childhood education: A preliminary study. *Early Childhood Education Journal*, 41:171–179.

Parette, H.P., Quesenberry, A.C. & Blum, C. 2010. Missing the boat with technology usage in early childhood settings: A 21st century view of developmentally appropriate practice. *Early Childhood Education Journal*, 37(5):335–343.

Parker, D.C. & Conversano, P. 2021. Narratives of systemic barriers and accessibility: Poverty, equity, diversity, inclusion, and the call for a post-pandemic new normal. *Frontiers in Education*, 6:1-19.

Patton, M.Q. 2014. *Qualitative research & evaluation methods: Integrating theory and practice*. Thousand Oaks, CA: SAGE.

Pearse, N. 2019. An illustration of a deductive pattern matching procedure in qualitative leadership research. *Electronic Journal of Business Research Methods*, 17(3). [Online]. Available from: https://doi.org/10.34190/JBRM.17.3.004 [Accessed: 2022-02-03].

Persuad, N. 2010. *Participants*. In: Salkind, N.J. (ed.). *Encyclopedia of research design*. Thousand Oaks, CA: SAGE.

Petriglieri, J.L. 2015. Co-creating relationship repair pathways to reconstructing destabilized organizational identification. *Administrative Science Quarterly*, 60(3):518-557.

Piaget, J. .1951. *Play, Dreams and Imitation in Childhood*. London: Routledge & Kegan Paul.

Piers, R., Williams, J.M. & Sharpe, H. 2023. Review: Can digital mental health interventions bridge the 'digital divide' for socioeconomically and digitally marginalised youth? A systematic review. *Child and Adolescent Mental Health*, 28(1):90-104.

Pila, S., Blackwell, C.K., Lauricella, A.R. & Wartella, E.A. 2019. *Technology in the lives of educators and early childhood programs: 2018 Survey*. Evanston, IL: Center on Media and Human Development, Northwestern University.

Plowman, L. & Stephen, C. 2014. Digital play. In: Brooker, L., Blaise, M. & Edwards, S. (eds.). *The SAGE handbook of play and learning in early childhood*. Thousand Oaks, CA: SAGE.

Plowman, L., Stevenson, O., McPake, J., Stephen, C. & Adey, C. 2011. Parents, pre-schoolers and learning with technology at home: some implications for policy. *Journal of Computer Assisted Learning*, 27(4):361–371.

Plowman, L., Stevenson, O., Stephen, C. & McPake, J. 2012. Preschool children's learning with technology at home. *Computers & Education*, 59(1):30–37.

Powell. 2016. Montessori practices: Options for a digital age. *North American Montessori Teachers' Association Journal*, 41(2):153–181.

Prinsloo, M. & Sasman, F. 2015. Literacy and language teaching and learning with interactive whiteboards in early schooling. *TESOL Quarterly,* 49(3):533–554.

Pritchard, A. 2009. *Ways of learning: Learning theories and learning styles in the classroom*. 2nd ed. New York, NY: Routledge.

Punch, K.F. 2013. *Introduction to social research: Quantitative and qualitative approaches*. Thousand Oaks, CA: SAGE.

Queirós, A., Faria, D. & Almeida, F. 2017. Strengths and Limitations of Qualitative and Quantitative Research Methods. *European Journal of Education Studies*, 3(9):369-387.

Ramorola, M. 2013. Challenge of effective technology integration into teaching and learning. *Africa Education Review*, 10(4):654–670.

Ratan, S.K., Anand, T. & Ratan, J. 2019. Formulation of research question – stepwise approach. *Journal of Indian Association of Pediatric Surgeons*, 24(1):15-20.

Ravitch, S.M. 2018. Ethical Issues in Educational Research. In: Frey, B.B. (ed.). *The SAGE Encyclopedia of Educational Research, Measurement, and Evaluation*. Thousand Oaks, CA: SAGE.

Reikerås, E. 2020. Relations between play skills and mathematical skills in toddlers. *ZDM: The International Journal on Mathematics Education*, 52(4):703–716.

Reikerås, E., Løge, I.K. & Knivsberg, A.-M. 2012. The Mathematical Competencies of Toddlers Expressed in Their Play and Daily Life Activities in Norwegian Kindergartens. *International Journal of Early Childhood*, 44(1):91–114.

Roblyer, M.D. 2005. Educational technology research that makes a difference: series introduction. *Contemporary Issues in Technology and Teacher Education*, 5(2):192–201.

Roblyer, M.D. & Knezek, G.A. 2003. New millennium research for educational technology: a call for a national research agenda. *Journal of Research on Technology in Education*, 36(1):60–71.

Rogers, C. & Portsmore, M. 2004. Bringing engineering to elementary school. *Journal of STEM Education*, 5(3/4):17–28.

Rogoff, B. 2003. *The cultural nature of human development*. New York, NY: Oxford University Press.

Rossou, E. & Rangoussi, M. 2020. On the use of robotics for the development of computational thinking in kindergarten: Educational intervention and evaluation. In: Merdan, M., Lepuschitz, W., Koppensteiner, G., Balogh, R. & Obdržálek, D. (eds.). *Robotics in Education: Current Research and Innovations*. Dordrecht: Springer.

Royal-Tangaere, A. 1997. Māori human development learning theory. In: Whaiti, P., McCarthy, M.B. & Durie, A. (eds.). *Mai I Rangiåatea: Maori wellbeing and development*. Auckland: Auckland University Press.

Rubin, K.H., Fein, G. & Vandenberg, B. 1983. Play of children. In: Mussen, P.H. (ed.). *Handbook of child psychology: Socialization, personality, and social development*. 4th ed. New York. NY: John Wiley & Sons.

Ruggiero, D. & Mong, C.J. 2015. The teacher technology integration experience: Practice and reflection in the classroom. *Journal of Information Technology Education: Research*, 14:161-178.

Ruppert, J. & Duncan, R.G. 2017. Defining and Characterizing Ecosystem Services for Education: A Delphi Study. *Journal of Research in Science Teaching*, 54(6):737–763. [Online]. Available from: https://onlinelibrary.wiley.com/doi/10.1002/tea.21384 [Accessed: 2023-05-26].

Sakakibara, T. 2014. Mathematics learning and teaching in Japanese preschool: Providing appropriate foundations for an elementary schooler's mathematics learning. *International Journal of Educational Studies in Mathematics*, 1(1):16–26.

Saldaña, J. & Omasta, M. 2018. *Qualitative research: Analyzing life*. Thousand Oaks, CA: SAGE.

Samuels, P. & Haapasalo, L. 2012. Real and virtual robotics in mathematics education at the school–university transition. *International Journal of Mathematical Education in Science and Technology*, 43(3):285–301.

Sanders, M. 2009. STEM, STEM education, STEMmania. *The Technology Teacher*, 68(4):20–26.

Santos, I.M. & Aliakbari, F. 2020. Digital technology and education. In: Tatnall, A. (ed). *Encyclopedia of Education and Information Technologies*. Dordrecht: Springer.

Santos, J.M. & Castro, R.D.R. 2021. Technological pedagogical content knowledge (TPACK) in action: Application of learning in the classroom by pre-service teachers (PST). *Social Sciences & Humanities*, 3(1):1–8.

Sapire, I. & Herholdt, R. 2023. *Examining successful numeracy programs: Evaluating learner mathematics outcomes in an RCT in South Africa*. University of the Witwatersrand: Funda Wande. [PowerPoint presentation]. [Online] Available from: https://www.jet.org.za/ [Accessed: 2023-04-02].

Sapounidis, T. & Alimisis, D. 2021. *Educational robotics curricula: Current trends and shortcomings*. Paper presented at EDUROBOTICS 2021, May 14, 2021:1-12. [Online]. Available from: https://edurobotics2020.edumotiva.eu/index.php/2021/ [Accessed: 2023-01-05].

Sarama, J. & Clements, D.H. 2016. Physical and virtual manipulatives: What is "concrete*"?. International perspectives on teaching and learning mathematics with virtual manipulatives*, 71-93. [Online]. Available from: https://www.researchgate.net/publication/304336083_Physical_and_Virtual_Manipulatives_What_Is_Concrete [Accessed: 2023-05-26].

Sarma, K. 2018. *Dash and dot: 21st century skills innovation library: Makers as innovators*. Ann Arbor, MI: Cherry Lake Publishing.

Savard, A. & Highfield, K. 2015. *Teachers' talk about robotics: Where is the mathematics*? Paper presented at the 38th Annual Conference of the Mathematics Education Research Group of Australia, Sunshine Coast, Australia: 28 June-2 July, 2015:540-546. [Online]. Available from: https://researchers.mq.edu.au/en/publications/teachers-talk-about-robotics-where-is-the-mathematics [Accessed: 2023-01-05].

Schüßler, E., Rüling, C.C. & Wittneben, B.B. 2014. On melting summits: the limitations of fieldconfiguring events as catalysts of change in transnational climate policy. *Academy of Management Journal*, 57(1):140-171.

Schwall, C. 2015. *Chapter six: The grammar of materials*. In: Gandini, L. Hill, L. Cadwell, L. & Schwall, C. (eds.). *In the spirit of the studio: Learning from the Atelier of Reggio Emilia.* 2nd ed. New York, NY: Teachers College Press.

Schina, D., Esteve-Gonzalez, V. & Usart, M. 2021. Teachers' perceptions of bee bot robotic toy and their ability to integrate it in their teaching. In: Lepuschitz, W., Merdan, M., Koppensteiner, G., Balogh, R. & Obdržálek, D. (eds.). *Robotics in Education. RiE 2020. Advances in Intelligent Systems and Computing*. Cham: Springer.

Schmidt, D.A., Baran, E., Thompson, A.D., Mishra, P., Koehler, M.J. & Shin, T.S. 2009. Technological Pedagogical Content Knowledge (TPACK): The Development and Validation of an Assessment Instrument for Preservice Teachers. *Journal of Research on Technology in Education*, 42(2):123–149.

Schneider, B. 2012. Participatory action research, mental health service user research, and the hearing (our) voices projects. *International Journal of Qualitative Methods*, 11(2):152-165.

Schunk, D.H. 2012. *Learning theories: An educational perspective*. 6th ed. Boston, MA: Pearson.

Segura Alonso, R. 2012. *The importance of teaching listening and speaking skills*. Unpublished master's dissertation. Grenada: University of Grenada.

Seldin, T. 2017. *How to raise an amazing child the Montessori way*. 2nd ed. London: Dorling Kindersley.

Shekelle, P.G., Woolf, S.H., Eccles, M. & Grimshaw, J. 1999. Developing guidelines. *Clinical guidelines*, 318(7183):593–596.

Shing, C.L., Saat, R.M. & Loke, S.H. 2015. The Knowledge of teaching – pedagogical content knowledge (PCK). *The Malaysian Online Journal of Educational Science*, 3(3):40-55.

Shulman, L.S. 1986. *Paradigms and research programs in the study of teaching: A contemporary perspective*. In: Wittrock, M.C. (ed.). *Handbook of research on teaching*. New York, NY: MacMillan.

Shumway, J.F. Welch, L.E., Kozlowski, J.S., Clarke-Midura, J. & Lee, V.R. 2021. Kindergarten Students' Mathematics Knowledge at Work: The Mathematics for Programming Robot Toys. *Mathematical Thinking and Learning*, 1–29. [Online]. Available from: https://www-tandfonline-com.uplib.idm.oclc.org/ [Accessed: 2023-05-26].

Siddiq, F., Gochyyev, P. & Wilson, M. 2017. Learning in digital networks – ICT literacy: A novel assessment of students' 21st century skills. *Computers & Education*, 109(1):11–37.

Silverman, D. 2017. *Doing qualitative research*. 4th ed. Thousand Oaks, CA: SAGE.

Sims, J.M. 2010. A brief review of the Belmont report. *Dimensions of Critical Care Nursing*, 29(4):173–174.

Sisman, B., Kucuk, S. & Yaman, Y. 2021. The effects of robotics training on children's spatial ability and attitude toward STEM. *International Journal of Social Robotics*, 13(1):379-389.

Slavin, R.E. 2006. Theories of development. *In: Educational Psychology: Theory and Practice*, 8th ed. Boston, MA: Allyn & Bacon.

Smidt, S. 2013. *Introducing Malaguzzi. A guide for practitioners and students in early year education*. New York, NY: Routledge.

Smith, B. 2018. Generalizability in qualitative research: Misunderstandings, opportunities and recommendations for the sport and exercise sciences. *Qualitative research in Sport, Exercise and Health*, 10(1):137-149.

Smith, J. & Noble, H. 2014. Bias in research. *Evidence Based Nursing*. 17(4), 100 101. [Online]. Available from: https://ebn.bmj.com/content/17/4/100 [Accessed: 2022-03-06].

Smith, P.K. & Vollstedt, R. 1985. On Defining Play: An Empirical Study of the Relationship between Play and Various Play Criteria. *Child Development*, 56(4):1042–1050.

Somerville, M.M. 2014. *Participatory Action Research: Improving Professional Practices and Local Situations.* Thousand Oaks, CA: SAGE.

South African Council for Educators. 2019. *Professional teaching standards*. [Online]. Available from: https://www.sace.org.za/assets/documents/uploads/sace_84066-2019-06-11-SACE%20Professional%20Teaching%20Standards%20Nov%202018%20X2.pdf [Accessed: 2022-03-06].

South African Government. 2015. *MEC Panyaza Lesufi: Gauteng Education budget vote 2015/16*. [Online]. Available from: https://www.gov.za/ [Accessed: 2021-06-13].

Spires, H.A., Medlock Paul, C. & Kerkhoff, S.N. 2017. Digital literacy for the 21st century. In: Khosrow-Pour, M. (ed.). *Encyclopedia of information science and technology*. 4th ed. Hershey, PA: IGI Global.

Stach, M. 2017. *The role of toy libraries in the provision of play-based learning opportunities for young children*. Unpublished doctoral thesis. Pretoria: University of Pretoria.

Stach, M. & Veldsman, A. 2021. The power of play. In: Van Heerden, J.C. & Veldsman, A. (eds.). *Rethinking learning through play*. Pretoria: Van Schaik Publishers.

Stephen, C. & Plowman, L. 2013. Digital technologies play and learning. *Early Childhood Folio*, 17(2):3–8.

Stevens. J. 2019. *Collecting Your Own Data: Improving Data Quality through Qualtrics Survey Design*. Presented at the Methodology Application Series, University of Nebraska, January 2, 2019. [Online] Available from: https://mediahub.unl.edu/media/10729 [Accessed: 2022-04-04].

Stipek, D. 2017. Playful Math Instruction in the Context of Standards and Accountability. *Young Children*, 72(3):8–12.

Stoeckelmayr, K., Tesar, M. & Hofmann, A. 2011. *Kindergarten children programming robots: A first attempt*. Paper presented at the International Conference on Robotics in Education, Vienna, Austria, 15-16 September, 2011: 185-192. [Online]. Available from: https://www.researchgate.net/publication/265092506_Kindergarten_Children_Programming_Robots_A_First_Attempt [Accessed: 2023-01-10].

Straessle, J.M.W. 2014. *Teachers' perspectives of effective lesson planning: A comparative analysis*. Unpublished doctoral thesis. Williamsburg, VA: The College of William and Mary.

Strom, A. (2021) *The negative effects of technology for students and educators*. Unpublished master's dissertation. Orange City, IA: Northwestern College. [Online]. Available from: https://nwcommons.nwciowa.edu/cgi/viewcontent.cgi?article=1322&context=education_masters [Accessed: 2023-01-06].

Sullivan, A. & Bers, M.U. 2016. Robotics in the early childhood classroom: learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade. *International Journal of Technology and Design Education*, 26(1):3–20.

Sullivan, A. & Bers, M.U. 2018. Dancing robots: Integrating art, music, and robotics in Singapore's early childhood centers. *International Journal of Technology and Design Education*, 28(2):325–346.

Sullivan, A., Kazakoff, E.R. & Bers, M.U. 2013. The wheels on the bot go round and round: Robotics curriculum in pre-kindergarten. *Journal of Information Technology Education: Innovation in Practice*, 12(1):203–219.

Sutton-Smith, B. & Kelly-Byrne, D. 1984. The idealization of play. In: Smith, P.K. (ed.). *Play in animals and humans*. Oxford: Basil Blackwell.

Tang, A.L.L., Wing Sun Tung, V. & Cheng, T. 2020. Teachers' perceptions of the potential use of educational robotics in management education. *Interactive Learning Environments,* 31(4):1-12

Tengler, K. 2021. Chapter 6: Develop storytelling activities supporting computational thinking using educational robots. In: Eteokleous, N. & Nisiforou, E. (eds.). *Designing, constructing, and programming robots for learning. Advances in educational technologies and instructional design*. Hershey, PA: IGI Global.

Tham. J. 2018. Digital technologies and the future of employment. *SSRN Electronic Journal*, 1–12. [Online] Available from: https://doi.org/10.2139/ssrn.3296213. [Accessed: 2022-08-08].

The American Association of Colleges of Teacher Education and the Partnership for 21st Century Skills. 2010. *21st century knowledge and skills in educator preparation. White paper*. [Online]. Available from: https://files.eric.ed.gov/fulltext/ED519336.pdf [Accessed: 2022-01-04].

The Ministry of Education, Culture, Sports, Science and Technology. 2018. *Basic Education in Japan: chi toku tai*. [Online]. Available from: https://www.mext.go.jp/en/policy/education/brochure/title01/detail01/__icsFiles/afieldfile/2018/10/09/1409899-01.pdf [Accessed: 2021-01-20].

The University of Cambridge. 2004. *Cambridge Learner's Dictionary*. 2nd ed. Cambridge, MA: Cambridge University Press.

Thomas, D.R. 2006. A general inductive approach for analyzing qualitative evaluation data. *American Journal of Evaluation*, 27(2):237-246.

Thompson, A.D. & Mishra, P. 2007. Breaking news: TPCK becomes TPACK! *Journal of Computing in Teacher Education*, 24(2):38–64.

Thornton, L. & Brunton, P. 2010. *Bringing the Reggio Approach to your early years practice*. Oxfordshire: Routledge.

Tongco, M.D.C. 2007. Purposive sampling as a tool for informant selection. *Ethnobotany Research and Applications*, 5:147-158.

Torres, K.M. & Giddie, L. 2020. Educator perceptions and use of technology in South African schools. *Pedagogy Journal of Education*, 95(2):117-126.

Tracy, S.J. & Hinrichs, M.M. 2017. Big tent criteria for qualitative quality. In: Matthes, J., Davis, C.S. & Potter, R.F. (eds.). *The international encyclopaedia of communication research methods*. Hoboken, NJ: John Wiley & Sons.

Tracy, S.J. 2020. *Qualitative research methods: Collecting evidence, crafting analysis, communicating impact*. 2nd ed. Hoboken, NJ: Wiley Blackwell.

Tranquillo, J. 2008. *Kinesthetic learning in the classroom. 2008 Annual Conference & Exposition*. [Online]. Available from: https://peer.asee.org/kinesthetic-learning-in-the-classroom [Accessed: 2021-09-09].

Tzur, S., Katz, A. & Davidovitch, N. 2022. The impact of social networks on student motivation and achievement. In: Zajda, J., Davidovitch, N. & Majhanovich, S. (eds.). *Discourses of globalisation, multiculturalism and cultural identity. Globalisation, comparative education and policy research*. Dordrecht: Springer.

Uğur-Erdoğmuş, F. 2021. How do elementary childhood education teachers perceive robotic education in kindergarten? A qualitative study. *Participatory Educational Research (PER)*, 8(2):421–434.

United Nations Children's Fund (UNICEF). 2018. *What we mean by: Learning through play*. New York: UNICEF. [Online]. Available from: https://www.unicef.org/ [Accessed 2023-05-24].

United Nations Educational Scientific and Cultural Organization (UNESCO). 2005. *Integrating ICTs into the Curriculum: Analytical Catalogue of Key Publications*. [Online]. Available from: https://files.eric.ed.gov/ [Accessed: 2023-01-08].

United Nations Educational Scientific and Cultural Organization (UNESCO). 2015. *Education 2030 Incheon Declaration and Framework for Action for the implementation of Sustainable Development Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*. [Online]. Available from: https://iite.unesco.org/ [Accessed: 2023-02-26].

Urlings, C.C., Coppens, K. M. & Borghans, L. 2019. Measurement of executive functioning using a playful robot in kindergarten. *Computers in the Schools*, 36(4):255–273.

US Department of Education Office of Educational Technology. 2016. *Policy brief on early learning and use of technology*. Washington, DC: US Department of Education.

Van Audenhove, L. 2007. *Expert interviews and interview techniques for policy analysis*. [Online]. Available from: https://www.academia.edu/21316654/Expert_Interviews_and_Interview_Techniques_for_Policy_Analysis [Accessed: 2021-07-07].

Van den Heuvel-Panhuizen, M. & Elia, I. 2020. Mapping Kindergartners' Quantitative Competence. *ZDM: Mathematics Education*, 52(4):805–819. [Online]. Available from: https://link.springer.com/ [Accessed: 2023-05-26].

Van der Veer, R. & Yasnitsky, A. 2016. Vyotsky the published: who wrote Vygotsky and what Vygotsky actually wrote. In: Yasnitsky, A. & Van der Veer, R. (eds.). *Revisionist Revolution in Vygotsky Studies*. New York, NY: Routledge.

Van Dijk, J.A.G.M. 2017. Digital divide: Impact of access. In: P. Rössler, (ed.). *The International Encyclopedia of Media Effects*, *Vol. 4*. Hoboken, NJ: John Wiley & Sons.

Van Heerden, J.C. 2011. *Understanding beneficiaries experiences of quality in early learning centres*. Unpublished doctoral thesis. Pretoria: University of Pretoria.

Van Heerden, J.C. & Du Preez, H. 2021. Chapter 6: Creating learning environments that promote play. In: Van Heerden, J.C. & Veldsman, A. (eds.). *Rethinking learning through play*. Pretoria: Van Schaik Publishers.

Van Laar, E., Van Deursen, A.J., Van Dijk, J.A. & De Haan, J. 2017. The relation between 21st century skills and digital skills: A systemic literature review. *Computers in Human Behaviour*, 72(1):577–588.

Van Maanen, J. 1979. The fact of fiction in organizational ethnography. *Administrative Science Quarterly*, 24(4):539-550.

Varela, C., Rebollar, C., García, O., Bravo, E. & Bilbao, J. 2019. Skills in computational thinking of engineering students of the first school year. *Heliyon*, 5(11):e02820. [Online]. Available from: 10.1016/j.heliyon.2019.e02820 [Accessed: 2023-01-27].

Vasileva, O. & Balyasnikova, N. 2019. (Re)Introducing Vygotsky’s thought: From historical overview to contemporary psychology. *Frontiers in Psychology*, 10(1515):1–15.

Vaughan, M. & Beers, C. 2017. Using an exploratory professional development initiative to introduce iPads in the early childhood education classroom. *Early Childhood Education Journal*, 45(3):321–331.

Vázquez, E.P., Lledó, G.L., Carreres, A.L., Lledó, A.L. & Cerdá, A.G. 2019. El uso del robot bee-bot como herramienta de aprendizaje de emociones en la enseñanza del alumnado con trastorno del espectro autista. *Psicología De La Educación Y Saberes Originarios*, 3(1):577–584.

Vidal-Hall, C., Flewitt, R. & Wyse, D. 2020. Early childhood practitioner beliefs about digital media: integrating technology into a child-centred classroom environment. *European Early Childhood Education Research Journal*, 28(2):167–181.

Vojislav, S., Vlajić, S., Milic, M. & Ognjanovic, M. 2011. *Guidelines for framework development process*. Paper presented at the 7th Central and Eastern European Software Engineering Conference in Russia (CEE-SECR), Moscow, Russia: 1-9. [Online]. Available from: http://dx.doi.org/10.1109/CEE-SECR.2011.6188465 [Accessed: 2022-01-27].

Voogt, J. & Roblin, N.P. 2012. A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies*, 44(3):299–321.

Vuori, T.O. & Huy, Q.N. 2016. Distributed attention and shared emotions in the innovation process: how Nokia lost the smartphone battle. *Administrative Science Quarterly*, 61(1):9-51.

Walker, K. 2011. *Play matters: Investigative learning for preschool to Grade 2.* 2nd ed. Victoria, Australia: ACER Press.

Watters, J., Comeau, S. & Restall, G. 2010. *Participatory action research: An educational tool for citizen-users of community mental health services*. Manitoba: University of Manitoba.

Webb, M. & Cox, M. 2007. A review of pedagogy related to information and communication technology. *Technology Pedagogy and Education*, 13(3): 235-286. [Online]. Available from: https://www.researchgate.net/publication/233300292_A_review_of_pedagogy_related_to_information_and_communication_technology/link/0c96052d41eae1888a000000/download [Accessed: 2023-05-26].

Weisberg, D.S. & Zosh, J.M. 2018. How guided play promotes early childhood learning. In: Tremblay, R.E. & Bovin, M. (eds.). *Encyclopedia on early childhood development*. Montreal, Quebec: Centre of Excellence for Early Childhood Development and Strategic Knowledge Cluster on Early Child Development.

West, J. & Meier, C. 2020. Overcrowded classrooms – The Achilles heel of South African education? *South African Journal of Childhood Education*, 10(1):1-10.

West Virginia Board of Education. 2020. *STEAM minded. Student and educator practices for STEAM education. Grades 6 -12*. [Online]. Available from: https://wvde.us/ [Accessed: 2022-01-07].

Whetten, D.A. 1989. What constitutes a theoretical contribution? *The Academy of Management Review*, 14(4):490–495.

White, D.W. 2014. What is STEM education and why is it important? *Florida Association of Teacher Educators Journal*, 1(14):1–9.

White, J., Ellis, F., O'Malley, A., Rockel, J., Stover, S. & Toso, M. 2009. Chapter 2: Play and Learning in Aotearoa New Zealand Early Childhood Education. In: Pramling-Samuelsson, I. & Fleer, M. (eds.). *Play and learning in early childhood settings: International perspectives*. Dordrecht: Springer.

Whitebread, D. & Basilio, M. n.d. *Play, culture and creativity*. [Online]. Available from: https://www.educ.cam.ac.uk/images/pedal/play-culture-article.pdf [Accessed 2022-04-08].

Wing, J.M. 2006. Computational thinking. *Communications of the ACM*, 49(3):33-35. [Online]. Available from: https://www.cs.cmu.edu/~15110-s13/Wing06-ct.pdf [Accessed: 2023-05-26].

Witzel, B.S. 2005. Using CRA to Teach Algebra to Students with Math Difficulties in Inclusive Settings. *Learning Disabilities: A Contemporary Journal*, 3(2):49–60.

Wolf, T. 2017. *Concrete-Representational-Abstract: Instructional sequence for mathematics*. [Online]. Available from: https://www.pattan.net/ [Accessed: 2021-07-08].

Wolz, U., Stone, M., Pearson, K., Pulimood, S. M. & Switzer, M. 2011. Computational thinking and expository writing in the middle school. *ACM Transactions on Computing Education*, 11(2):1–22.

Wood, D., Bruner, J.S. & Ross, G. 1976. The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry*, 17(2):89–100.

World Economic Forum. 2021. *Harnessing technology for the global goals: A framework for government action*. World Economic Forum. MS check

Wright, R.J. 2013. Assessing early numeracy: Significance, trends, nomenclature, context, key topics, learning framework and assessment tasks. *South African Journal of Childhood Education*, 3(2):21–40.

Wriston, J.M. 2015. *The importance of a strong mathematical foundation. Honors Research Projects*, 177:2–37. [Online]. Available from: https://ideaexchange.uakron.edu/ [Accessed: 2020-07-15].

Yıldırım, B. 2021. Preschool STEM activities: Preschool teachers' preparation and views. *Early Childhood Education Journal*, 49(2):149–162.

Yin, R.K. 2009. *Case Study Research: Design and Methods*. Thousand Oaks, CA: SAGE.

Yin, R.K. 2016. *Qualitative research from start to finish*. 2nd ed. New York, NY: The Guilford Press.

Yousuf, M.I. 2007. Using Experts' Opinions through Delphi Technique. *Practical Assessment, Research & Evaluation*, 12(4):1–8. [Online]. Available from: https://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1171&context=pare [Accessed: 2023-05-26].

Yu, T.-K., Lin, M.-L. & Liao, Y.-K. 2017. Understanding Factors Influencing Information Communication Technology Adoption Behavior: The Moderators of Information Literacy and Digital Skills. *Computers in Human Behavior*, 71:196–208.

Zhong, B. & Xia, L. 2020. A systematic review on exploring the potential of educational robotics in mathematics education. *International Journal of Science and Mathematics Education*, 18(1): 79-101.

Zhuang, Y., Foster, J.K., Conner, A., Crawford, B.A., Foutz, T. & Hill, R.B. 2022. Teaching Elementary Mathematics with Educational Robotics. *Journal of STEM Teacher Education*, 57(1):62-86.

Zulu, M.Z. 2020. *An exploration of the integration of technology by mathematics teachers: the case of 10 schools in KwaZulu-Natal under Umlazi District*. Unpublished masters' dissertation. KwaZulu-Natal: University of KwaZulu-Natal.

APPENDIX A: LETTER OF CONSENT FOR RESEARCH (PRINCIPAL)

"EDUCATION IS THE MOST POWERFUL WEAPON WHICH YOU CAN USE TO CHANGE THE WORLD."

May 2022

LETTER OF CONSENT FOR RESEARCH

Dear Principal

As a PhD student from the University of Pretoria, I am required to conduct research as part of my postgraduate studies. The topic of technology is particularly important to me and I have, therefore, chosen to *develop a framework to teach specific mathematical concepts by using coding and robotics*.

It was my aim to select four early learning centres in Tshwane, one of these being your school. In order to address the research questions of my study, a qualitative approach will be followed, which will include different methods for data generation:

Instrument	Duration, platform, and recording of data	Amount	Goal
Introductory session	• 30-45 minutes • Face-to-face	1	Provide participants with information before data generation commences
Semi-structured individual interview schedule	• 30 minutes • *Qualtrics*	1 participant per interview	Find out from participants how coding and robotics are currently addressed in early learning centres
3x Collaborative discussion groups	• 1 hour – 2 hours • Google Meet • Recorded via Google Meet	All participants at once	Discussing the implementation of coding and robotics
2x Guided observations	• 1 hour – 2 hours • Face-to-face • Not recorded	1 participant per observation	Observe how teachers teach specific mathematical concepts by using coding and robotics

Attached, please find the necessary permission granted to me from the Department of Education as well as the Faculty of Education Ethics Committee at the University of Pretoria. I will, furthermore, also obtain permission from the respective teachers at your school to conduct my study. Once permission has been granted, I shall arrange a convenient time with the teachers to conduct data generation without infringing on their teaching time. I can assure confidentiality and anonymity will be upheld by omitting any personal information of all participants and blurring out faces in any picture. Only my supervisor and I will have access to the raw data. I can also assure you that your teachers and pupils will not be harmed in any way. Please be informed that a teacher may withdraw at any point in time. Similarly, if the data generation process elicits negative outcome, participation can be terminated.

We also would like to request your permission to use your data, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria and the funders of the project. Further research may include secondary data analysis and using the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

Taking part in this study will hopefully prepare your teachers for the implementation of coding and robotics as a subject in the curriculum.

Should you agree, please sign the letter of consent below. Kindly provide me with the permission for research slip indicating your consent/non-consent to participate in the study.

Should you require any further information, please do not hesitate to contact me or my supervisor.

Your assistance is greatly appreciated.

Mrs K. Willemse *Student & researcher*	Prof R. Callaghan *Supervisor*
Lecturer [redacted]	**Head of Department** [redacted]

PERMISSION FOR RESEARCH

I, ………………………………………………., herewith grant ☐ / do not grant ☐ permission for my early learning centre, ………………………………………………., to be involved in the study on how coding and robotics can be used to teach specific mathematical concepts in the Grade R learning environment.

I am aware that these sessions will be recorded with the participants, for further reference.

If any research is published, the personal information and photographs of each participant, as well as confidentiality, anonymity and privacy of each participant will be protected at all time.

Signature: ……………………………………………….

Date: ……………………………………………….

APPENDIX B: LETTER OF CONSENT FOR RESEARCH (TEACHER)

"EDUCATION IS THE MOST POWERFUL WEAPON WHICH YOU CAN USE TO CHANGE THE WORLD."

May 2022

LETTER OF CONSENT FOR RESEARCH

Dear Teacher

As a PhD student from the University of Pretoria, I am required to conduct research as part of my postgraduate studies. The topic of technology is particularly important to me and I have, therefore, chosen to *develop a framework to teach specific mathematical concepts by using coding and robotics*.

It was my aim to select four early learning centres in Tshwane, one of these being your school. Since I am exploring how coding and robotics can be used to teach specific mathematical concepts in the Grade R learning environment, I would, therefore, like to request your consent to involve you in my study.

Firstly, I would like to meet with you in your learning environment to explain the nature and intent of my study. Thereafter, the data generation of my research will be split according to observations and collaborative discussion groups (Google Meet) over the course of a few weeks. Each session will be scheduled according to your availability and will not infringe on your duties as a teacher. In total, more or less six sessions will be required from you over a period of three months. During these sessions you will be asked to take photographs, reflect in a journal and partake in observations, partake in interviews as well as collaborative discussion groups. Please note that all these sessions will be recorded for future reference by me and my supervisor.

Your personal information will be kept confidential and anonymity will be upheld. Any photographs containing faces will be blurred out. Only my supervisor and I will have access to the raw data. I can also assure that you will not be harmed in any way through the research.

Taking part in this study will hopefully prepare you for the implementation of coding and robotics as a subject in the curriculum. Furthermore, it will provide you with the opportunity to act as an active participant in developing a collaborative guideline to explain how coding and robotics can be used to teach specific mathematical concepts.

Should you agree please sign the letter of consent below. Kindly provide me with the permission for research slip indicating your consent/non-consent to participate in the study.

We also would like to request your permission to use your data, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria and the funders of the project. Further research may include secondary data analysis and using the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

Should you require any further information, please do not hesitate to contact me or my supervisor.

Your assistance is greatly appreciated.

Mrs K. Willemse *Student & researcher*	Prof R. Callaghan *Supervisor*
Lecturer [redacted]	**Head of Department** [redacted]

PERMISSION FOR RESEARCH
I, ..., herewith grant ☐ / do not grant ☐ permission to be involved in the study on how coding and robotics can be used to teach specific mathematical concepts in the Grade R learning environment. I am aware that these sessions will be recorded with the participants for further reference. If any research is published, the personal information and photographs of each participant, as well as confidentiality, anonymity and privacy of each participant will be protected at all time. Signature: .... Date: ....

APPENDIX C: LETTER OF CONSENT FOR RESEARCH (CAREGIVER)

"EDUCATION IS THE MOST POWERFUL WEAPON WHICH YOU CAN USE TO CHANGE THE WORLD."

May 2022

LETTER OF CONSENT FOR RESEARCH

Dear Caregiver(s)

As a PhD student from the University of Pretoria, I am required to conduct research as part of my postgraduate studies. The topic of technology is particularly important to me and I have, therefore, chosen to *develop a framework to teach specific mathematical concepts by using coding and robotics*. I am working under the supervision of Prof R. Callaghan from the Department of Science, Mathematics and Technology Education at the University of Pretoria.

It was my aim to select four early learning centres in Tshwane, one of these being the school that your child attends. I was then able to identify and obtain your child's name from his/her teacher, to include your child in my study. I would like to request your consent to involve your child in my studies. The research I am doing is focusing on how coding and robotics can be used to teach specific mathematical concepts. With regard to your child(ren), I want to observe them during two lessons presented by the teacher to understand how the teacher uses coding and robotics to teach specific mathematical concepts.

Firstly, I will meet with both the teacher and the learners to explain the nature and intent of my study. As soon as informed consent and assent have been established by all parties, your child(ren) will be involved in two observation sessions. These observations will take place in the Grade R learning environment during school hours and will be scheduled according to the teacher's availability. You are very welcome to sit in on the observations with your child, should you or he/she prefer it. Please note that during these sessions photographs will be taken for future reference by me and my supervisor.
I can assure confidentiality and anonymity by omitting any personal information of your child and blurring out faces in any picture. Only my supervisor and I will have access to the raw data. I will also assure you that your child will not be harmed in any way. Please be informed that the respective research may be terminated should you or your child wish to end participation in this study.

Taking part in this study will hopefully support teachers to use coding and robotics to teach specific mathematical concepts.

I urge you to discuss this opportunity with your child. Should you agree please sign the letter of consent below. Kindly deliver the permission slip by hand (at the school) indicating your consent/non-consent for your child to participate in the study.

Should you require any further information, please do not hesitate to contact me or my supervisor.

Your assistance is greatly appreciated.

Mrs K. Willemse *Student & researcher*	Prof R. Callaghan *Supervisor*

Lecturer

[redacted]

Head of department

[redacted]

PERMISSION FOR RESEARCH
I, ……………………………………………………, herewith grant ☐ / do not grant ☐ permission for my child, ……………………………………………………, to be involved in the study on how coding and robotics can be used to teach specific mathematical concepts in the Grade R learning environment. I am aware that during these sessions photographs will be taken for further reference. If any research is published, the personal information and photographs of each participant and child, as well as confidentiality, anonymity and privacy of each participant and child will be protected at all times. Signature: …………………………………………………… Date: ……………………………………………………

APPENDIX D: LETTER OF ASSENT FOR RESEARCH (LEARNER)

Dear learner

I am a lecturer (which is the same as being a teacher) and I am also studying at the University of Pretoria. To complete my degree, I have to do research. This means that I need your help because I have chosen to look at how you learn.

Before I will start with the research I need, I will meet with you at school to explain everything to you. I will also introduce you to a robot called the BEE-BOT. After our first meeting, I will meet with you twice during school hours at a time that is most convenient for your teacher.

During these meetings, I will observe how your teacher uses coding and robotics to teach easy mathematics. You will partake during these two meetings and I will also observe how you learn.

I want this study to help your teacher to use exciting activities of coding and robotics to teach mathematics.

If you feel uncomfortable at any time and want to withdraw, you are welcome to do so even if your parent(s) said you are allowed to participate.

I look forward to learning with you!

Kayla

This form will be completed with the researcher during the individual administration sessions.

Name: ___________________________________

Do you understand the letter that I read to you and did I explain what you are going to do?	☺ ☹
Do you understand that it is your choice to help me today and that you can stop at any time you want to?	☺ ☹
Do you have any questions?	☺ ☹

APPENDIX E: LETTER OF CONSENT FOR RESEARCH (EXTERNAL PARTICIPANT)

"EDUCATION IS THE MOST POWERFUL WEAPON WHICH YOU CAN USE TO CHANGE THE WORLD."

May 2022

LETTER OF CONSENT FOR RESEARCH

Dear Expert

I, Mrs Kayla Willemse, as a PhD student from the University of Pretoria am required to conduct research as part of my postgraduate studies. I have chosen to *develop a framework to teach specific mathematical concepts by using coding and robotics*. I am working under the supervision of Prof R. Callaghan from the Department of Science, Mathematics and Technology Education.

Your role of expert will be to critically examine the framework developed by myself as well as eight teachers from four learning environments in the Tshwane South district of Gauteng. I will meet with you via an online platform at a time that is most convenient for you to deliberate the guidelines discussed in the framework to use coding and robotics to teach specific mathematical concepts. This meeting will be scheduled for approximately 60 to 120 minutes. Before the session, you will be asked to read through the guidelines proposed in the framework to familiarise yourself with the content. This session will be recorded for future reference by me and my supervisors.

I can assure confidentiality and anonymity will be upheld by omitting any personal information. All audio recordings of the session will be used to ensure the transcription of data is valid and authentic. These recordings will be safely kept at the University of Pretoria. Only my supervisors and I will have access to the raw data. I can also assure you that you will not be harmed in any way through the research. Please be informed that you may withdraw at any point in time. Similarly, if the data generation process elicits a negative outcome, participation can be terminated. I can also assure you that you will not be harmed in any way through the research.

We also would like to request your permission to use your data, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria and the funders of the project. Further research may include secondary data analysis and using the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

Should you agree please sign the letter of consent below. Kindly email me the permission for research slip (*page 3*) indicating your consent/non-consent to participate in the study.

Should you require any further information, please do not hesitate to contact me or my supervisor.

Your assistance is greatly appreciated.

Mrs K. Willemse
Student & researcher

Prof R. Callaghan
Supervisor

Lecturer

[redacted]

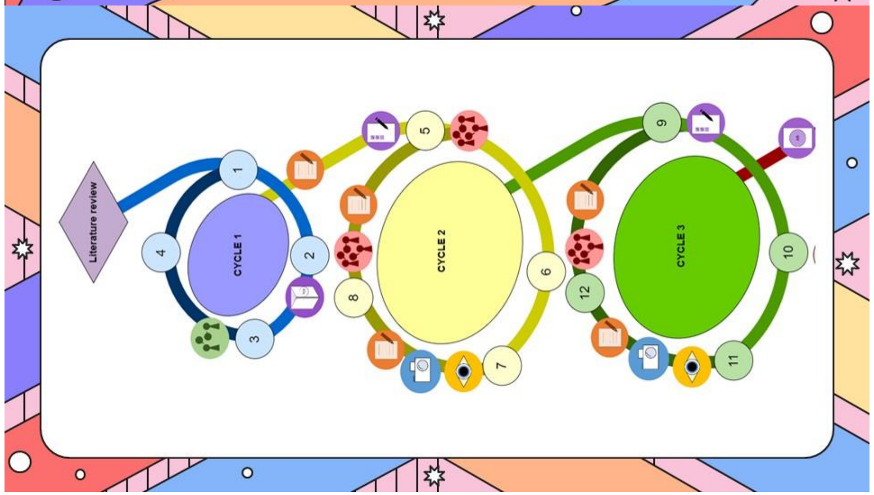
Head of department

[redacted]

PERMISSION FOR RESEARCH
I, ..., herewith grant ☐ / do not grant ☐ permission to be involved in the study on how coding and robotics can be used to teach specific mathematical concepts in the Grade R learning environment. I am aware that the session will be recorded for further reference. If any research is published, the personal information of each participant, as well as confidentiality, anonymity and privacy of each participant will be protected at all times. Signature: .... Date: ....

APPENDIX F: TEACHER COLLABORATION BOOKLET

Proposed date	Instrument	Participants	Duration	Recording of data
May 2022	**Interview**	Individual	15-30 minutes	Qualtrics
May 2022	**Discussion group**	All participants	1 hour – 2 hours	Microsoft Teams Meeting / Google Meet
May 2022	**Observations**	Individual	Dependent on your presentation	Using photographs, reflection journal, observation schedule
June 2022	**Discussion group**	All participants	1 hour – 2 hours	Microsoft Teams Meeting / Google Meet
June 2022	**Observations**	Individual	Dependent on your presentation	Using photographs, reflection journal, observation schedule
July 2022	**Discussion group**	All participants	1 hour – 2 hours	Microsoft Teams Meeting / Google Meet



Imagine you had the opportunity to form part of a collaborative group to design a framework to make teaching easier…

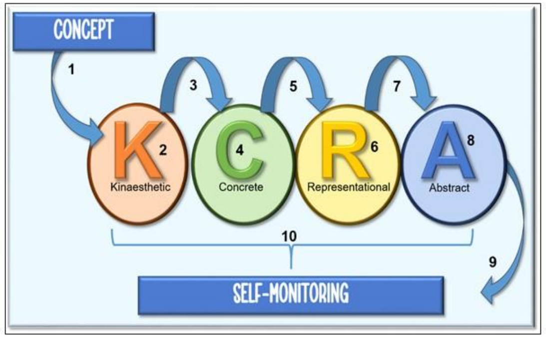
That is what this study is about!

I [Kayla] want you to use your voice as a teacher to develop a framework with me in order to find out how coding and robotics can be used to teach specific mathematical concepts. This process is called **participatory action research**, or **PAR**, in short.

Theory/ practice	The teacher's role	How this can be accomplished
Lev Vygotsky	The teacher must plan learning opportunities that incorporate not just what learners can do on their own, but also what they cannot do on their own.	• Activities within the Zone of Proximal Development (activity starts with known and moves to unknown); • Cooperative learning opportunities (learning together); • Scaffolding or guided participation; • Assisted discovery.
Jean Piaget	Teachers offer a wide range of activities that allow learners to interact directly with the physical environment.	• The process of learning is emphasised; • Teachers should offer a variety of activities; • Learning opportunities should be based on the developmental level of the learner; and • Assessment should be individualised.
Maria Montessori	Teachers must provide learning opportunities that are learner-centred and advance learner's developmental potential to higher levels.	• Teachers must use a quality educational program; • Teachers should possess knowledge of learners' interests and learning styles; • A wide range of resources should be utilised; • Assessment should be based on observation; and • High emphasis is placed on preparing and directing learning opportunities.
Reggio Emilia	The teacher's responsibility is to organise the starting points for learning opportunities and provide open-ended resources for learners to explore and build their own thinking and learning experiences.	• Observe learners' learning to extend individual experiences; • Encourage learners to learn from one another; • Teachers should possess knowledge of learners' interests, learning styles, and needs; and • Working with other professionals within and beyond the learning environment.

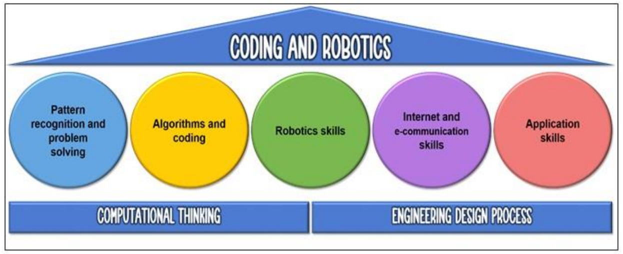
TOPIC	ACTIVITIES
Counting objects	Estimate and count to at least ten.
Counting forwards and backwards	• Count forwards and backwards in ones from one to ten. • Use number rhymes and songs. • Say and use number names in a familiar context.
Number symbols and number names	Recognise, identify, and read number symbols and names from one to ten.
Describe, compare, and order numbers	• Describe whole numbers up to ten. • Compare two objects by using mathematical vocabulary: big, small, smaller than, greater than, more than, less than, equal to, most, least, and fewer. [up to ten] • Order more than two given collections of objects from smallest to greatest up to ten. • Develop an awareness of ordinal numbers, such as first, second, third, up to sixth as well as last.
Problem-solving techniques	Compare apparatus such as counters up to ten.
Addition and subtraction	• Solve word problems (story sums) in context and explain own solution to problems involving addition and subtraction with answers up to ten. • Solve verbally stated addition and subtraction problems with solutions up to ten.
Grouping and sharing leading to division	Solve and explain solutions to word problems in context that involve equal sharing, grouping with whole numbers up to ten and answers that may include remainders.
Money	Develop an awareness of South African coins and bank notes.
Mental mathematics	• Counting everyday objects. • Counting forwards and backwards. • Ordinal counting.

THE KCRA APPROACH



WHAT IS CODING AND ROBOTICS?

The coding and robotics subject is essential for learners to function in a digital and information-driven environment, as well as to apply digital ICT abilities and transfer these skills to solve everyday problems (DBE, 2021:12).



THE BEE-BOT

- Looks like a bumblebee in black and yellow.
- Up to forty commands.
- Moves right, left, forward, and backward.

NOTES

BEE-BOT CODING CARDS

- right
- left
- forward
- pause
- backward
- GO
- go
- X
- stop

NOTES

APPENDIX G: SEMI-STRUCTURED INDIVIDUAL INTERVIEW SCHEDULE

Date	
Platform	*Qualtrics*
Duration	
Participant pseudonym	

Purpose and instruction

In my consent letter I have indicated to you that I am currently busy with my PhD on using coding and robotics to teach specific mathematical concepts in the Grade R learning environment. The information gathered will only be used for research reasons, and no names of participants or any other personally identifiable information will be revealed in my thesis or future publications.

If you want to discontinue the interview altogether at any point throughout the session, simply let me know and then we will stop. All of your responses are treated with confidentiality.

Before we begin the interview, do you have any questions? May I then continue the interview, with your permission?

Interview questions

1. How are the learners in your learning environment exposed to the use of technology? Please motivate your answer.
2. How are the learners in your learning environment exposed to the use of coding and robotics (if at all)?
3. Have you received any training opportunities in the use of coding and robotics or any other technology-enhanced tools? Please motivate your answer.
4. Do you know of any possible training opportunities that you can attend in the use of coding and robotics or any other technology-enhanced tools? Please elaborate.
5. In your opinion, how does coding and robotics or any other technology-enhanced tools influence the learners' learning?
6. In your opinion, how does coding and robotics or any other technology-enhanced tools influence your teaching?
7. How does technology (or coding and robotics) influence your teaching of content during mathematical activities? (Content refers to numbers, operations, and relationships). Please elaborate.
8. What do you think are the possible advantages of using coding and robotics (or other technology-enhanced tools)?
9. What do you think are the possible disadvantages of using coding and robotics (or other technology-enhanced tools)?
10. Do you think coding and robotics should be used in Grade R? Please motivate your answer.
11. When I met you, I introduced you to the KCRA approach. How do you use the constructs (kinaesthetic learning, concrete learning, representational learning, and/or abstract learning) of this approach in your learning environment (if at all)?
12. What other methods do you use to teach learners numbers, operations, and relationships?
13. Should learning and teaching in Grade R be implemented through a play-based approach? Please motivate your answer.
14. When I met you, I introduced you to the theories of Lev Vygotsky and Jean Piaget. By using your booklet, do you implement any of these theories in your learning environment? Please motivate your answer.
15. When I met you, I introduced you to the practices of Maria Montessori and Reggio Emilia. By using your booklet, do you implement any of these practices in your learning environment? Please motivate your answer.
16. Would you like to add anything else before we conclude the interview?

Thank you for your valued input!

APPENDIX H: SYSTEMATISING EXPERT INTERVIEW

Date	17 January 2023
Platform	Microsoft Teams
Duration	60-120 minutes
Participant pseudonym	EP

External: Systematising expert interview

Purpose and instruction

In my consent letter I have indicated to you that I am currently busy with my PhD on the integration of coding and robotics with mathematical concepts in the Grade R learning environment. I would like to reiterate that the aim of this interview is to ensure the trustworthiness of my study by verifying the preliminary framework. The interview will take approximately 60 minutes to 120 minutes and will include approximately nine questions. The information gathered will only be used for research purposes, and no personally identifiable information will be revealed in my thesis or future publications.

If you want to discontinue using the recorder or the interview altogether at any point throughout the session, simply let me know and then we will stop. All of your responses are treated with confidentiality.

Before we begin the interview, do you have any questions?

Is it alright if I record the interview so that I may listen to it later and write a transcript to appropriately document the facts you provide?

May I then continue the interview, with your permission?

Interview questions

1. For the purpose of constructing a participant profile, can you please provide me with some personal information? E.g. age (*optional), experience, highest qualification and year obtained, published research, etc.

2. In the external participant booklet (EPB), I indicated that the integration of coding and robotics with Grade R mathematical concepts is implemented through four guidelines. These are teachers' needs; external factors that need to be addressed; the learning process; as well as possible outcomes. What is your opinion of these four guidelines according to its organisation and presentation?

3. Regarding teachers' needs three challenges are presented that need to be addressed before using coding and robotics to teach Grade R mathematical concepts can take place. Please provide your opinion of each of the following aspects:

Sufficient teacher training	Teachers must be trained in the use of coding and robotics in order to understand why it should be implemented, where to begin with implementation, and how to use coding and robotics to teach mathematics.
Guidelines	Teachers require a manual or textbook with clear aims and objectives in order to plan lessons or lesson plans that are already completed; information on how to integrate coding and robotics into the daily programme; and information on how to set up the classroom for free play with coding and robotics.
Robot	Teacher need a robot in order to successfully implement robotics.

4. Please provide your expert opinion of identifying teachers' needs as a guideline for the development of a framework to integrate coding and robotics with Grade R mathematical concepts.

5. External factors that need to be addressed before the integration of coding and robotics with Grade R mathematical concepts relate to high teacher-to-learner ratio classrooms; financial constraints; the neglect of other learning areas; the replacement of traditional teaching methods; and learners forming a dependency. Please provide your opinion of each of the following aspects:

Overcrowded learning environments	Class management would be critical in learning environment with a high teacher-to-learner ratio.
Financial constraints	Financial constraints may be an issue if specific equipment is required when using coding and robotics to teach mathematical concepts.
The neglect of other learning areas	Learning areas such as language (listening skills) and physical education (gross motor skills) might be negatively affected through the technology, however, these skills are supported in the implementation of coding and robotics.
The replacement of traditional teaching methods	Coding and robotics should not replace traditional teaching methods but rather be used as a tool to enhance learners' learning.
Learners forming a dependency	Learners should not become overly reliant on coding and robotics, or technology in general, to solve problems.

6. Please provide your expert opinion of identifying these external factors as a guideline for the development of a framework to use coding and robotics to teach specific mathematical concepts.

7. During the integration of coding and robotics with Grade R mathematical concepts, certain aspects need to be included or addressed during the learning process. Please provide your opinion of each of the following aspects:

Enjoyment	Coding and robotics will capture learners' attention, therefore, it can be used as an enjoyable teaching tool to enhance learner participation and pique their interest.
Play-based teaching and learning	Playing is the best way for learners to learn. When learners play, they are free to make mistakes and are not pressured to perform at a fixed level. Learners learn easily and eagerly through play since they are motivated to learn and take part in educational activities because they are having fun.
KCRA approach	Learning and teaching in Grade R should implemented through kinaesthetic experiences firstly, then concrete experiences, then representational experiences, and lastly, abstract experiences.
Integration of subject areas	Teachers subconsciously integrate language, Life Skills, and mathematics during learning activities. The integration of subject areas is successful in reinforcing concepts and abilities, particularly with younger learners because they are more likely to remember information if they encounter and practice it often.
Use of pedagogical theories and/or international practices	Teachers subconsciously apply these pedagogical theories and/or international practices in their instruction. However, teachers should be encouraged to develop an active awareness of what each entails.
Assessment	The use of coding and robotics to teach specific mathematical concepts should be assessed as part of the general assessments administered by Grade R teachers through informal observations. The assessment should be centred on the identified mathematical concept.

8. Please provide your expert opinion on identifying these constructs of the learning process as a guideline for the development of a framework to integrate coding and robotics with Grade R mathematical concepts.

9. During the integration of coding and robotics with Grade R mathematical concepts, four possible outcomes can be anticipated. Please provide your opinion of each of the following aspects:

Mathematical skills	Using coding and robotics to teach numbers, operations, and relationships, support learners' development in counting; identifying and reading number names and symbols; describing, ordering, and comparing numbers; as well as simple addition.
Formal school and life after school	Coding and robotics may support learners' ethics and discipline in using technology in the future, as well as to assist learners in comprehending DT and prepare them for life after school.
Learners' understanding and holistic development	Coding and robotics have the possibility to support learners' collaboration skills, creativity skills, lateral thinking, critical thinking, and understanding of algorithms. It also has the possibility to expose learners to technology.
Teachers keeping abreast with new developments	Coding and robotics are new skills and a teaching method that teachers can become acquainted with in order to improve their teaching and stay current with educational developments.

10. Please provide your expert opinion of identifying these possible outcomes as a guideline for the development of a framework to integrate coding and robotics with Grade R mathematical concepts.

Would you like to add anything else before we conclude the interview?

THANK YOU FOR YOUR VALUABLE INPUT!

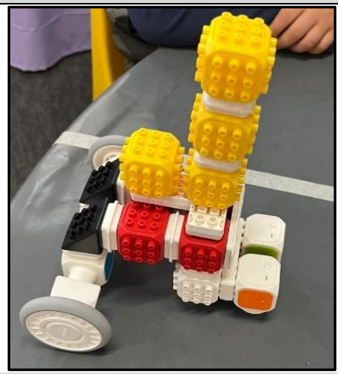
APPENDIX I: PHOTOVOICE (MORE EXAMPLES)



TO1

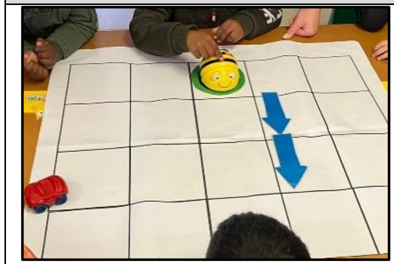

TO2





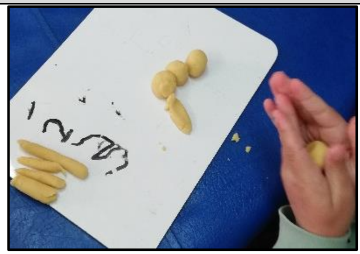
TO3


TO4

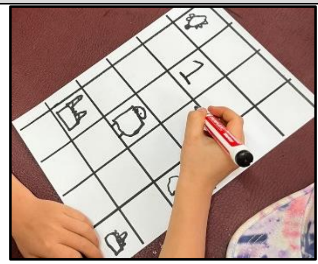


TO5

TO6



TO7



TO8

TO9 & TO10

APPENDIX J: ETHICS LETTER (THE DEPARTMENT OF BASIC EDUCATION)

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Personal information has been removed

Date:	**04 May 2022**
Validity of Research Approval:	**08 February 2022– 30 September 2022** **2022/172**
Name of Researcher:	**Willemse K**
Address of Researcher:	[redacted]
	[redacted]
	Tshwane
Telephone Number:	[redacted]
Email address:	[redacted]
Research Topic:	**Developing a framework to use coding and robotics to teach Grade R mathematical concepts**
Type of qualification	**Philosophiae Doctor**
Number and type of schools:	[redacted]
District/s/HO	**Tshwane South**

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

06/05/2022

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below are met. Approval may be withdrawn should any of the conditions listed below be flouted:

1

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

1. *The letter would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. ***Because of the relaxation of COVID 19 regulations researchers can collect data online, telephonically, physically access schools, or may make arrangements for Zoom with the school Principal. Requests for such arrangements should be submitted to the GDE Education Research and Knowledge Management directorate.***
4. ***The Researchers are advised to wear a mask at all times, Social distance at all times, Provide a vaccination certificate or negative COVID-19 test, not older than 72 hours, and Sanitise frequently.***
5. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s has been granted permission from the Gauteng Department of Education to conduct the research study.*
6. *A letter/document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs, and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
7. *The Researcher will make every effort to obtain the goodwill and cooperation of all the GDE officials, principals, and chairpersons of the SGBs, teachers, and learners involved. Persons who offer their cooperation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
8. *Research may only be conducted after school hours so that the normal school program is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
9. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
10. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
11. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
12. *The researcher is responsible for supplying and utilising his/her research resources, such as stationery, photocopies, transport, faxes, and telephones, and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
13. *The names of the GDE officials, schools, principals, parents, teachers, and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
14. *On completion of the study, the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
15. *The researcher may be expected to provide short presentations on the purpose, findings, and recommendations of his/her research to both GDE officials and the schools concerned.*
16. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a summary of the purpose, findings, and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

....

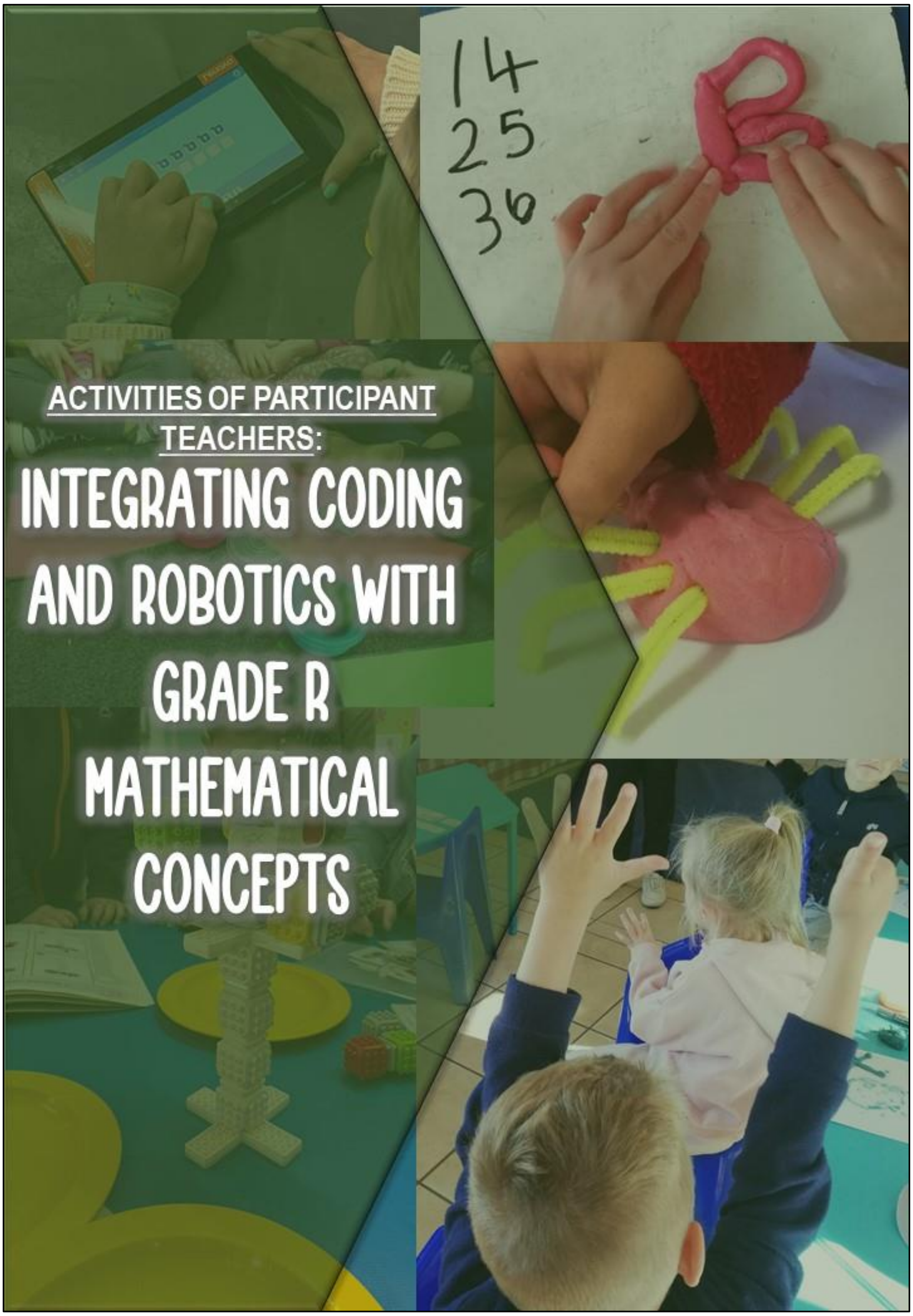
Mr. Gumani Mukatuni
Acting CES: Education Research and Knowledge Management

DATE: 06/05/2022

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

APPENDIX K: ACTIVITIES OF INTEGRATING CODING AND ROBOTICS WITH MATHEMATICAL CONCEPTS



ACTIVITY 1

CONTEXT	**Topic**	Counting & number skills
	Theme	Dinosaurs
	Total activity time	30-45 minutes
	Resources	Chalk, dinosaur action pictures, grid (5x5), directional arrows, pictures of dinosaurs, number cards, dice
AIMS	Use counting skills to solve a problem in the context of a coding and robotics activity.	

PLAN

INTRODUCTION (10-15 MINUTES)

X K	X C	☐ R	☐ A

The teacher will introduce the topic of 'coding' to the learners by focusing on number recognition and integrating the theme of dinosaurs. The teacher draws a 'hop-scotch' grid with chalk on the carpet. The blocks of the grid have a start and an end block. The blocks between the start and end blocks consist of number symbols or pictures of dinosaurs. When the learners are on a number symbol block, they have to say the number out loud. The dinosaur pictures are action blocks that the learners have to act out.

DEVELOPMENT (10-15 MINUTES)

X K	X C	☐ R	☐ A

The development of the activity focuses on integrating coding with counting skills. The learners play a game to get the mom dinosaur to her baby. The learners have to place different directional arrows on the grid to move the plastic dinosaur toy in the correct direction. The learners are not allowed to be on a block with an obstacle which are either a volcano or a meteoroid. The game is completed when the mom dinosaur reaches her baby and the learners now have to count the number of directional arrows they had placed.

CONSOLIDATION (10-15 MINUTES)

☐ K	X C	☐ R	X A

The consolidation of the lesson focuses on number recognition. The learners have to match the correct number of dinosaur toys to the number symbol card.

MATHEMATICAL SKILLS

X Counting objects	☐ Addition and subtraction
☐ Counting forwards and backwards	☐ Grouping and sharing leading to division
X Number symbols and number names	☐ Money
☐ Describe, compare, and order numbers	☐ Mental mathematics
☐ Problem-solving techniques	☐ Other: ______________________

Elaboration and justification

During the introduction of this lesson, the learners have to 'read' number symbols on a hop-scotch grid. This develops their understanding of number symbols and number names. The development focuses on counting because they have to count the number of directional arrows. The consolidation focuses on number symbols and number names because the learners have to match the correct number of toys to the correct number symbol card.

THEORIES

X Lev Vygotsky	X Jean Piaget

Elaboration and justification

The learners are involved in cooperative learning opportunities in this lesson plan through guided participation and assisted discovery. Furthermore, the teacher has provided a variety of activities that are based on the developmental levels of the learners.

BEST PRACTICES

X Montessori	☐ Reggio Emilia

Elaboration and justification

The learners' interests are piqued by using the theme of dinosaurs and various learning styles are accommodated. The teacher also uses a variety of resources and the learning opportunities have been prepared.

ACTIVITY 2

CONTEXT	**Topic**	Counting and number recognition
	Theme	Insects
	Total activity time	25-30 minutes
	Resources	Playdough
AIMS	Use mathematical skills to solve a problem in the context of a coding and robotics activity.	

PLAN

INTRODUCTION (5 MINUTES)

☐ K	☐ C	☐ R	X A

The teacher will introduce the topic to the learners by asking the following questions:

- In the animal kingdom we have a group of animals that have 6 feet, do you know what they are called?
- These animals have segmented bodies, do you know what these animals are called?
- These animals have jointed legs, do you know what these animals are called?
- These animals have external skeletons, do you know what these animals are called?

The learners have to realise that the topic of the activity is 'insects'.

DEVELOPMENT (10-15 MINUTES)

☐ K	X C	☐ R	☐ A

The development of the activity focuses on integrating coding (following a sequence) with counting.
The teacher will now provide each learner with play dough and ask them to build an insect. For the first insect, they will not provide them with any instructions. After the learners have built an insect with play-dough, the teacher will now give the learners a specific set of instructions to build an insect, and more specifically, a bee. The instructions are as follows: (1) Roll 1 round ball for the head of your insect; (2) Sculpt 2 wings for your insect; (3) Sculpt an oval shape for your insect's body; (4) Roll 2 small round balls for your insect's eyes; (5) Roll 6 small worms for your insect's feet; and (6) Roll 2 antlers for your insect.
Ask the learners whether the insect they have created looks like a bee. When the learners create their bees, a clear sequence of instructions will help save time and minimise mistakes. This is also true for abstract coding, because a robot needs step-by-step instructions to perform tasks.

CONSOLIDATION (10 MINUTES)

☐ K	☐ C	☐ R	X A

The consolidation of the lesson focuses on number symbols.
The learners now have to count the number of feet each of their insects has. They then have to write the number on a whiteboard or a piece of paper next to the insects that they have created.
* Additional: Ask the learners to subtract or add the two numbers that they have written. This will use addition skills to solve a problem in the context of a coding and robotics activity.

MATHEMATICAL SKILLS

X Counting objects	X Addition and subtraction
X Counting forwards and backwards	☐ Grouping and sharing leading to division
X Number symbols and number names	☐ Money
☐ Describe, compare, and order numbers	☐ Mental mathematics
☐ Problem-solving techniques	☐ Other: ____________________

THEORIES

☐ Lev Vygotsky	X Jean Piaget

Elaboration and justification

The process of learning during this activity is emphasised and the teacher has offered a variety of activities. The activity is also based on the developmental levels of the learners.

BEST PRACTICES

X Montessori	☐ Reggio Emilia

Elaboration and justification

The teacher has taken into account the learners' interests and different learning styles and the learning opportunity has been thoroughly prepared.

ACTIVITY 3

CONTEXT	**Topic**	Counting
	Theme	Robots
	Total activity time	25-30 minutes
	Resources	4x5 grid, Bee-Bot, directional arrows
AIMS	Use counting skills to solve a problem in the context of a coding and robotics activity.	

PLAN	☐ K	**X** C	**X** R	☐ A
	The teacher used a 4x5 grid and the Bee-Bot integrated with counting. Each learner had the opportunity to move the Bee-Bot in a desired direction to a specific location. The teacher taught the learners how to move the Bee-Bot and provided assistance to the learners who required it. Each time the Bee-Bot moved, the learners had to count the number of blocks. The teacher also used directional arrows to explain to the learners the path that the Bee-Bot could move.			

MATHEMATICAL SKILLS	**X** Counting objects	☐ Addition and subtraction
	☐ Counting forwards and backwards	☐ Grouping and sharing leading to division
	☐ Number symbols and number names	☐ Money
	☐ Describe, compare, and order numbers	☐ Mental mathematics
	X Problem-solving techniques	☐ Other: ____________________
PEDAGOGICAL THEORIES	☐ Lev Vygotsky	**X** Jean Piaget
	Elaboration and justification	
	The teacher planned learning opportunities that incorporate not just what learners can do on their own, but also what they cannot do on their own.	
BEST PRACTICES	**X** Montessori	☐ Reggio Emilia
	Elaboration and justification	
	Teachers provides learning opportunities that are learner-centred and advance learners' developmental potential to higher levels.	

ACTIVITY 4

CONTEXT	**Topic**	Counting
	Theme	Shapes and colours
	Total activity time	25-30 minutes
	Resources	4x5 grid, Bee-Bot
AIMS	Use counting skills to solve a problem in the context of a coding and robotics activity.	

PLAN	☐ K	☐ C	**X** R	**X** A
	The teacher used a 4x6 grid with different coloured shapes in each block. Each learner had the opportunity to choose a specific block that they would like their Bee-Bot to travel to from a location chosen by the teacher. When the Bee-Bot moved, they had to count how many steps the Bee-Bot moved.			

MATHEMATICAL SKILLS	**X** Counting objects	☐ Addition and subtraction
	☐ Counting forwards and backwards	☐ Grouping and sharing leading to division
	☐ Number symbols and number names	☐ Money
	☐ Describe, compare, and order numbers	☐ Mental mathematics
	☐ Problem-solving techniques	☐ Other: ____________________

PEDAGOGICAL THEORIES	**X** Lev Vygotsky	☐ Jean Piaget
	Elaboration and justification	
	The teacher planned learning opportunities that incorporate not just what learners can do on their own, but also what they cannot do on their own.	

BEST PRACTICES	**X** Montessori	☐ Reggio Emilia
	Elaboration and justification	
	Teacher provides learning opportunities that are learner-centred and advance learners' developmental potential to higher levels.	

ACTIVITY 5

CONTEXT	**Topic**	Counting
	Theme	Wild animals
	Total activity time	25-30 minutes
	Resources	6x4 grid, figurines, die
AIMS	Use counting skills to solve a problem in the context of a coding and robotics activity.	

PLAN	**X** K	☐ C	**X** R	☐ A
	The teacher used a 6x4 grid to move a figurine to a desired block. The figurine (mother bear) had to collect two other figurines (baby bears) along the path. The learners each had a turn to throw a die and move the figurine the indicated number of dots represented on the die. There were also some blocks on the grid that represented obstacles that the learners were not allowed to move through. The figurine was only allowed to move forwards, backwards, left and right.			

MATHEMATICAL SKILLS	**X** Counting objects	☐ Addition and subtraction
	☐ Counting forwards and backwards	☐ Grouping and sharing leading to division
	☐ Number symbols and number names	☐ Money
	☐ Describe, compare, and order numbers	☐ Mental mathematics
	☐ Problem-solving techniques	☐ Other: ______________________
PEDAGOGICAL THEORIES	**X** Lev Vygotsky	☐ Jean Piaget
	Elaboration and justification	
	The teacher planned learning opportunities that incorporate not just what learners can do on their own, but also what they cannot do on their own	
BEST PRACTICES	**X** Montessori	☐ Reggio Emilia
	Elaboration and justification	
	Teacher provides learning opportunities that are learner-centred and advance learners' developmental potential to higher levels.	

ACTIVITY 6

CONTEXT	**Topic**	Counting and number recognition
	Theme	Pets
	Total activity time	35 minutes
	Resources	Chalk, boxes, tape for carpet, 4x5 egg cartons, figurines, die, cat and mouse ears
AIMS	Use counting skills to solve a problem in the context of a coding and robotics activity.	

PLAN

INTRODUCTION (10 MINUTES)

X K	☐ C	☐ R	☐ A

Teacher uses tape to measure a 4x5 grid on the carpet. On the grid, boxes are placed to mark the blocks that the learners are not allowed to move through. One learner is given a headband with mouse ears and another learner is given a headband with cat ears. The goal is for the cat to find the mouse by moving the number of blocks indicated by throwing a die. The learners are allowed to move forward, backward, left, or right. The teacher draws the direction that the learners move on a piece of cardboard as well as on the grid with chalk for all the learners to see.

DEVELOPMENT (10-15 MINUTES)

X K	☐ C	☐ R	**X** A

Learners are involved in a concrete coding activity by moving a cat figurine to find a mouse figurine. The learners have to throw a die to know how many blocks they can move on a 4x5 grid – they are allowed to move forward, backward, left or right. Gifted learners are provided a die with number symbols which they must recognise, the other learners count the number of dots on the die.

CONSOLIDATION (10-15 MINUTES)

☐ K	☐ C	**X** R	**X** A

Learners are required to draw arrows on a piece of paper with a 4x5 grid, to move the cat to the block of the mouse. The blocks which the learners are not allowed to draw arrows on, are marked with an 'x'.
The learners then have the opportunity to code the Bee-Bot to follow the path indicated on the paper. Each learner's path is explored through using the Bee-Bot.

MATHEMATICAL SKILLS

X Counting objects	☐ Addition and subtraction
X Counting forwards and backwards	☐ Grouping and sharing leading to division
X Number symbols and number names	☐ Money
☐ Describe, compare, and order numbers	☐ Mental mathematics
X Problem-solving techniques	☐ Other: ________________________

Elaboration and justification

Learners are required to recognise number symbols and need to count dots on the die. They have to make use of problem-solving techniques to solve the coding activity.

THEORIES

X Lev Vygotsky	**X** Jean Piaget

Elaboration and justification

The teacher has planned learning opportunities that incorporates not just what learners can do on their own but also what they cannot do on their own. The teacher has prepared a variety of developmentally appropriate activities that allow learners to interact with the environment.

BEST PRACTICES

X Montessori	☐ Reggio Emilia

Elaboration and justification

Learning opportunities are learner-centred and a wide range of resources have been used to meet the aims of the activity.

ACTIVITY 7

CONTEXT

Topic	Counting and describing, comparing and ordering numbers
Theme	Wild animals
Total activity time	35 minutes
Resources	Giraffe masks, 6x black circles (big enough to jump on), building blocks, Cubroid coding blocks premium kit, tablet, stickers, die

AIMS

Use mathematical concepts to solve a problem in the context of coding and robotics.

PLAN

INTRODUCTION (10 MINUTES)

X K	☐ C	☐ R	X A

A 4x6 grid is designed on the classroom carpet with black circles. Four learners at a time can be involved in this activity. Each learner stands at the back of the black circles and throws the die. The learner counts the number of dots on the die to jump the correct number of times. The learners wear giraffe masks and have to measure who has the longest neck, shortest neck, who has the same length, second longest, and so forth. Learners then have to recognise the number name of the position they have.

DEVELOPMENT (10-15 MINUTES)

☐ K	X C	☐ R	X A

Learners move to second station where they are asked to pick up a certain amount of blocks. They then have to stack these blocks on top of each other and place it on a piece of paper to see who has the tallest, shortest, same length, second longest, and so forth neck. The tallest number of blocks receive a face block with two eyes. The learners then place these blocks flat on the piece of paper to see who has the tallest neck. Learners then have to recognise the number name of the position they have.

CONSOLIDATION (10 MINUTES)

☐ K	☐ C	X R	X A

The learners move to the last station. They have to throw the die and count the number of dots on the die again. They then have to move the giraffe robot forwards the number of dots indicated on the die by using a coding application on a tablet. They place a giraffe sticker next to where the giraffe robot has stopped. They then have to answer again who has longest neck, shortest neck, who has the same length, second longest, and so forth.

MATHEMATICAL SKILLS

X Counting objects	☐ Addition and subtraction
X Counting forwards and backwards	☐ Grouping and sharing leading to division
X Number symbols and number names	☐ Money
X Describe, compare, and order numbers	☐ Mental mathematics
X Problem-solving techniques	☐ Other: ____________

PEDAGOGICAL THEORIES

X Lev Vygotsky	X Jean Piaget

Elaboration and justification

The teacher offers a variety of activities that allow the learners to interact directly with the physical environment. The teacher has planned learning activities that incorporate what the learners can do on their own, but also what they cannot do on their own.

BEST PRACTICES

X Montessori	☐ Reggio Emilia

Elaboration and justification

The activities are learner-centred and a wide range of resources were used.

ACTIVITY 8

<table>
<tr><td rowspan="4">CONTEXT</td><td>Topic</td><td colspan="3">Counting</td></tr>
<tr><td>Theme</td><td colspan="3">Wild animals</td></tr>
<tr><td>Total activity time</td><td colspan="3">35 minutes</td></tr>
<tr><td>Resources</td><td colspan="3">Die, wild animal figurines, Cubroid coding blocks premium kit, tablet</td></tr>
<tr><td>AIMS</td><td colspan="4">Use mathematical concepts to solve a problem in the context of coding and robotics.</td></tr>
<tr><td rowspan="9">PLAN</td><td colspan="4">INTRODUCTION (10 MINUTES)</td></tr>
<tr><td>X K</td><td>☐ C</td><td>☐ R</td><td>☐ A</td></tr>
<tr><td colspan="4">The lesson starts with the teacher grouping the learners into two groups – male and female learners. The female learners will have a chance to start and the male learners are asked to pay attention. Some female learners are given a wild animal figurine and asked to stand on a specific block on a 4x5 grid on the carpet (made with tape). Three female learners are left – which two are given a die that they need to roll and one learner will be moving on the grid. The two female learners take turns to roll the die and then the other learner moves the number of dots that is represented on the die. She is not allowed to move through a block with an obstacle (wild animal).</td></tr>
<tr><td colspan="4">DEVELOPMENT (10-15 MINUTES)</td></tr>
<tr><td>☐ K</td><td>X C</td><td>☐ R</td><td>X A</td></tr>
<tr><td colspan="4">Five learners are then moved to a station where they have to use the Cubroid coding blocks to design a flashlight. Two female learners need to build the flashlight, one other female learner is in charge of handing out the coding cards to build the flashlight, and two male learners are in charge of the coding blocks that make a light by using the tablet. The other learners in the learning environment are involved in other activities.</td></tr>
<tr><td colspan="4">CONSOLIDATION (10 MINUTES)</td></tr>
<tr><td>X K</td><td>☐ C</td><td>☐ R</td><td>☐ A</td></tr>
<tr><td colspan="4">The male learners then have the opportunity to move through the 4x5 grid by using the flashlight.</td></tr>
<tr><td rowspan="7">MATHEMATICAL SKILLS</td><td colspan="2">X Counting objects</td><td colspan="2">☐ Addition and subtraction</td></tr>
<tr><td colspan="2">☐ Counting forwards and backwards</td><td colspan="2">☐ Grouping and sharing leading to division</td></tr>
<tr><td colspan="2">☐ Number symbols and number names</td><td colspan="2">☐ Money</td></tr>
<tr><td colspan="2">☐ Describe, compare, and order numbers</td><td colspan="2">☐ Mental mathematics</td></tr>
<tr><td colspan="2">X Problem-solving techniques</td><td colspan="2">☐ Other: ____________________</td></tr>
<tr><td colspan="4">Elaboration and justification</td></tr>
<tr><td colspan="4">Learners have to count the number of dots on the dice. Learners have to build a flashlight by using problem-solving techniques.</td></tr>
<tr><td rowspan="3">PEDAGOGICAL THEORIES</td><td colspan="2">X Lev Vygotsky</td><td colspan="2">☐ Jean Piaget</td></tr>
<tr><td colspan="4">Elaboration and justification</td></tr>
<tr><td colspan="4">The learning opportunities incorporate what the learners can do on their own, but also what they cannot do on their own.</td></tr>
<tr><td rowspan="3">BEST PRACTICES</td><td colspan="2">X Montessori</td><td colspan="2">☐ Reggio Emilia</td></tr>
<tr><td colspan="4">Elaboration and justification</td></tr>
<tr><td colspan="4">The learning opportunities are learner-centred.</td></tr>
</table>

ACTIVITY 9

<table>
<tr><td rowspan="3">CONTEXT</td><td>Topic</td><td colspan="4">Numbers and number recognition</td></tr>
<tr><td>Total activity time</td><td colspan="4">25-30 minutes</td></tr>
<tr><td>Resources</td><td colspan="4">Bee-Bot, human-sized chessboard</td></tr>
<tr><td>AIMS</td><td colspan="5">Use mathematical concepts to solve a problem in the context of coding and robotics.</td></tr>
<tr><td rowspan="2">PLAN</td><td>X K</td><td>X C</td><td>☐ R</td><td colspan="2">X A</td></tr>
<tr><td colspan="5">The teacher took the learners outside of the classroom to play chess on a human-sized chessboard. Two learners were provided with an opportunity to move the learners seated on the chessboard. The learners that had to move the other learners had to be very specific when providing instructions and had to read the name of each individual block, for example, "B2 move to B3". The learners were only allowed to move forwards. The learners then moved inside to the carpet and played with the Bee-Bot. They had to move the Bee-Bot to specific locations on the grid provided by the teacher, for example, "The Bee-Bot is now on A2. Move the Bee-Bot to C4". Each learner had an opportunity to move the Bee-Bot.</td></tr>
<tr><td rowspan="5">MATHEMATICAL SKILLS</td><td colspan="3">X Counting objects</td><td colspan="2">☐ Addition and subtraction</td></tr>
<tr><td colspan="3">X Counting forwards and backwards</td><td colspan="2">☐ Grouping and sharing leading to division</td></tr>
<tr><td colspan="3">X Number symbols and number names</td><td colspan="2">☐ Money</td></tr>
<tr><td colspan="3">☐ Describe, compare, and order numbers</td><td colspan="2">☐ Mental mathematics</td></tr>
<tr><td colspan="3">☐ Problem-solving techniques</td><td colspan="2">☐ Other: ____________________</td></tr>
<tr><td rowspan="3">PEDAGOGICAL THEORIES</td><td colspan="2">X Lev Vygotsky</td><td colspan="3">☐ Jean Piaget</td></tr>
<tr><td colspan="5">Elaboration and justification</td></tr>
<tr><td colspan="5">The teacher planned learning opportunities that incorporate not just what learners can do on their own, but also what they cannot do on their own.</td></tr>
<tr><td rowspan="3">BEST PRACTICES</td><td colspan="2">X Montessori</td><td colspan="3">☐ Reggio Emilia</td></tr>
<tr><td colspan="5">Elaboration and justification</td></tr>
<tr><td colspan="5">Teacher provides learning opportunities that are learner-centred and advance learners' developmental potential to higher levels.</td></tr>
</table>

ACTIVITY 10

CONTEXT	**Topic**	Coding
	Theme	Royalty
	Total activity time	25-30 minutes
	Resources	Human-sized chessboard. Blindfold, printed 6x4 grid for each learner
AIMS	• Following and remembering instructions; • Develop listening skills; and • Use mathematical concepts to solve a problem in the context of coding and robotics.	

PLAN

INTRODOUCTION (5 MINUTES)

X K	☐ C	☐ R	☐ A

The learners have to look at the teacher moving her body in a certain direction and copy it. For example, if the teacher moved her arms right, the learners had to move right.

DEVELOPMENT (15 MINUTES)

X K	☐ C	☐ R	☐ A

The learners then move outside to human-sized chessboard. One learner is blindfolded and the teacher asks each other learner to direct the blindfolded learner to a specific block, for example, "move forwards three times".

CONSOLIDATION (10 MINUTES)

☐ K	☐ C	X R	☐ A

The learners then have to draw a king and queen on a 6x4 grid and then indicate the path that the queen has to move to reach the king by working in pairs.

MATHEMATICAL SKILLS

X Counting objects	☐ Addition and subtraction
X Counting forwards and backwards	☐ Grouping and sharing leading to division
X Number symbols and number names	☐ Money
☐ Describe, compare, and order numbers	☐ Mental mathematics
☐ Problem-solving techniques	☐ Other: ____________

PEDAGOGICAL THEORIES

X Lev Vygotsky	☐ Jean Piaget

Elaboration and justification

The teacher planned learning opportunities that incorporate not just what learners can do on their own, but also what they cannot do on their own.

BEST PRACTICES

X Montessori	☐ Reggio Emilia

Elaboration and justification

Teacher provides learning opportunities that are learner-centred and advance learners' developmental potential to higher levels.

ACTIVITY 11

<table>
<tr><td rowspan="4">CONTEXT</td><td>Topic</td><td colspan="3">Counting skills, describing numbers and addition</td></tr>
<tr><td>Theme</td><td colspan="3">Farming</td></tr>
<tr><td>Total activity time</td><td colspan="3">25 minutes</td></tr>
<tr><td>Resources</td><td colspan="3">Pictures of produce and products; whiteboard and whiteboard markers to draw 10x8 grid; pictures of a tractor, different fruits and vegetables; scarecrows, and leaves; and directional arrows.</td></tr>
<tr><td>AIMS</td><td colspan="4">Use mathematical concepts to solve a problem in the context of coding and robotics.</td></tr>
<tr><td rowspan="9">PLAN</td><td colspan="4">INTRODOUCTION (5 MINUTES)</td></tr>
<tr><td>☐ K</td><td>☐ C</td><td>☐ R</td><td>X A</td></tr>
<tr><td colspan="4">The teacher introduces the topic of “farming” to the learners by asking them to identify different products and asking them what each product is made from. For example, the teacher asks the learners to identify a picture of butter and then the learners have to identify butter is made from milk. The teacher then puts both pictures on a blackboard for the learners to see.</td></tr>
<tr><td colspan="4">DEVELOPMENT (10-15 MINUTES)</td></tr>
<tr><td>☐ K</td><td>☐ C</td><td>X R</td><td>☐ A</td></tr>
<tr><td colspan="4">For the development phase, the teacher asked the learners to develop a path for a tractor to reach a farm gate on a 10x8 grid on the whiteboard. Each learner had an opportunity to say where the tractor had to move by counting the number of times it had to move forwards, backwards, left, or right. Along the path the learners had to collect different fruits and vegetables and had to watch out for grass and scarecrows.</td></tr>
<tr><td colspan="4">CONSOLIDATION (10 MINUTES)</td></tr>
<tr><td>☐ K</td><td>☐ C</td><td>☐ R</td><td>X A</td></tr>
<tr><td colspan="4">At the end, the learners had to count the number of fruits and vegetables that they had collected. The teacher then asked the learners questions such as: “how many fruits do we have in total?”; “which fruit is the most/least/same?”.</td></tr>
<tr><td rowspan="5">MATHEMATICAL SKILLS</td><td colspan="2">X Counting objects</td><td colspan="2">X Addition and subtraction</td></tr>
<tr><td colspan="2">X Counting forwards and backwards</td><td colspan="2">☐ Grouping and sharing leading to division</td></tr>
<tr><td colspan="2">☐ Number symbols and number names</td><td colspan="2">☐ Money</td></tr>
<tr><td colspan="2">X Describe, compare, and order numbers</td><td colspan="2">☐ Mental mathematics</td></tr>
<tr><td colspan="2">☐ Problem-solving techniques</td><td colspan="2">☐ Other: ____________________</td></tr>
<tr><td rowspan="3">PEDAGOGICAL THEORIES</td><td colspan="2">X Lev Vygotsky</td><td colspan="2">☐ Jean Piaget</td></tr>
<tr><td colspan="4">Elaboration and justification</td></tr>
<tr><td colspan="4">The teacher planned learning opportunities that incorporate not just what learners can do on their own, but also what they cannot do on their own.</td></tr>
<tr><td rowspan="3">BEST PRACTICES</td><td colspan="2">X Montessori</td><td colspan="2">☐ Reggio Emilia</td></tr>
<tr><td colspan="4">Elaboration and justification</td></tr>
<tr><td colspan="4">Teacher provides learning opportunities that are learner-centred and advance learners’ developmental potential to higher levels.</td></tr>
</table>

APPENDIX L: AN OVERVIEW OF THE THEME, SUB-THEMES, CATEGORIES AND CODES

<table>
<tr><th>TPACK construct(s)</th><th>Code</th><th>Category</th><th>Sub-theme</th><th>Theme</th><th>Research question addressed</th></tr>
<tr><td colspan="6">Main theme: Integrating coding and robotics with Grade R mathematical concepts</td></tr>
<tr><td rowspan="3">PK</td><td>Relaxed
A game
Not worried about making mistakes
Learn the easiest
Resonates on learners' level
Fun
Enthusiasm</td><td>Category 1.1.1
Benefits of play</td><td>Sub-theme 1.1
Play-based teaching and learning</td><td rowspan="4">THEME 1
How teaching occurs in Grade R</td><td rowspan="4">SRQ 1</td></tr>
<tr><td>Listen to instructions
Vocabulary
Using language
Speaking skills
Reading
Handwriting
Resources</td><td>Category 1.2.1
Language</td><td rowspan="3">Sub-theme 1.2
Integration of subject areas</td></tr>
<tr><td>Physical development
Beginning knowledge
Creative Arts</td><td>Category 1.2.2
Life Skills</td></tr>
<tr><td>PCK</td><td>Recognise and write numbers
Simple operations
Ordinal numbers
Counting
Patterns
Spatial understanding
Symmetry
Shapes</td><td>Category 1.2.3
Mathematics</td></tr>
</table>

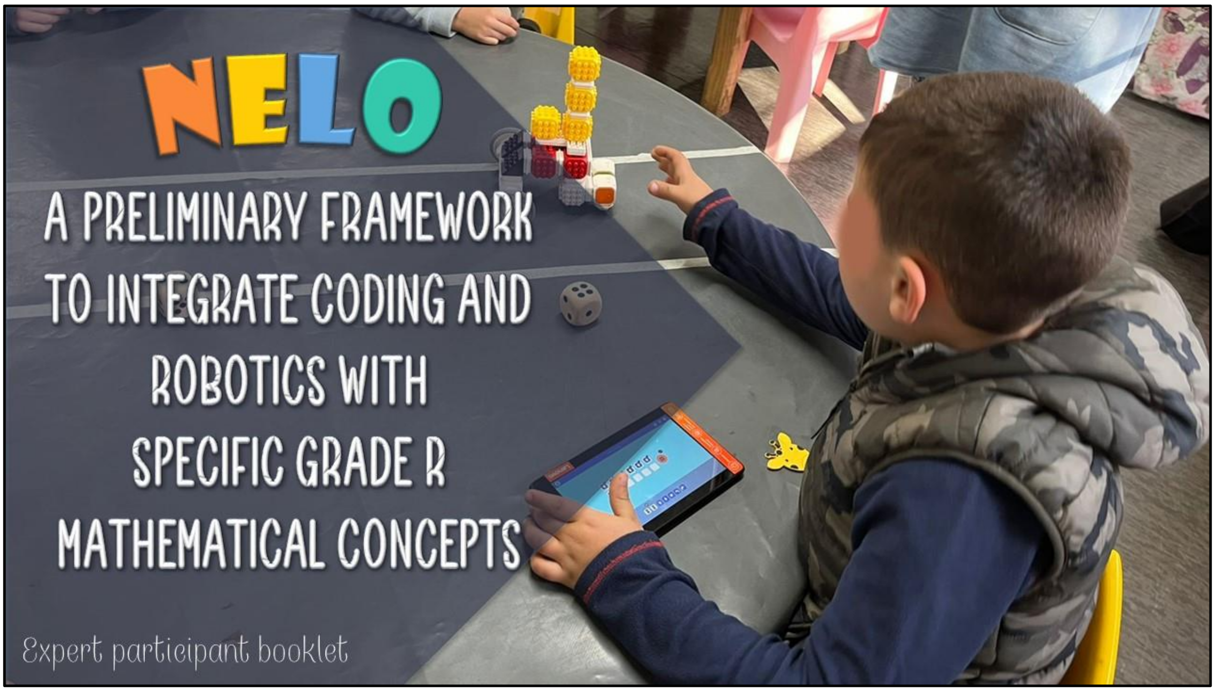
TPACK construct(s)	Code	Category	Sub-theme	Theme	Research question addressed
Main theme: Integrating coding and robotics with Grade R mathematical concepts					
	• Measurement • Mathematical language				
	• Important • Overall picture • Integration • Workload • Retain information	**Category 1.2.4** Teachers' views regarding the integration of subject areas			
PK	• Varying degrees of difficulty • Socially interactive	**Category 1.3.1** Lev Vygotsky	**Sub-theme 1.3** Pedagogical theories and/or international practices		
	• Emphasis on learning • Variety of activities	**Category 1.3.2** Jean Piaget			
	• Learners' interests • Range of resources	**Category 1.3.3** Maria Montessori			
	• Observation • Encourage peer learning • Learners' interests	**Category 1.3.4** Reggio Emilia			
	• Unconsciously • Sharing knowledge • Instinctively	**Category 1.3.5** Teachers' views regarding the use of the pedagogical theories and/or international practices			
PCK	• Physically involved • Using senses • Hop-scotch • Human-sized chessboard	Kinaesthetic	**Sub-theme 2.1** KCRA approach *[categories discussed in sub-theme]*	**THEME 2** Mathematics in Grade R teaching	SRQ 3
	• Using objects • Sensory experiences	Concrete			
	• Using pictures	Representational			
	• Coding • Robotics	Abstract			

TPACK construct(s)	Code	Category	Sub-theme	Theme	Research question addressed
Main theme: Integrating coding and robotics with Grade R mathematical concepts					
TCK	• Counting • Number symbols • Number names • Describe, compare, and order numbers • Addition	Skill and knowledge development	**Sub-theme 3.1** Integrating coding and robotics with mathematical concepts *[category discussed in sub-theme]*	**THEME 3** Integrating coding and robotics with mathematics	SRQ 2
TPK	• Technologically equipped • Extramural activity • Before Grade 1	**Category 4.1.1** Equipping learners for formal schooling *[category discussed in sub-theme]*	**Sub-theme 4.1** Benefits of using coding and robotics	**THEME 4** The effect and use of coding and robotics in Grade R	
	• Necessity	**Category 4.1.2** Equipping learners for life after school			
	• Different thinking • Focuses attention	**Category 4.1.3** Supporting learners' understanding			
	• New skill • New method • Knowledge • Improve teaching • New developments	**Category 4.1.4** Teachers keeping abreast with new developments *[category discussed in sub-theme]*			
	• Manual or textbook • Training • Guidelines • Robot • Integration into daily programme	**Category 4.2.1** Teachers' needs	**Sub-theme 4.2** Difficulties that arise in the integration of coding and robotics		

TPACK construct(s)	Code	Category	Sub-theme	Theme	Research question addressed
Main theme: Integrating coding and robotics with Grade R mathematical concepts					
	• Overcrowded classes • Lack of finances	**Category 4.2.2** External factors influencing successful integration			
	• Part of general assessments • Informal observation	Assessment *[category discussed in sub-theme]*	**Sub-theme 4.3** Assessment of coding and robotics		
	• Different way of learning • New area of learning • Different, newer and more exciting • Think creatively and innovatively • Advantageous to learning	**Category 4.4.1** Innovation	**Sub-theme 4.4** Teachers' attitudes and dispositions regarding the integration of coding and robotics		
	• Enjoyable teaching tool • Captured attention • Interesting • Enthusiasm • Fun	**Category 4.4.2** Enjoyment			
	• Work together	**Category 4.4.3** Collaboration			
	• Creative thinking	**Category 4.4.4** Creativity			
	• Think in different ways • Creative solutions	**Category 4.4.5** Lateral thinking			
	• Equipping learners for the future • More exposed to new technology everyday • Part of everyday life	**Category 4.4.6** Exposure to technology			

TPACK construct(s)	Code	Category	Sub-theme	Theme	Research question addressed
Main theme: Integrating coding and robotics with Grade R mathematical concepts					
	• Critical thinking • Learn concepts • Connections • Problem solving	**Category 4.4.7** Critical thinking			
	• Following steps	**Category 4.4.8** Algorithms			
	• Listening skills • Gross motor skills • Passive rather than active • Addictive	**Category 4.4.9** Neglect of other learning areas			
	• Optimal learning	**Category 4.4.10** Replacement of traditional methods			
	• Teacher training • Traditional equipment	**Category 4.4.11** Basic issues in education			
	• Dependency	**Category 4.4.12** Dependency			
	• Limited functions	**Category 4.4.13** Simplicity			

APPENDIX M: EXTERNAL PARTICIPANT BOOKLET



Dear expert,

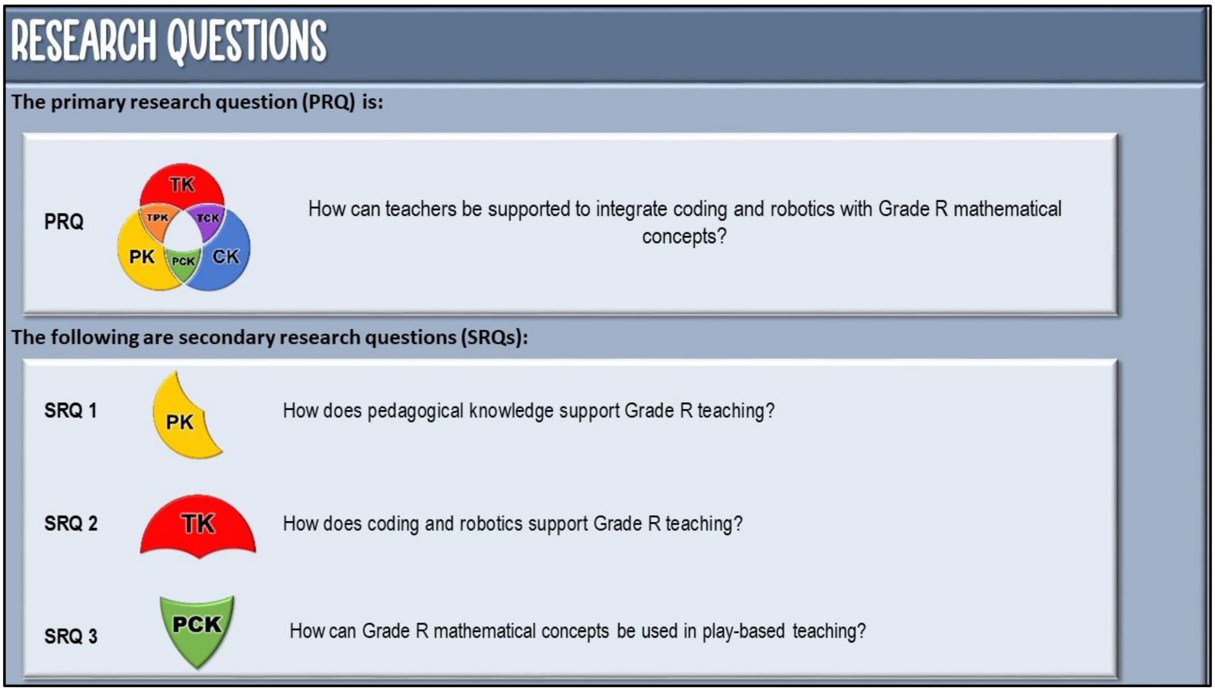
Before I start to discuss what the preliminary framework consists of, I need to explain how I got to these conclusions.

Please have a look at the following imperative aspects:

PURPOSE OF THE STUDY

In the near future, coding and robotics as a subject will be incorporated in our schools, including Grade R ELEs (DBE, 2023). Teachers should be trained in the context, content, and pedagogy of this topic, according to the DBE (2023). Furthermore, as the DBE (2023) mentions that this subject has the potential to be linked to other learning areas, particularly mathematics, teachers should be given the chance not only to learn about coding and robotics but also to contribute their own ideas on how they may be integrated successfully.

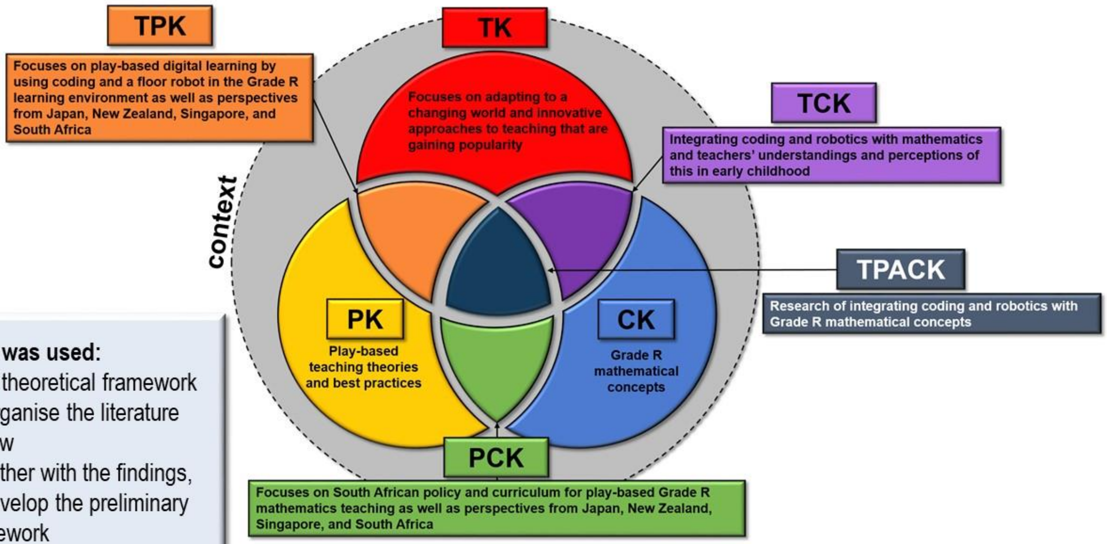
A teaching framework is defined as an evidence-based model that assists teachers to align learning objectives with classroom activities, create stimulating and inclusive environments, and incorporate assessment into the learning process (OECD, 2009). The teaching framework that I want to develop in this study should focus specifically on supporting teachers in using coding and robotics to teach the content area of numbers, operations, and relationships in Grade R.



RESEARCH QUESTIONS
The primary research question (PRQ) is:
PRQ
TK
TPK
TCK
PK
PCK
CK
How can teachers be supported to integrate coding and robotics with Grade R mathematical concepts?
The following are secondary research questions (SRQs):
SRQ 1
PK
How does pedagogical knowledge support Grade R teaching?
SRQ 2
TK
How does coding and robotics support Grade R teaching?
SRQ 3
PCK
How can Grade R mathematical concepts be used in play-based teaching?

PARTICIPATORY ACTION RESEARCH
RESEARCH QUESTIONS AND OBJECTIVES
TPACK
LITERATURE REVIEW
CYCLE 1
DEDUCTIVE DATA ANALYSIS
CYCLE 2
DEDUCTIVE DATA ANALYSIS
CYCLE 3
DEDUCTIVE DATA ANALYSIS
CYCLE 4
INDUCTIVE DATA ANALYSIS AND INTERPRETATION
INDUCTIVE DATA ANALYSIS AND INTERPRETATION
FRAMEWORK
KEY
AB Activity booklet
Activity template
Collaborative discussion group
EPB Expert participant booklet
Guided observation
Photovoice
Reflection journal
Semi-structured individual interview schedule
Systematising expert interview
TCB Teacher collaboration booklet
EXPERT REVIEW
PAR, as a research design, was chosen as the most appropriate approach for the development of the teaching framework as it involves teachers providing first-hand opinions and reflections to develop a framework consisting of guidelines that can support teachers in integrating coding and robotics with specific mathematical concepts.

TPACK



TPACK was used:

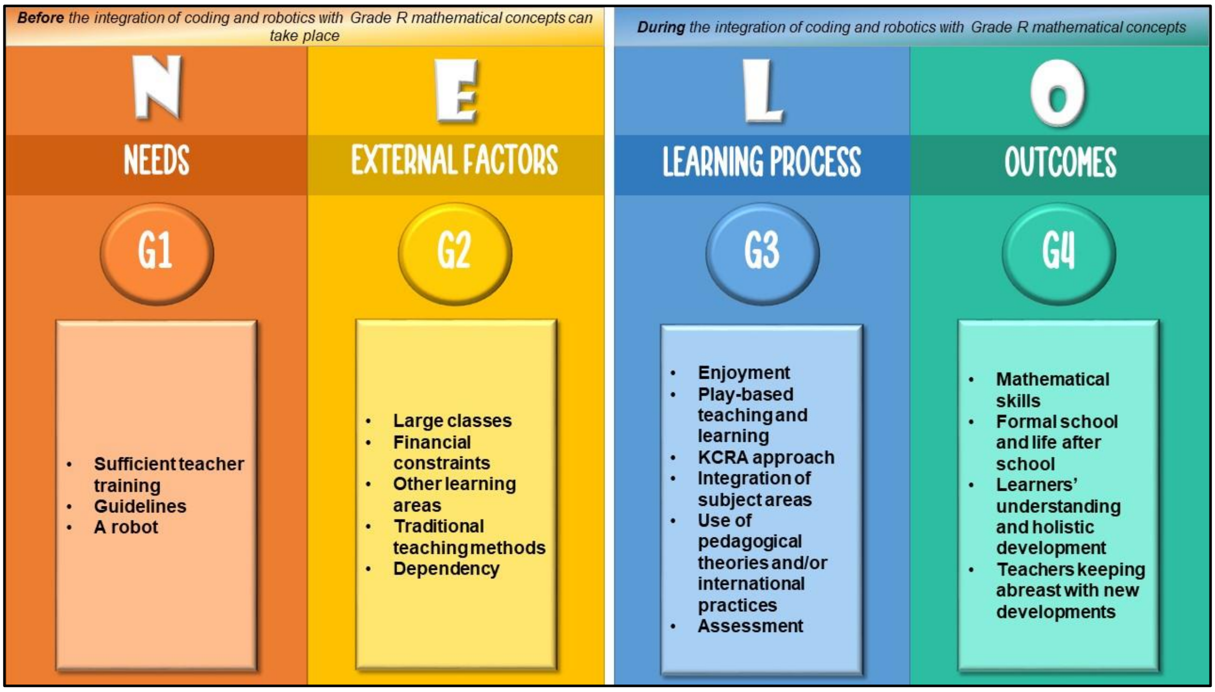
- As a theoretical framework
- To organise the literature review
- Together with the findings, to develop the preliminary framework

SUB-THEMES, MAIN THEME, AND GUIDELINES

Sub-theme	When aspect will be addressed	Summarised guideline
Sub-theme 1.1 Play-based teaching and learning	During implementation	Learning process
Sub-theme 1.2 Integration of subject areas	During implementation	Learning process
Sub-theme 1.3 Pedagogical theories and/or international practises	During implementation	Learning process
Sub-theme 2.1 KCRA approach	During implementation	Learning process
Sub-theme 3.1 Keeping the focus on mathematics	During implementation	Learning process
Sub-theme 3.2 Mathematical skills developed when using coding and robotics	During implementation	Outcomes
Sub-theme 4.1 Benefits of using coding and robotics	During implementation	Outcomes
Sub-theme 4.2 Difficulties that arise in the implementation of using coding and robotics	Before implementation	Needs External factors
Sub-theme 4.3 Assessment of coding and robotics	During implementation	Learning process
Sub-theme 4.4 Teachers' attitudes and dispositions regarding the implementation of coding and robotics	During implementation Before implementation	Outcomes External factors

The categories, sub-themes, main theme, and interpretation of data were used to develop these guidelines.

For more information on the categories, please refer to: *1. Categories, sub-themes, main theme_KWillemse*



N

NEEDS

G1

Sufficient teacher training

Teachers require training with regard to the use of coding and robotics by focusing on the following aspects:

- Why should coding and robotics be implemented?
- Where should one begin when implementing coding and robotics?
- How does one integrate coding and robotics with mathematics?

Guidelines

Teachers need:

- Information on how to integrate coding and robotics in the daily programme:
  - A manual or textbook with clear aims and objectives to plan lessons.
  - Worked out lesson plans.
- Information on how to set up the classroom for free play with coding and robotics to take place.

A robot

Teachers need a robot to implement robotics successfully. The choice of the robot should be influenced by an abundance of uses and functions.

E
EXTERNAL FACTORS
G2

Large classes

- Large classes (teacher-to-learner ratio) would require careful class management.
- Inexperienced teachers need support with regard to class management.

Financial constraints

Financial constraints might pose a difficulty if certain equipment has to be bought.

Other learning areas

Learning areas such as language (listening skills) and physical education (gross motor skills) might be negatively affected through the technology, however, these skills are supported in the integration of coding and robotics.

Traditional teaching methods

The integratopm of coding and robotics should not replace traditional teaching methods. It should be used as a tool to enhance learners' learning.

Dependency

Learners should not become dependent on coding and robotics, or technology as a whole, to solve problems. Coding and robotics should only be used as a tool to facilitate learners' understanding.

L
LEARNING PROCESS
G3

Enjoyment

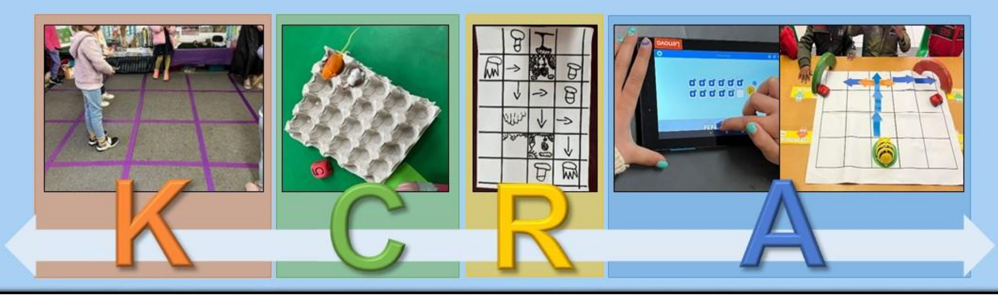
Coding and robotics captures learners' attention, therefore, it can be used as an enjoyable teaching tool to enhance learner participation and pique their interest.

Play-based teaching and learning

All learning and teaching in Grade R should be informed through a play-based approach.

KCRA approach

Grade R activities should first be implemented through kinaesthetic experiences, then through concrete experiences, then through representational experiences, and fianlly, through abstract experiences.



L

LEARNING PROCESS

G3

Integration of subject areas

Language, life skills, and mathematical content areas can also be addressed.

Use of pedagogical theories and/or international practices

When employing a play-based approach in Grade R, the use of pedagogical theories (such as those of Lev Vygotsky and Jean Piaget) as well as international best practices (such as those of Montessori and Reggio Emilia) is inevitable. Teachers subconsciously implement these theories and/or practices without necessarily having thorough knowledge of what each entails, they should, however, be encouraged to develop an active awareness of what each entails.

Assessment

The assessment of integrating coding and robotics with specific mathematical concepts should form part of the general assessments conducted by Grade R teachers. Assessments should be conducted through informal observations.

O

OUTCOMES

G4

Mathematical concepts

The integration of coding and robotics with mathematical concepts include:

Numbers, operations, and relationships	Other mathematical content areas (integration)	
• Counting • Number symbols and number names • Describe, compare, and order numbers • Addition	• Ordinal numbers • Patterns • Spatial understanding	• Symmetry • Shapes • Measurement

Formal school and life after school

- Using coding and robotics may equip Grade R learners for formal school.
- Technology is part of the future, and coding and robotics could support learners' ethics and discipline to use technology.
- Coding and robotics supports learners' understanding of digital technology and, thus, equip them for life after school.

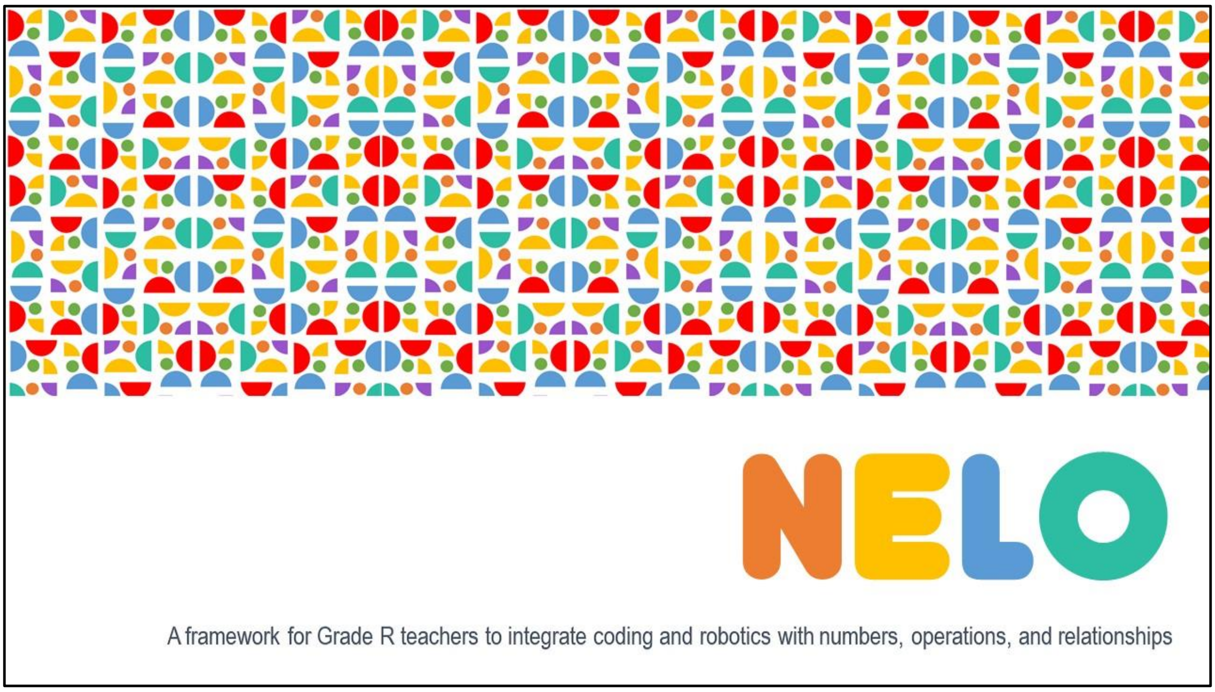
Learners' understanding and holistic development

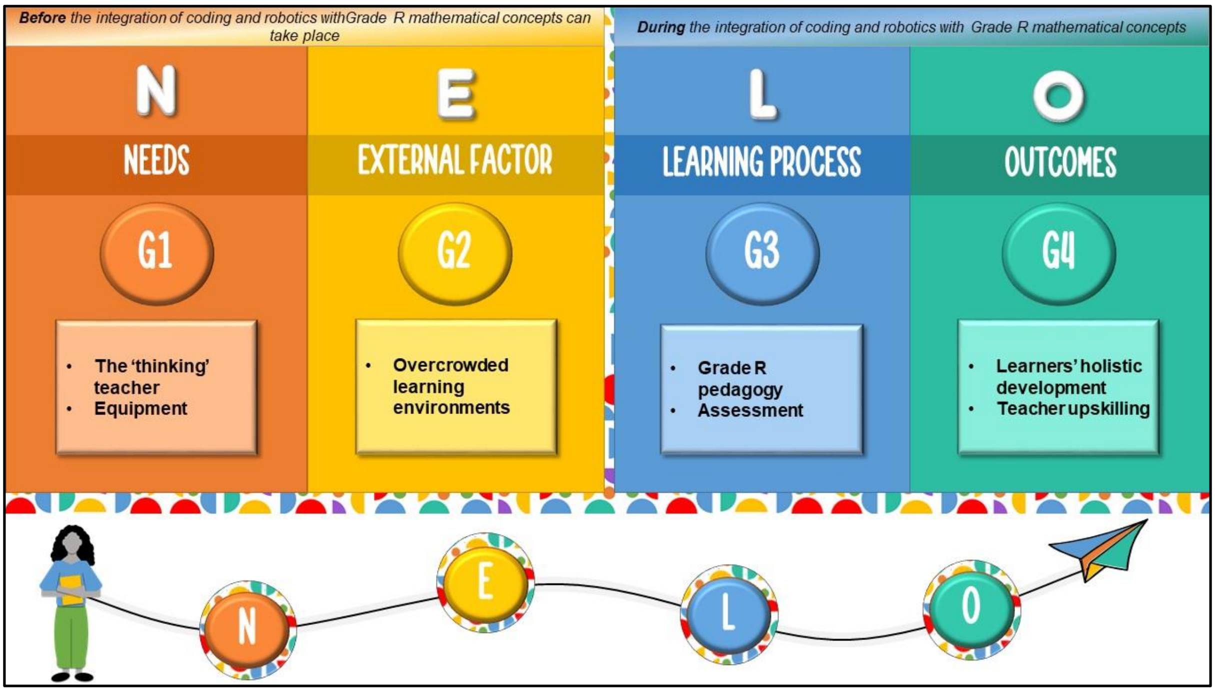
Coding and robotics has the potential to support learners' collaboration skills, creativity skills, lateral thinking, critical thinking, and understanding of algorithms. It also has the potential to expose learners to technology.

Teachers keeping abreast of new developments

Integrating coding and robotics is a new tool with which teachers can familiarise themselves to improve their teaching and to keep abreast of new developments in education.

APPENDIX N: FRAMEWORK TO INTEGRATE CODING AND ROBOTICS WITH SPECIFIC GRADE R MATHEMATICAL CONCEPTS





N

NEEDS

G1

TK

TPK

The 'thinking' teacher

Training | **Material**

Teachers require training (initial teacher education and professional development opportunities) and training material with regard to:

- The importance of integrating coding and robotics.
- The starting point of integrating coding and robotics in an activity.
- Integrating coding and robotics with mathematics.
- Information on how to integrate coding and robotics in the daily programme.
- Information on how to set up the learning environment for free play with coding and robotics.
- The importance and implementation of pedagogical theories and/or international best practices in South African learning environments.
- Framing coding and robotics within learning areas: Knowledge of how coding and robotics, and technology in general, benefits learners' development and how it can be used as an enjoyable and complementary tool for both teaching and learning.

Equipment

Teachers need a robot. Financial constraints might pose a difficulty if a robot needs to be bought, however, this can be overcome by using recyclable materials.

E

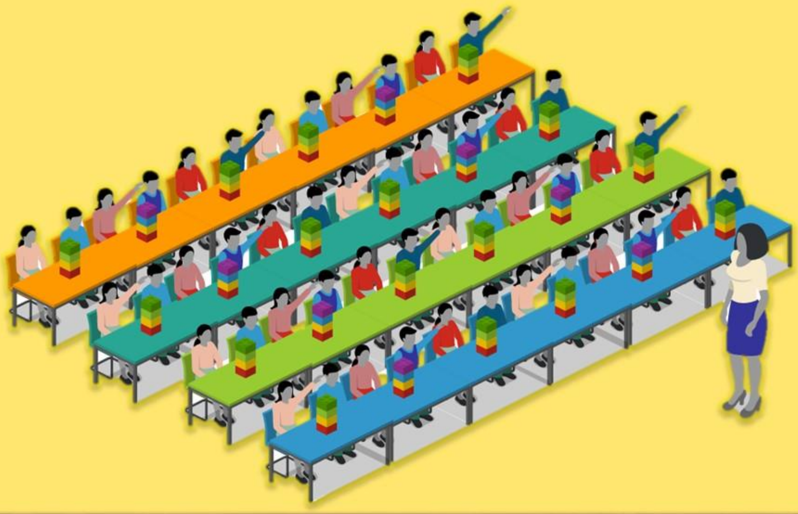
EXTERNAL FACTOR

G2

CONTEXT OF TPACK

Overcrowded learning environments

Overcrowding in schools is a problem in South Africa and might pose a difficulty to successfully integrate coding and robotics with mathematical concepts.



L

LEARNING PROCESS

G3

PK

CK

PCK

TCK

TPK

Grade R pedagogy

Grade R pedagogy is informed through enjoyable play-based activities; the KCRA approach; the integration of subject areas; and a specific learning outcome.

Assessment

The assessment of integrating coding and robotics with specific mathematical concepts should form part of the general assessments conducted by Grade R teachers through informal observations.

O

OUTCOMES

G4

TK

CK

TCK

TPK

Learners' holistic development

- Coding and robotics has the potential to support learners' collaboration skills, creativity skills, lateral thinking, critical thinking, and understanding of algorithms. It also has the potential to expose learners to technology.
- Using coding and robotics may equip Grade R learners for formal school.
- Technology is part of the future, and coding and robotics could support learners' ethical use and discipline to use technology.
- Coding and robotics supports learners' understanding of digital technology and, thus, equip them for life after school.
- Possible mathematical knowledge that are integrated when using coding and robotics include:

Numbers, operations, and relationships	Other mathematical content areas (integration)	
• Counting • Number symbols and number names • Describe, compare, and order numbers • Addition	• Ordinal numbers • Patterns • Spatial understanding	• Symmetry • Shapes • Measurement

Teacher upskilling

Integrating technology, specifically coding and robotics, is a new tool with which teachers can familiarise themselves to improve their teaching to stay current on educational innovations.


O
L
N
E

APPENDIX O: DATA GENERATION TIMELINE

MAY 2022

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
16	17	18	19	20	21	22
Ethical clearance obtained		S1 Meet	S2 Meet	S3 Meet		
23	24	25	26	27	28	29
	S4 Meet	S5 Meet				
30	31					
T1	T2, 3, 4	**DATA ANALYSIS**				

JUNE 2022

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
		1	2	3	4	5
		T5, 6	T7, 8	T9, 10	**DATA ANALYSIS**	
6	7	8	9	10	11	12
DATA ANALYSIS						
13	14	15	16	17	18	19
			Youth Day			
20	21	22	23	24	25	26
T1	T2, 3, 4		**SCHOOL HOLIDAY COMMENCED**			
27	28	29	30			
SCHOOL HOLIDAY						

JULY 2022

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
11	12	13	14	15	16	17
SCHOOL HOLIDAY ENDED						
18	19	20	21	22	23	24
			T5, 6	T7, T8		
25	26	27	28	29	30	31
T9, T10			**DATA ANALYSIS**			

AUGUST 2022

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	2	3	4	5	6	7
DATA ANALYSIS						
8	9	10	11	12	13	14
DATA ANALYSIS						
15	16	17	18	19	20	21
T1	T2, 3, 4	T5, 6	T7, T8	T9, T10		
22	23	24	25	26	27	28
		DATA ANALYSIS				

SEPTEMBER 2022

DATA ANALYSIS

OCTOBER 2022

DATA ANALYSIS

NOVEMBER 2022

DATA ANALYSIS

DECEMBER 2022

DATA ANALYSIS

JANUARY 2023

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
16	17	18	19	20	21	22